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# *Creating the Fleet Maker* - Lessons Learned from the First Series of Workshops on Maker Concepts for Active Duty Personnel

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Dr. Anthony W. Dean has had several roles in academia. He is currently Assistant Dean for Research, Batten College of Engineering and Technology (BCET) at ODU. His previous appointments include Associate Professor of Engineering Technology and as Associate Director of the Institute for Ship Repair, Maintenance, and Operations at Old Dominion University (ODU).His research has focused mostly on control systems (integration and testing) and the reliability and maintainability of complex systems. He has been selected as both a NASA and an ONR Faculty Fellow. He regularly teaches courses in Marine Engineering and in Maintained Systems. Most recently Dr. Dean was on the Headquarters Staff the American Society of Naval Engineers. He received his Ph.D. from the Department of Engineering Management and Systems Engineering, and a B.S. in Nuclear Engineering Technology, from the Batten College of Engineering and Technology at Old Dominion University. Additionally, Dr. Dean received an MBA from the College of William and Mary. Prior to is academic career Dr. Dean was Director of Operations and Business Development for Clark-Smith Associates, P.C., and served as an Electrician in the US Navy aboard the USS South Carolina and the USS Enterprise.

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# *Creating the Fleet Maker* – Lessons Learned from the First Series of Workshops on Maker Concepts for Active Duty Personnel


## Abstract

The US Navy has supported research related to the 3D printing or Additive Manufacturing area for more than 20 years. More recently, efforts like the *Print the Fleet* initiative and *Marine Makers* are exploring ways to design and create solutions to future problems with the possibility of reducing maintenance costs, increasing equipment readiness, and improving combat effectiveness. The *Creating the Fleet Maker* project is an effort supported by the Navy and Marine Corps Science, Technology, Engineering and Mathematics Education, Outreach and Workforce Program of the Office of Naval Research. It examines the concept of *making* in order to develop skills for active duty personnel in 3D printing, computer aided design, and reverse engineering. As part of the *Creating the Fleet Maker* project, educational materials, and hands-on activities, based on STEM concepts, were developed for a 2-day workshop. During the first year of the project, a series of five workshops were delivered, with a total of 92 active active-duty sailors attending the workshops. This paper presents the lessons learned during the first series of workshops, including successes, challenges encountered, how these challenges were overcome, as well as areas for improvement as the project enters its second year. Results from the workshop assessments are very positive with the majority of sailors reporting an improvement in their knowledge of the concepts covered during the workshop, as well as in the skills for 3D printing, computer aided design, and reverse engineering. Furthermore, attendees reported interest in taking part in an extended version of the workshop or having it as part of their regular naval training.


## Introduction

Research related to the 3D Printing or Additive Manufacturing area has found support from the US Navy for more than 20 years. In 2013, the U.S. Navy created the *Print the Fleet* initiative through the Chief of Naval Operations' Rapid Innovation Cell (CRIC), consolidating Navy-wide efforts to bring Additive Manufacturing (AM) to service and to improve sailors' access to AM technologies [1], [2]. The Combat Direction Systems Activity (CDSA) at Dam Neck is a technical lead for *Print the Fleet*, and has provided feasible and cost-effective solutions to issues encountered by sailors, like adapter brackets for phone boxes and models to use in the flight deck control board [2]. More recent efforts to support future Navy innovations and problem-solving skills include 3D Print-a-thon events, and the establishment of the Marine Maker community, which includes Maker Labs, Maker Units, Mobile Training, Collaboration Portals, and courses [3] – [5].

The *Creating the Fleet Maker* (CFM) project is an effort supported by the Navy and Marine Corps Science, Technology, Engineering and Mathematics Education, Outreach and Workforce Program of the Office of Naval Research [6]. CFM is a concept program with the goal of advancing STEM education and outreach to active duty military personnel, improving the Navy's STEM workforce. Specifically, the project examines the concept of *making* in order to

develop skills for active duty personnel in computer aided design (CAD), reverse engineering (RE), 3D printing, and layering effects on 3D printed parts. The *Creating the Fleet Maker* project has four main objectives: 1) Engage active duty personnel in a maker environment; 2) Provide informal STEM learning through collaborative workshops; 3) Provide workforce development for active duty Naval STEM and Non-STEM professionals; and 4) Support the Maker Movement within the Navy.

