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Curriculum Alignment for Workforce Development in Advanced Manufacturing

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Abstract

The purpose of this paper is to describe the NASA-funded advanced manufacturing project at Elizabeth City State University (ECSU) that eventually will create an aerospace manufacturing ecosystem to support collaboration with and advancement of the industry. This project is designed to prepare students with advanced manufacturing competencies that are delivered through effective manufacturing training courses including academic preparation, summer training workshop, internship experience, and industry certification. These competencies include cognitive functions, skills, knowledge, and abilities essential for successful performance in the advanced manufacturing industry. This paper focuses on building students' academic preparation based on what they are primarily taught in the school setting. Through various core courses and mini-projects, students use CAD/CAM software, CNC machines, reverse engineering techniques, simulation software, and 3D printing to learn how to design, analyze, and fabricate or prototype mechanical parts of UAVs/drones. A few certification programs would also be available for workforce development in these areas. In addition, course content related to manufacturing would be delivered through different project ideas, leaving room for the instructor's creativity.

Introduction

In recent years, one of the most visible impacts of COVID-19 has been felt in the global production and supply chain. After COVID-19, manufacturing industries start to recover and grow. The rebounding manufacturing sector recorded a growth of 6.9 percent in 2021, bucking the trend after a suppressed growth of negative 0.4 percent in 2020 [1]. According to the Bureau of Labor Statistics, this sector is expected to add 41,400 new jobs through 2022 with an estimated 1,184,100 jobs across all manufacturing industries [2]. Boeing's Current Market Outlook 2018-2037 reports the aerospace commercial sector has recorded eight straight years of steady, above-trend growth and predicts the trend will continue for the next 20 years, requiring 42,000 new airplanes by 2037 [3]. Over the last decade, the aerospace industry has experienced increased interest in the form of Unmanned Aircraft Systems (UAS) of various sizes, as well as passenger-carrying Urban Air Mobility (UAM) applications [4]. Several industry reports have indicated that there is currently a skills gap affecting the manufacturing industry [5]. In December 2017, a survey of 662 manufacturing companies conducted by the National Association of Manufacturers found the inability to attract and retain a quality workforce as the top business challenge, cited by 72.9% of respondents [6].

Manufacturers are worried about their futures. The industry is dealing with a severe shortage of workers equipped with the knowledge and skills needed to function in advanced manufacturing workplaces. Thankfully, this NASA-funded project provides more opportunities to prepare students to enter the manufacturing career and excel with adequate competencies fostering hands-on, simulation, and experiential learning through problem-solving. It also provides training opportunities for professional development to other faculty and industry certification to industry workers to acquire newer skills to advance in their careers.

Through various selective courses and mini-projects, students will be trained to develop adequate knowledge and state-of-the-art skills to design, analyze, simulate, and fabricate/prototype components of both multirotor and fixed-wing Unmanned Arial Vehicles (UAVs). They will also be trained to troubleshoot the malfunction of the system and replace the damaged or nonfunctional components.

The fundamental design and manufacturing courses offered in the Engineering Technology program at ECSU are redesigned to add specific modules to improve the competencies of students for integrating additive manufacturing concepts, internships, manufacturing careers, and industry certifications. The new modules use multirotor and/or fixed-wing UAV/drone platforms to redesign some critical components, perform stress and deformation analysis, upgrade, and manufacture them. Some critical components of multirotor and fixed-wing UAVs include propellers, motor mounts, chassis, booms, and landing gears. Students are focused on (a) studying the existing frames and other mechanical components of UAVs/drones to optimize the structural design for better strength-to-weight ratio, (b) utilizing CAD or reverse engineering techniques to create computer models of the mechanical components, (c) using Finite Element Analysis software to simulate and validate the ability of mechanical components to withstand the worst case stress levels within allowable deformation in real word operation, (d) using carbon fiber composite materials to prototype the mechanical components of UAVs by 3D printers, and (e) create G and M codes to manufacture the parts by CNC machines if metal parts are desirable such as linkage and landing components.

