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FROM THE EDITOR.

It has been an honor and privilege to serve as the editor of the ATEC Journal over the past year. With the support of Crystal Maguire and the editorial staff, significant changes were made during this time to ensure that the Journal will continue to be an important resource for aviation maintenance educators. Our hope and plan is to continue to be responsive to the needs of this community, creating opportunities for all of us to publish and to share valuable knowledge and experiences for the benefit of all.

During this time my responsibilities and time commitments have increased significantly. As a result, I came to the conclusion that it was time for a change in order to meet the needs of the Journal. We are happy that Karen Johnson has agreed to assume the duties of the Journal editor; having worked closely with Karen over the last year, I know that she will do a great job for us in this new role. Thanks for your support over the last year – it has been a great experience for me.

Karen Johnson has been an Associate Professor in the Department of Aviation Technologies at Southern Illinois University Carbondale for 12 years. She possesses a Master's degree in Curriculum and Instruction and is currently working on her doctorate in Learning Systems Design and Technology. Her research at SIUC and with ATEC includes multiple projects for online applications for use in aviation maintenance technician schools. Prior to her work in academia, Karen was a field mechanic on Bell 206Ls for Air Evac Lifeteam.

Best Regards,

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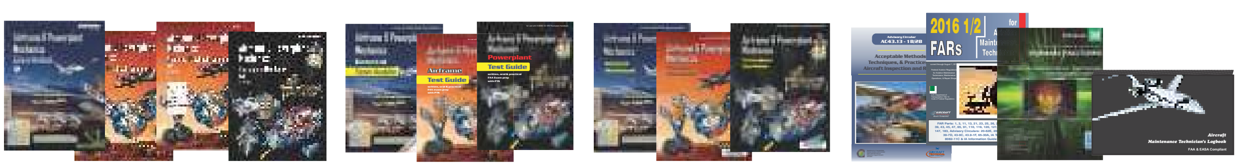

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DIY SIMULATIONS:
THE CASE FOR USING THEM AND WHERE TO FIND THEM

Submitted to the ATEC Journal
By Kelly M. Filgo
Lead Aviation Maintenance Instructor
Texas State Technical College (TSTC) in Waco
Fall 2017

ABOUT THE AUTHOR

The author just finished his fifth year at TSTC and is the lead instructor (similar to a department chair at other colleges) of the dual major Airframe and Powerplant programs at the Waco campus of TSTC. Mr. Filgo is in his second year of a Master of Arts in Higher Education Administration with a Master's Certificate in Higher Education Assessment and Institutional Research at Sam Houston State University. He has served on a Texas Education Association committee making recommendations to high school Career and Technical Education programs in the state of Texas and received a NISOD Excellence award in 2015.

Mr. Filgo will be presenting on this topic at the 2018 Annual Conference, taking place in Washington DC on March 17-20. For more information, visit http://www.atec-amt.org/annual-conference.html.

ABSTRACT

Part 147 Aircraft Maintenance Technician Schools are facing challenges in how to deliver content to today's students. The new wave of students, most of them Millennials, have grown up learning in drastically different ways than many AMTS instructors teach. As an industry, we face a disconnect between our teaching methodologies and the learning patterns of these students and quickly ascribe the problem to media-addicted young-adults. This article looks deeper into the issue and proposes that the new generation and their instructors are not very different after all. It will explore constructivism as an educational theory that shows where instructor and student can find common ground. Finally, this article gives examples of affordable and easily implementable strategies using computer simulations that can be used as vehicles to explore ideas and build up the students' understanding of abstract concepts.

INTRODUCTION

Aviation maintenance instructors, like most aviation professionals, are pretty stubborn people. We have been turning out mechanics for generations with our methods and we trust what works. The way we learned our trade worked fine for us, we reason, so why ever change it?

However, right at the time our industry is facing massive labor shortages, a generation comes along that does not seem to mesh with our tried and true teaching methods. These students are called The Millennials and we often perceive them as media-addicted and unmotivated. Educational professionals tell us that we have to reach them in ways that are culturally relevant. We are told that they learn in non-linear ways, rely on visual cues, and want to explore ideas (Jones, 2012). Our response is to clutch our PowerPoint slides (or overheads, maybe) a little tighter and claim that we are not about to provide info-tainment just because kids, these days, don't read.