### *Creating the Fleet Maker* - Workshop Structure and Specifics

The curriculum covering the topics of computer aided design, reverse engineering, 3D printing, and layering effects on 3D printed parts, as well as the hands-on activities that take place during a two-day workshop are described in detail elsewhere [7], [8]. Briefly, the workshop is divided into six modules, each with an associated hands-on activity. Table 1 shows the schedule for the two-day workshop with the topics covered and the hands-on activity for each module. The main equipment used during the workshop includes: i) a fused filament fabrication (FFF) 3D printer (InventorCloud, Youngstown, OH), which was developed for the MENTOR2 program, sponsored by DARPA [9], and ii) a 3D scanner sensor for mobile devices (Structure Sensor, Occipital, San Francisco, CA)[10], which is mounted on an iPad tablet.

The InventorCloud 3D printer uses filament of A-PLA material (Workday PLA [APLA], 3D-Fuel ®, Fargo, ND), which is manufactured from high heat grade PLA (poly lactic acid) resin specifically developed for 3D printing purposes. It has low odor, good print detail and resolution, excellent first layer adhesion, as well as improved inter-layer adhesion and reduced warping [11]. The main software that participants learn in the workshop are Inventor (Inventor, Autodesk, San Rafael, CA), a 3D CAD software for product development used in the computer aided design portions, and Slic3r (Slic3r, GNU Affero General Public License, slic3r.org), a free software to convert a digital 3D model into digital instructions for the 3D printer [12].

### *Creating the Fleet Maker* - 1st Year Impact and Outcomes

The first five workshops from the *Creating the Fleet Maker* project took place from January to June of 2017 (see Table 2). A total of 92 participants attended the workshops from the following commands: USS San Jacinto (CG 56), USS Kearsarge (LHD 3), USS Mason (DDG 87), USS Normandy (CG 60), USS Whidbey Island (LSD 41), Naval Station Norfolk, USS WASP (LHD 1), US Navy's Military Sealift, and USS Monterrey (CG 61). The following summarizes the responses to the pre- and post-workshop surveys administered to participants to determine their perceptions and attitudes on Making concepts and 3D printing, as well as their evaluation of the workshop. The assessment was planned to include all participants in each workshop. As can be seen in the workshop schedule (Table 1), time was allocated to both the pre- (Day 1, first activity) and post- (Day 2, last activity) assessments. The post-workshop survey response rate was 88%, based on the number of participants on Day 1. This could be caused by some participants leaving early on Day 2 of the workshop due to other obligations, and participation on the assessment is voluntary.

Table 1. *Creating the Fleet Maker* Two-Day Workshop Schedule

| **Day 1 - Creating the Fleet Maker Workshop** | | |
|---|---|---|
| **Time** | **Activity** | **Duration (estimate)** |
| 8:00 – 9:00 | Workshop Introduction and Other Information | 15 min. |
| | Pre-Workshop Assessment | 45 min. |
| 9:00 – 10:00 | Module 1: 3D Printing | 50 min.<br>(10 min. break) |
| 10:00 – 12:00 | 3D Printing Hands-On<br>- Components, Loading Material, Leveling, Printing | 2 hrs. |
| 12:00 – 1:00 | LUNCH | 1 hr. |
| 1:00 – 2:30 | Module 2: CAD – Computer Aided Design | 1hr. 30 min. |
| 2:30 – 3:00 | Module 3: Slic3er – Layer Preparation Software | 30 min. |
| 3:00 – 3:30 | 3D Printing Hands-On<br>- Sending to Print | 20 min.<br>(10 min. break) |
| 3:30 – 4:30 | Module 4: Materials and Properties, Effects of Print Orientation, and Testing for Stiffness | 1hr. |
| 4:30 – 4:50 | Slic3r Hands-On<br>- Importance of Layers and Orientation | 20 min. |
| 4:50 – 5:00 | Homework Discussion | 10 min. |
| **Day 2 - Creating the Fleet Maker Workshop** | | |
| **Time** | **Activity** | **Duration (estimate)** |
| 8:00 – 8:15 | Homework Discussion | 15 min |
| 8:15 – 9:00 | Module 5: Reverse Engineering in CAD | 45 min. |
| 9:00 – 12:00 | Instructor Guided CAD, Slicing and 3D Printing: Hands-On Session<br>- Design, Slice, Print your Own Design | 3 hr. |
| 12:00 – 1:00 | LUNCH | 1 hr. |
| 1:00 – 1:45 | Module 6: Advanced Reverse Engineering | 45 min. |
| 1:45 – 4:30 | Instructor Guided Advanced Reverse Engineering<br>- Scanning, Mesh Fixing, 3D Printing | 2 hr. 45 min. |
| 4:30 – 5:00 | Post-Workshop Survey<br>Wrap-up | 30 min. |