This paper explains samples of mini projects that are developed to prepare students to accomplish the above tasks (a-e) and their ability for entry into manufacturing careers. In addition, the mini projects in newly developed modules and sequences will also prepare students for senior capstone projects and internships.

Methodology

The initial designs of mechanical/structural components of two UAVs/drones start in ENGT 105: Computer-Aided Design (CAD) I, course, and will be completed in a Senior Capstone Project, ENGT 498, course. Two quadcopter drone platforms namely, Parallax ELEV-8 [7] and COEX Clover [8], are used in this project.

ENGT 105: CAD I: The new additive manufacturing modules are added to CAD I course. Designing the frame of a UAV is primarily an analytical and iterative process, which is accompanied by the creation of CAD models of frame parts. Students use SolidWorks, CAD software, to model the complete frame of a UAV including chassis, booms, and landing legs that can carry the desired load. Then, the 3D printer is utilized to produce prototypes of different parts of the frame to ensure the manufacturability of the parts early in the design phase. Students use different materials and the associated technologies, including ABS (a common thermoplastic polymer), and fiber carbon composites to prototype the parts of the frames. Then, they measure weight in order to compare these prototyped frames. In addition, basic 3D printer technology of Fused Filament Fabrication (FFF), Selective Laser Sintering (SLS), and Stereolithography (SLA) are introduced to students. Figures 1-2 show CAD models of two parts of the frame of the

ELEV-8 Quadcopter drone. Figure 3 shows the prototypes of the different pieces of the frame of the ELEV-8 drone by 3D printers.