Table 2. *Creating the Fleet Maker* First Year Workshops.

| Workshop Date | Attending Command | Number of Participants |
|---|---|---|
| January 27 -28, 2017 | USS San Jacinto (CG 56) USS Kearsarge (LHD 3) | 20 |
| March 17 – 18, 2017 | USS Mason (DDG 87) USS Normandy (CG 60) | 20 |
| April 14 – 15, 2017 | USS Whidbey Island (LSD 41) Naval Station Norfolk | 18 |
| May 12 – 13, 2017 | USS WASP (LHD 1) US Navy's Military Sealift | 20 |
| June 2 – 3, 2017 | USS Monterrey (CG 61) | 14 |
| Total Number of Attendees | | 92 |

***Participants' Demographics***

The first section of the survey requested demographic information about the participants. The demographic characteristics of participants (as per the pre-workshop survey) were as follows: 54.7% White, 27.4% Black, 8.3% Hispanic, 5.9% Asian or Pacific Islander, and 1.1% Native American or Alaskan Native. The gender distribution of participants included 81.2% male and 17% female. The military tenure of workshop participants followed a normal distribution (see Figure 1C), from participants joining the military within the last year to those who have been in the military more than 20 years, although the majority of participants (20.7%) joined the military within five years. Regarding the participants' active duty status, 56.8% were non-commissioned officers.

***Pre and Post- Workshop Participants' Attitudes and Perceptions on Making Concepts and 3D Printing***

The second section of the survey consisted of six questions to assess the participants' attitudes and perceptions on Making Concepts and 3D Printing. The first question (Q1) asked if the participant was aware of the *Print the Fleet* initiative, with only 35.9% of participants aware in the pre-workshop survey. Responses from the post-workshop survey indicate that after the workshop 77.8% of participants were aware of the *Print the Fleet* initiative. The following four questions asked participants to state their opinion on: (Q2) 3D Printing in the Navy, (Q3) how several factors are influencing the way 3D printing technology is currently being applied in their organization, (Q4) the main factors serving as barriers for 3D printing adoption, and (Q5) the most disruptive effect on US Navy if 3D printing technologies were widely adopted. Overall, pre- and post- workshop responses to these questions show no significant changes to the participants' opinions in these topics. Question six in this section asked participants to rate their