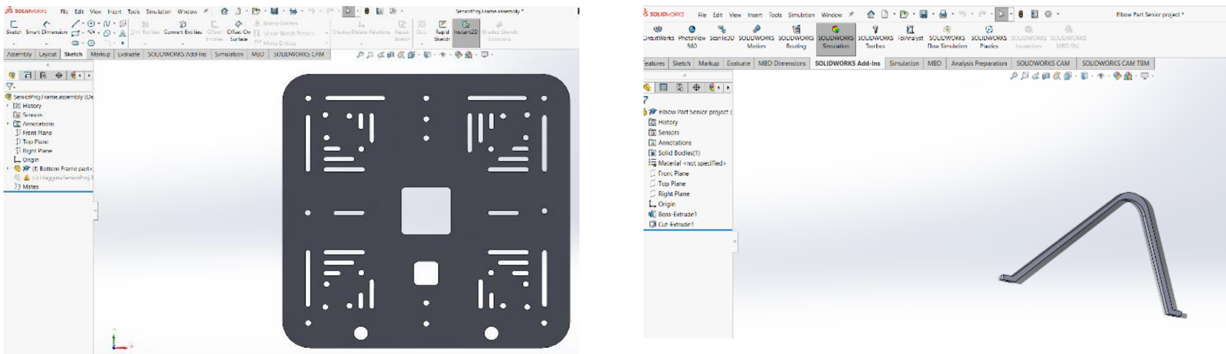


Fig.1: CAD models of the base and landing parts of the ELEV-8 drone

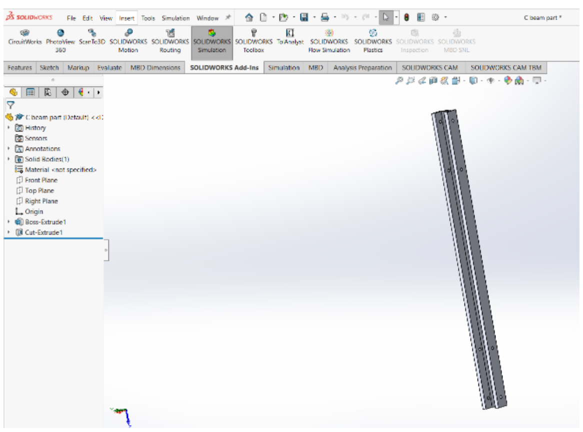


Fig.2: CAD model of the boom of the drone

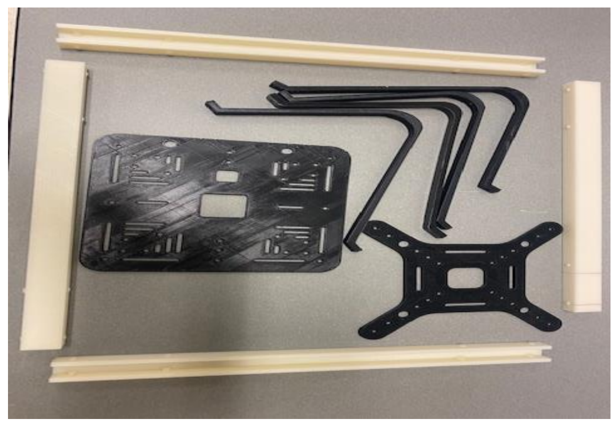


Fig.3: 3D printing of frame components

ENGT 370: Computer-Aided Design and Manufacturing (CAD/CAM): The new Computer Numerical Control (CNC) modules that include the manufacturing of different parts of the frame by CNC machine are added to this course. CNC machining is usually capable of removing material much faster than 3D printing. In this course, the basics of CNC technology and programming (G and M codes) are introduced. Students learn to write codes for drilling holes, and cutting lines, circles, and curves in different models. Then virtual machining software, CNC simulation pro, is used to simulate CNC programs before running them on an actual machine. If the part has a complicated geometry, then CAMWork/SolidWorks software is used to create the G and M codes for the UAV parts of the frame and verify machinability early in the product design development stage. Finally, the parts of the frame are machined by a CNC machine. In this course, first, students use CAD models of the ELEV-8 drone, which were developed in the ENGT 105 course, to generate CNC codes. Figure 4 shows the creation and simulation of the CNC codes by CAMWorks software for two parts of the ELEV-8 drone. In addition, students use the CAD software to design the different components of the frame of the other drone, COEX Clover, and then prototype them with 3D printers and create CNC codes by CAMWorks software for parts of this drone as well. Figures 5, 6, and 7 show the CAD models and prototypes of different components of the COEX Clover drone by the 3D printer.

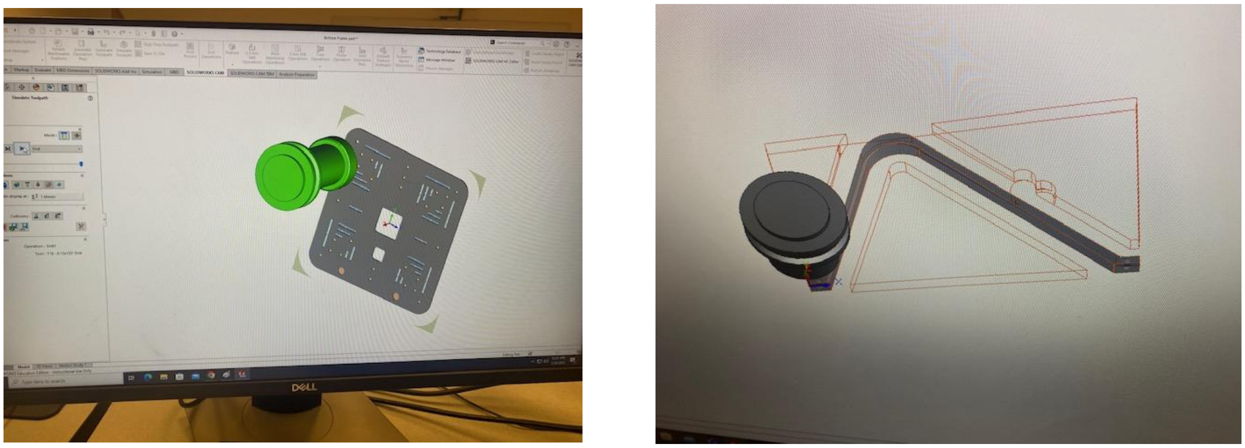


Fig.4: Process of generation of CNC codes and the simulation of the code by CAMWorks software

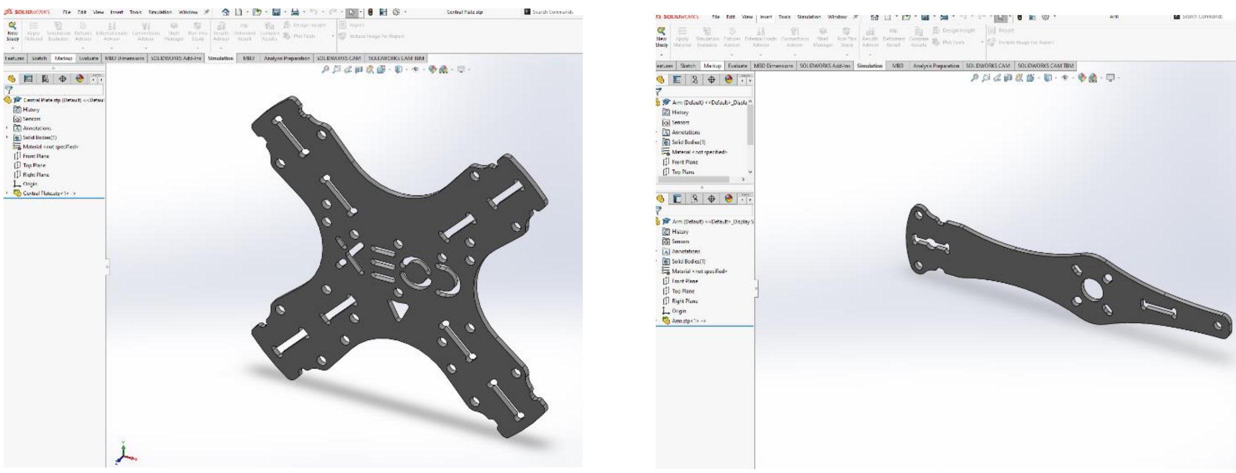


Fig.5: CAD models of COEX Clover drone's frame parts

Fig.6: Prototyping the parts of the COEX Clover drone by 3D printer

Fig.7: Prototypes of frame components of the COEX Clover drone by 3D printer

ENGT 460: Engineering Software Application: The SolidWorks simulation software (Finite Element Analysis Software) is used to analyze stress and deflection/displacement on the UAV frame and connections to validate the reliability of the frame structure in real-world operations. The stress and displacement of the frame's critical components, when UAV drops from 10 meters and during takeoff, are simulated and analyzed. The frame may need to be modified to withstand the required stress and displacement. The Von Mises stress results of the dropping test and during takeoff for the two UAVs are reported in Figures 8-11.