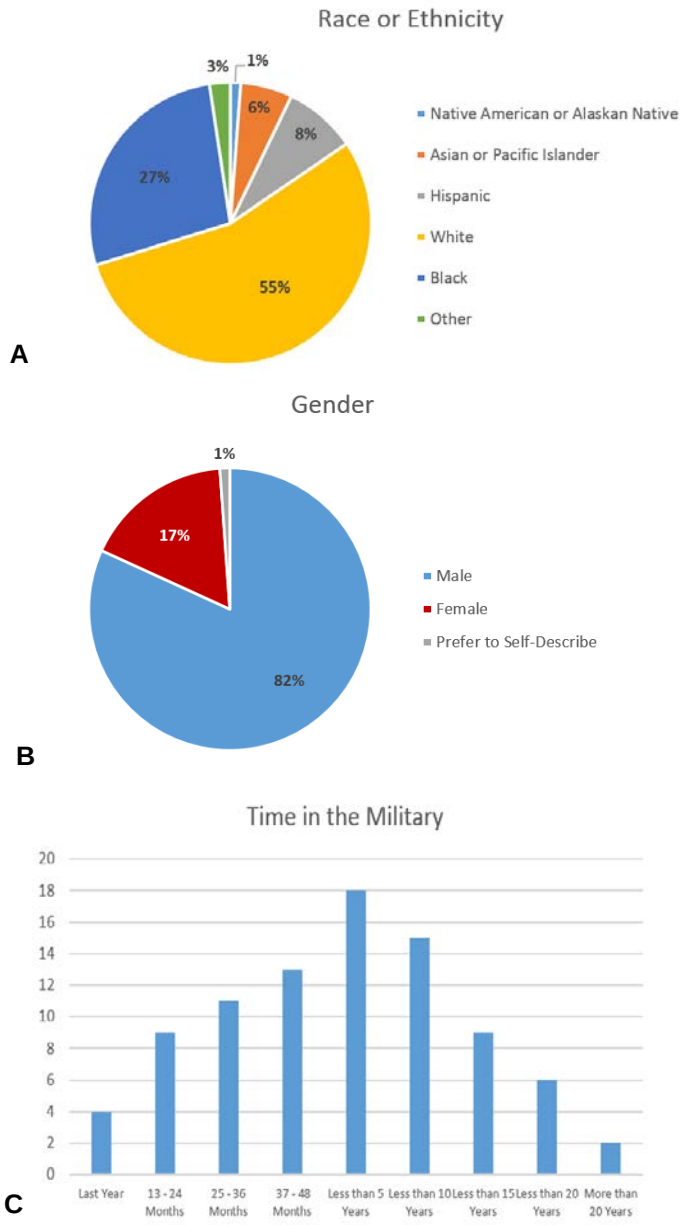



Figure 1. Participants' information. A) Race and Ethnicity, B) Gender, C) Time in the Military

knowledge of 3D printing, their ability and comfort at using the 3D Printer from the workshop, as well as their ability to use the layering software, CAD software, and scanner for advanced RE. Figure 2 shows the pre- and post- workshop responses to this question. As it can be seen comparing the two graphs in Figure 2, most of the participants' rated their knowledge and skills before the workshops from neutral (40 – 50%) to extremely bad, their rating after the workshop improved, being in the somewhat good (53.3 – 66.7%) to extremely good range.

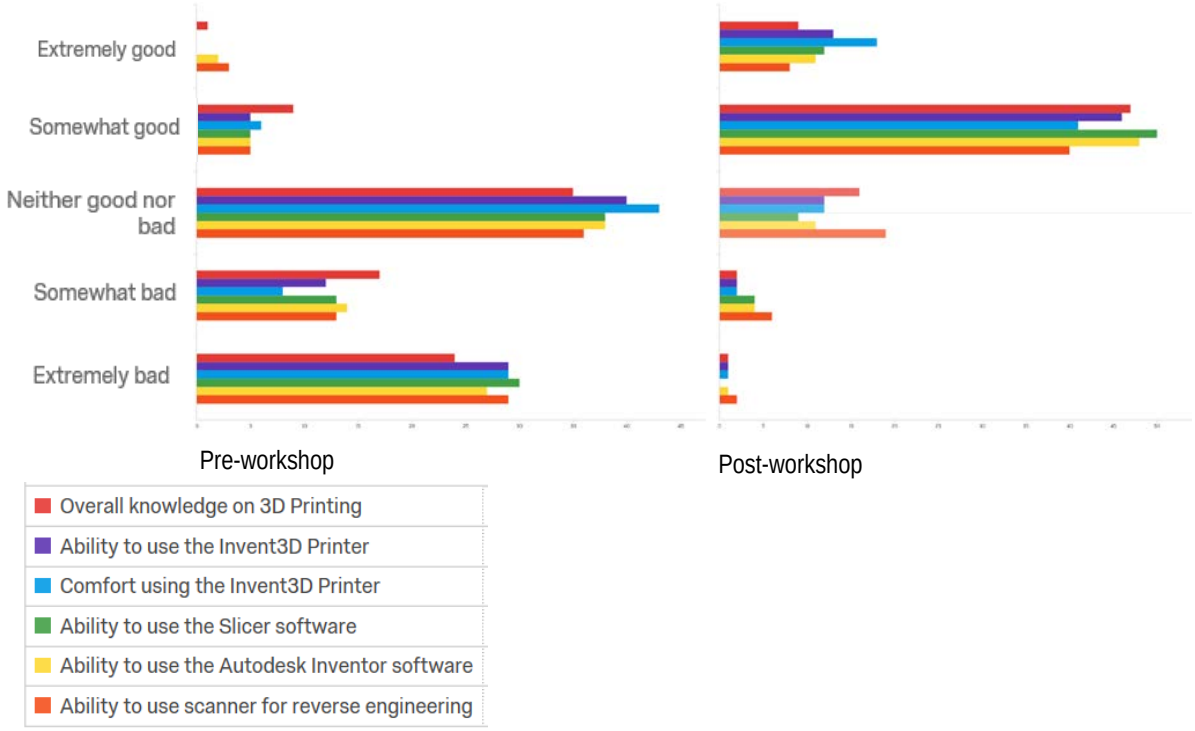



Figure 2. Participants' responses to rate their knowledge and skills on 3D Printing, Layering Software, Computer Aided Design Software, Use of a Scanner for Reverse Engineering.

***Participants' Evaluation of the Workshops***

In the post-workshop survey, five questions were included for participants to evaluate the workshop and provide feedback (see Figure 3). The first question asked participants for their opinion on various aspects of the workshop. Some of these aspects are related to expectations of the workshop, learning during the workshop, and relevance to their job. Other aspects were related to the difficulty of the content, pace of the workshops, and the instructors. Overall, all the aspects were rated positively, with most of the participants strongly agreeing with the statements. For example, 79% of participants strongly agreed that the workshop lived up to their expectations and 77.7% strongly agreed that the workshop was a good way to learn the content.

In regard to the content of the workshop being relevant to their job, 51.4% of respondents strongly agreed. For the evaluation of the hands-on activities in the workshop, 76.3% of respondents strongly agreed that the activities that stimulated their learning, and 72.2% strongly agreed that the activities provided sufficient practice and feedback. Regarding the level of difficulty and pace of the workshops, 61.1% and 57% strongly agreed that the level of difficulty and pace, respectively, were appropriate. For the evaluation of the instructors, 80.5% of respondents strongly agreed that the instructors were well prepared and 82% strongly agreed that the instructors were helpful. In general, 75% of participants strongly agreed that they will be able to use the concepts learned in the workshop.