Fig.8: Result of drop test of ELEV-8 drone

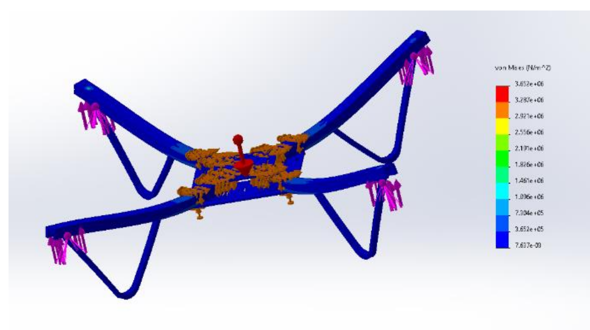


Fig.9: Result of takeoff test of ELEV-8 drone

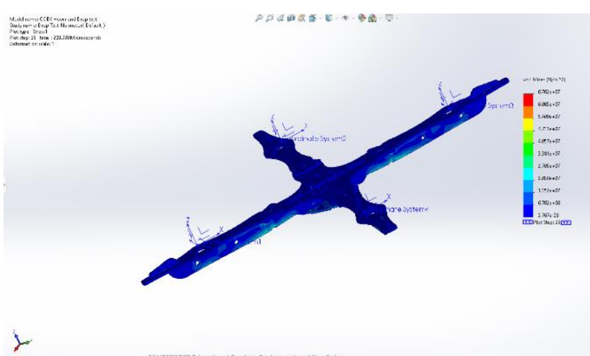


Fig.10: Result of drop test of COEX drone

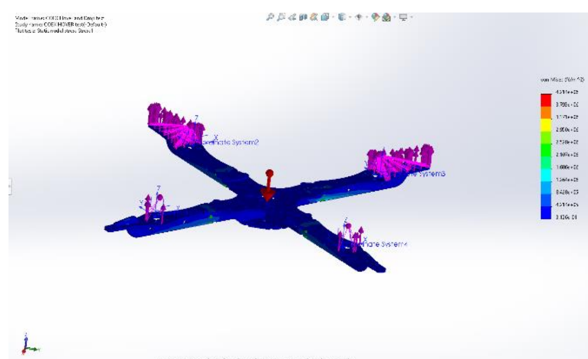
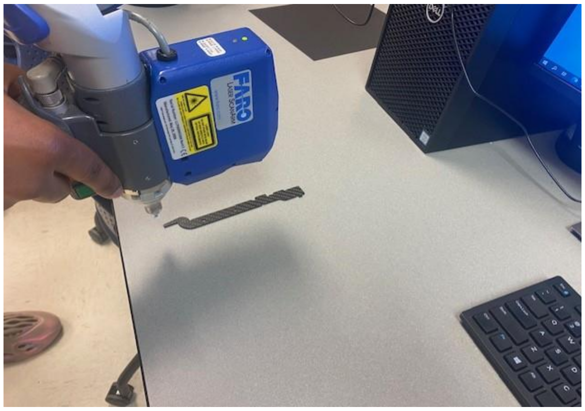


Fig.11: Result of takeoff test of COEX drone

Figures 8 and 10 show that high-value stresses are developed at the legs and sections that hit the ground. Figures 9 and 11 display that the stress level during takeoff is in the low range.

ENGT 455 & 498: Senior Seminar and Senior Capstone Project: The UAV project including modification, assembly, and testing is completed in the senior project course. Innovative design methods are used to enhance the performance of the UAV. Prior to the assembly of the parts, several factors including lighter weight, durability, minimum stress and displacement, flight time, and payload are investigated and considered in the modification process. All structure components may need to be further modified and remanufactured either by the 3D printer or CNC machine in order to improve the assembly and installation of UAV components to ensure optimal flight operation. In addition, the reverse engineering technique is introduced to students. Figure 12 shows the scanning of parts by faro arm, a reverse engineering method, to generate the CAD models.



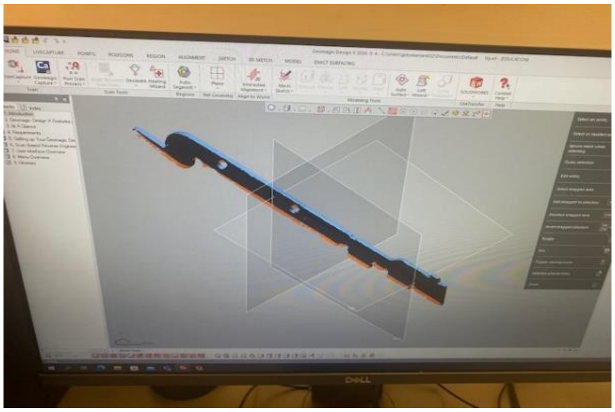


Fig.12: Reverse Engineering Technique

Assessment of the Project

The purpose of this ongoing project is to provide an explanation of the methodology for curriculum alignments to achieve the goals of the three-year project funded by NASA. This is the first year of the project and therefore, the assessment of the project would be completed by the end of summer 2023. The authors will produce a report describing the details of the assessment and outcomes of the project and publish the findings in the proceedings of the American Society for Engineering Education (ASEE) 2024 conference.

Conclusion

Overall, the new modules introduced in each course along with mini projects would help students develop essential skills to achieve useful and practical manufacturing competencies that include understanding the design of products, selecting the equipment and tooling management procedures, validating the parts for their reliability and safety, and choosing appropriate techniques of their production. The courses are also available to industry employees. It is aimed that these revised courses would bridge the skills gap that exists currently in the manufacturing sector.

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