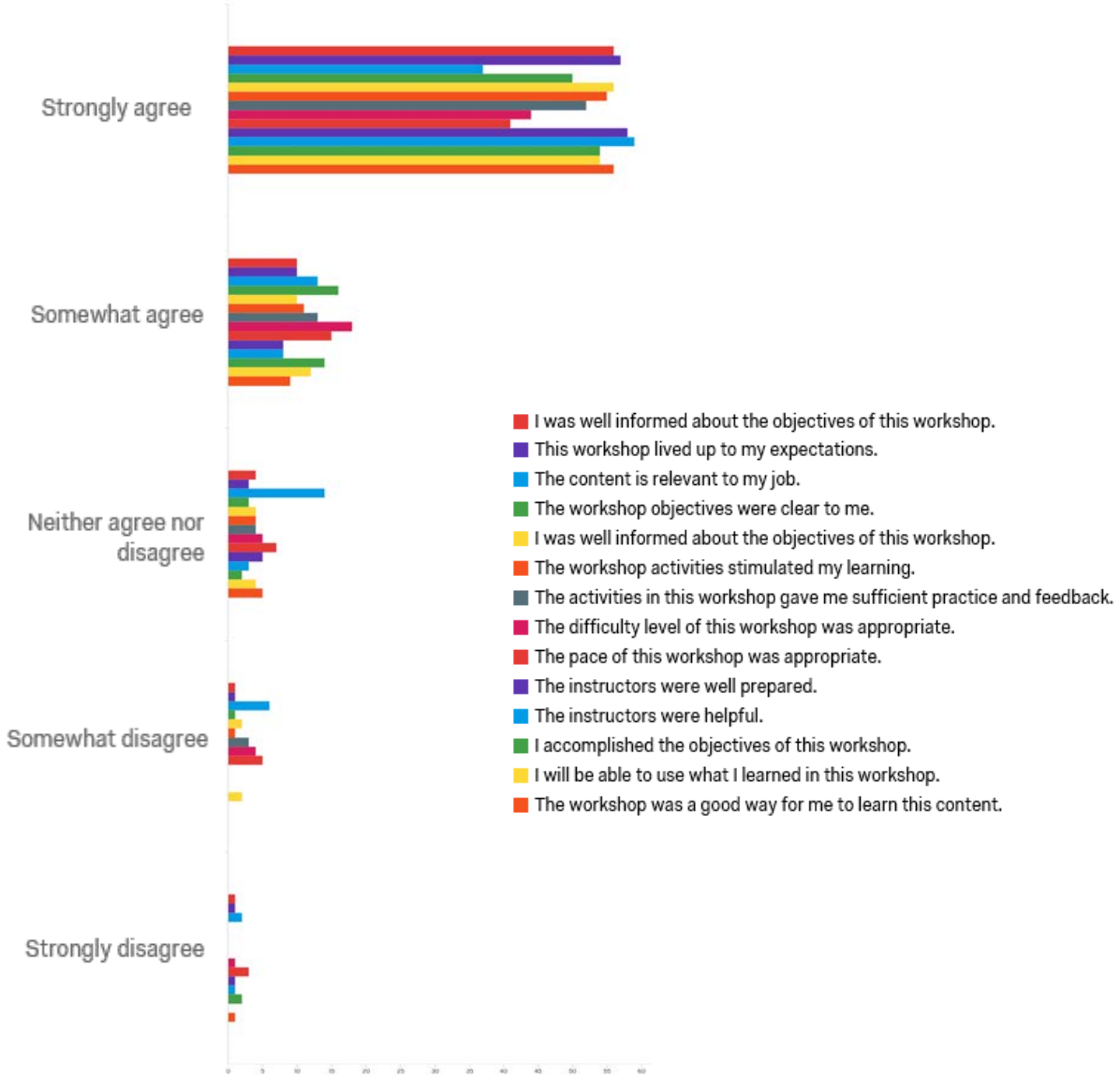



Figure 3. Post-workshop survey - Participants' opinions to various aspects of the workshop.

The second question that evaluated the workshop asked participants to select different options to for its improvement. The most popular options selected were to allot more time (55.5%), to increase the content (26.4%), and to slow down the pace of the workshop (25%). It is worth noting that at least 19% of participants selected the option to improve the workshop related to provide more information before the workshop. Participants in the workshops are being recruited by working directly with the Naval Surface Force Atlantic and the Regional Navy Science Advisors, and more information about the workshop is currently being provided beforehand.

The last three evaluative workshop questions were open-ended, and allowed participants to provide their input on what they found most valuable, least valuable, and what other

improvements they would recommend. The comments to improve the workshops were very positive with at least 35% of the comments being related to increasing the time of the workshop, exemplified through comments such as: “turn the workshop into a course, program, or C-school for technicians”. About 10% of the comments were related to needing more time to learn CAD, and another 10% suggested having more printers available. During the first two workshops there were five printers available for participants (four participants per printer). On the third workshop, a sixth printer was added, which allowed three participants at four of the printers and four participants at two of the printers.

The comments regarding what participants’ found most valuable were also very positive. Most comments (22.6%) were related to the hands-on activities. Some comments were specific to practicing on the 3D printers (17%) which could be combined with the hands-on activities comments. Another 17% of the comments were related to the computer aided design topic. The rest of the comments were related to the instructors (7.5%) and the design-print activity (5%).

Similarly, the comments regarding what the participants’ found least valuable were also very positive. One of the comments stated, “All of the information received in this workshop is the most valuable tool. It inspires innovation and broader thinking in our Sailors.” The leading category of comments (23%) stated that participants either found everything in the workshop valuable or that everything in the workshop had equal value. A smaller percentage of comments were related to the specific topics in the workshop being the least valuable, with 9.3% of the comments stating that the materials testing or information about the layering effects of 3D printed parts were the least valuable. Also, 9.3% of the comments stated the lecture portion on the history of 3D printing was the least valuable. There were 4.6% of the comments that expressed the RE and CAD modules were the least valuable.

## Lessons Learned

### *Information on Workshop Participants*

A limited amount on information was collected from participants (race, gender, time in the military, active duty status) during the first series of workshops. To better understand the characteristics of participants, it is important to collect other information such as age, current active status (to include rating specialty and rank), and highest level of education completed. Since the *Creating the Fleet Maker* project is directed towards active-duty personnel, it is important to better understand the characteristics of participants, who would be classified or considered as non-traditional students, according National Center for Education Statistics (NCES).

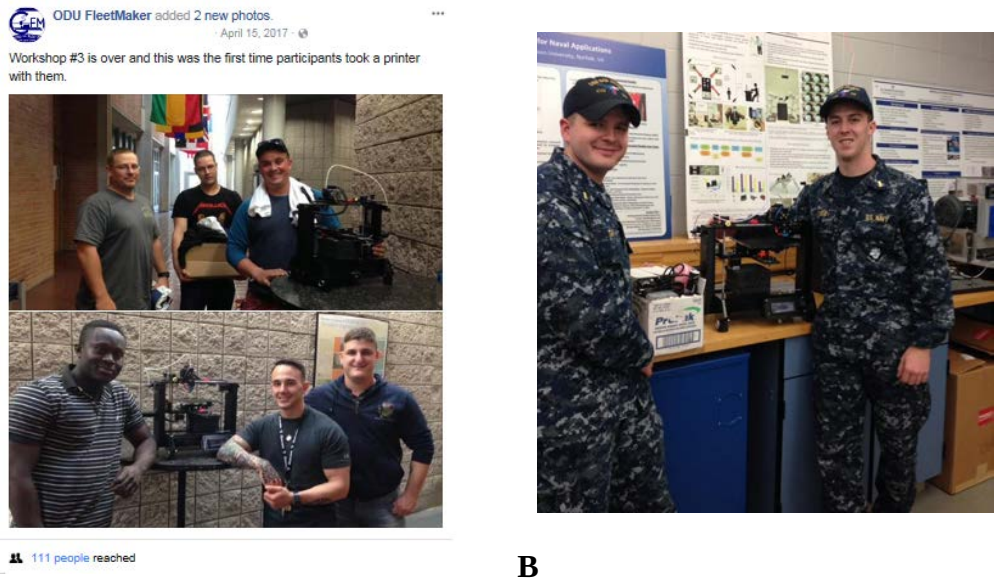
### *3D Printer Giveaway after Participation in the Workshops*

Each workshop was designed for 20 sailors, and as an incentive for participation, if 10 sailors from a command completed the workshop, they received an InventorCloud printer to take back to their command. Due to logistic issues, the giveaway printers were not available until workshop 3. Sailors from Naval Station Norfolk and the USS Whidbey Island (LSD 41) were the first to take a printer with them at the end of the second day of the workshop (April 15). This

was also the first time the workshop ended on time, as sailors had the certainty that they could continue their projects later since they would have access to a 3D printer. Sailors who participated in workshops 1 and 2 scheduled the pickup of their 3D printer at least 3 months after attending the workshop. Despite the delay between the workshop and 3D printer acquisition, the sailors were enthusiastic and had questions for the instructors, such as seeking advice on the best place to install the 3D printer and how to get access to CAD software.

### *Pre and Post- Workshop Assessment of Knowledge Learned by Participants*

The pre- and post- workshop survey included a section with 25 questions to assess the participants' knowledge on concepts related to 3D printing, CAD, RE, material testing and the effects of layers on mechanical properties of 3D printed parts. The same questions were used for the pre- and post- workshop surveys to have a baseline on the knowledge and assess if there were any changes after attendance of the workshop. Most of these content-knowledge questions were open-ended and the analysis is still underway. The content-knowledge section has been modified for the second series of workshops to contain closed-ended questions and now consists of 22 questions.




**A** **B**

Figure 4. Taking a 3D Printer after participation in the workshop. A) Participants from workshop 3 take a printer after the end of the second day (April 15, 2017). B) Sailors from the USS San Jacinto pick the 3D printer on May 3rd, 2017.

### *Curriculum and Schedule Changes*

Responses to the post-workshop surveys provided formative evaluation for the project. Especially after the first two workshops, recommendations to make improvements were used to guide and implement curriculum and schedule changes. The two main curriculum changes included a separate module on the layering software, Slic3r, which followed the computer aided

design module, and the design of a cell phone case in the CAD module was replaced by the design of a keychain (similar to a dog tag). The latter instructions include the basic operations in design (sketch, extrude, fillet, cut, sketch text) described in a more systematic way. The workshop schedule was also revised to better structure the hands-on activities with the lecture time for each module.

**Conclusions**

*Creating the Fleet Maker* is a concept program with the goal of advancing STEM education and outreach to active duty military personnel, improving the Navy's STEM workforce. Specifically, the project examines the concept of making in order to develop skills for active duty personnel in 3D printing, computer aided design, and reverse engineering. The efforts from the *Creating the Fleet Maker* program are an attempt to meet the training needs of the next-generation workforce capable of contributing to the advanced manufacturing sector and maintaining the global competitiveness of the US Navy and related industries. This paper summarized the outcomes and lessons learned from the first series of workshops from the *Creating the Fleet Maker* project.

Results from the first series of *Creating the Fleet Maker* workshop assessment and evaluation were very positive, with the majority of the participants reporting an improvement in their knowledge on the concepts covered during the workshop as well as CAD, RE and 3D printing skills. Overall, most of the participants (40 – 50%) rated their knowledge and skills before the workshops from neutral to extremely bad. In the post-workshop survey, the participants rated an improvement to their knowledge and skills learned during the workshop, being in the somewhat good to extremely good range (53.3 – 66.7%). In general, 75% of participants strongly agreed that they will be able to use the concepts learned in the workshop. Furthermore, workshop attendees reported an interest in attending an extended version of the workshop or having it as part of their regular naval training. Responses to the post-workshop surveys provided formative evaluation for the project and have guided the implementation of changes both in the schedule of the workshop and content of the modules.

Aside from the positive responses from the workshop evaluations, evidence of success for the workshops is that the rest of the workshops have all been filled and are now waitlisted. A better way to assess the impact of the workshops on content knowledge for the participants was been developed and will be implemented in the second series of workshops. Since the *Creating the Fleet Maker* program is directed towards active-duty personnel, it is important to better understand the characteristics of participants. Because a limited amount on information was collected from participants (race, gender, time in the military, active duty status) during the first series of workshops, future workshops will collect other important information such as age, current active status (to include rating specialty and rank), and highest level of education completed. This information will likely classify the workshops participants as non-traditional students, according to the definition of the National Center for Education Statistics (NCES) and will offer more insights to plan educational programs for active-duty personnel.

The literature available on workshops related to 3D printing or additive manufacturing is scarce. Topics usually covered over a 14-week semester, and that have been adapted to one-week short programs for professionals [13], have been successfully condensed into a 2-day workshop in the *Creating the Fleet Maker* curriculum. The estimated cost per workshop in the *Creating the Fleet Maker* program is $70,000, which includes development costs, the cost of the 3D printers and materials used in the workshops, and the cost of the giveaway package (3D Printer, spools of filament material, and platform protectors) to commands with ten sailors completing a workshop.

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