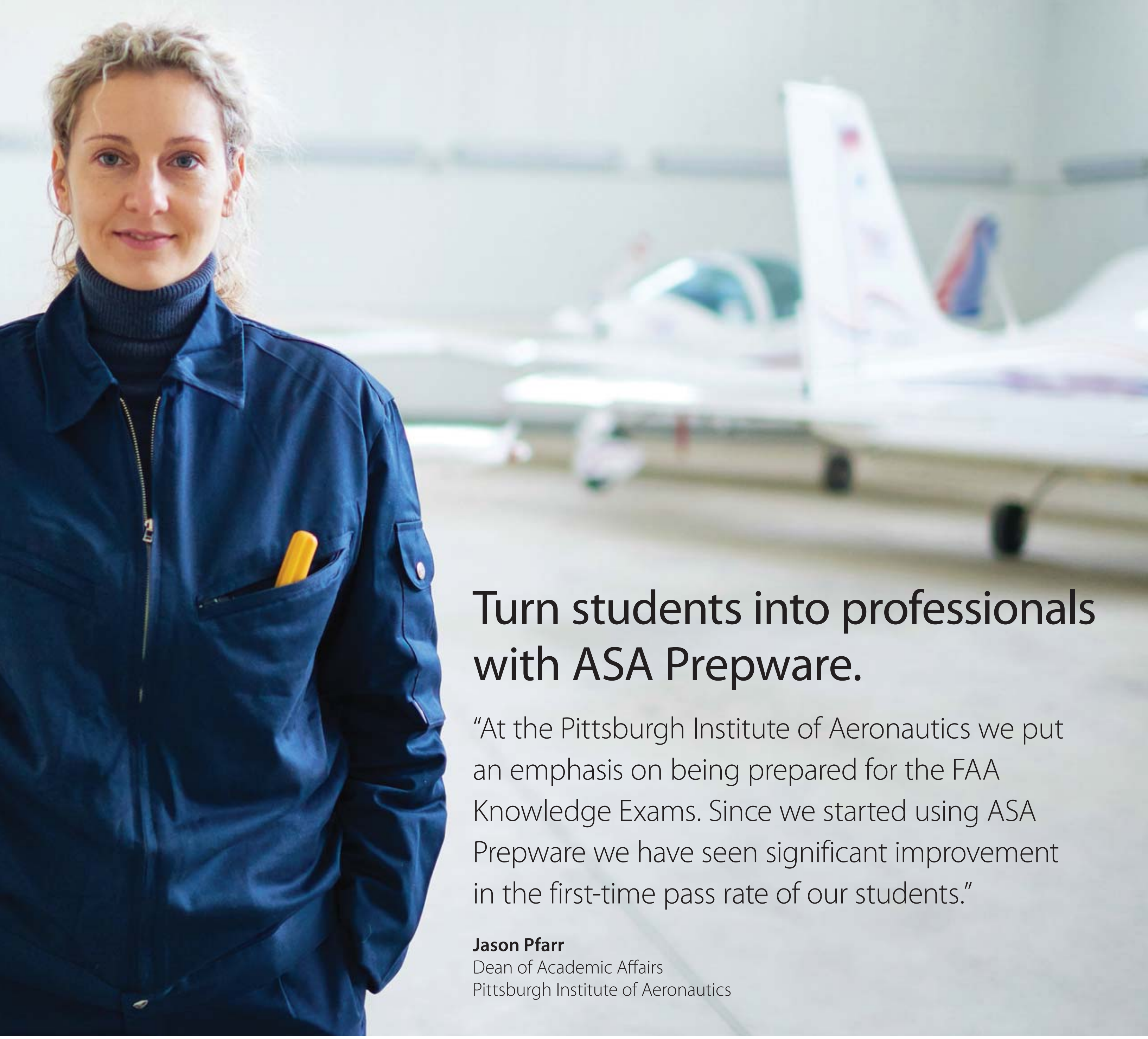
THE CONSTRUCTIVIST STUDENT

An educational theory, its roots going back as far as Socrates, relates to this subject. It found modern expression over 100 years ago in the work of Jean Piaget and John Dewey ("Constructivism as a Paradigm for Teaching and Learning," 2004). Constructivist Theory has since been developed by many scholars, including Lev Vygotsky, who summed up the foundation of this theory in his statement, "The one who does the talking, does the learning. ("Lev Vygotsky," 2014)"

Instructors bemoan the fact that young students come to us with many habits that do not promote success in the classroom. How to cure them of those habits is a debate that could go on and on. But they do have one habit that primes them for learning. More and more often, we find students who need to tear down and rebuild what we are presenting in class before they can move on to the next topic. As frustrating as that can be sometimes, we need to make room for this behavior in class. The Constructivist students are not being disrespectful, but instead are gaining knowledge. They take what is presented as fact, test it for weak areas by comparing it to their previous experiences, and rebuild it into an accepted idea that either enforces their correct assumptions or redefines them into refined knowledge. And this is nothing new; mechanics are kinesthetic learners and this is how we "get physical" with abstract concepts. We learn best when we take things apart and rebuild them. We learn by making sense of the world around us (Miller-First & Ballard, 2017). It turns out we have something in common with the Millennial students, after all. They are just looking for more sophisticated and interactive tools.

How do instructors take students to this place where they grasp and internalize a concept instead of simply memorizing a fact to pass an exam? Since mechanics are hands-on people, it is always best to put those hands on a real object. Engine stands, live-systems trainers, and functional aircraft are still the best simulators a Part 147 school can use. An engine that students can tear down and rebuild, step-by-step, is an easy application of Constructivist methodology, and our labs are full of this kind of activity. But how can we do interactive training with gas molecules, dangerously out-of-limits loaded aircraft, objects that need to move on frictionless surfaces, or a host of other exotic circumstances? Sketching on a dry-erase board or a concession to use YouTube videos on occasion falls far short of providing an opportunity for students to play with abstract concepts in a meaningful way. A drawing or video can only show. A live and dynamic computer simulation allows students to explore and develop persistent understanding. By creating virtual environments where we can make room for abstract thinking and reflective examination of a topic, we give Constructivist students a place where they can build knowledge on their own terms (Alt, 2015).

In 2004, Hsiao-Ching She published a paper, Fostering Radical Conceptual Change through Dual-Situated Learning Model (She, 2004), that proposes an effective method of reaching the Constructivist student. Her work centers around first identifying what misconceptions students have about a topic and then finding ways to lead them to a moment where they see the difference between their misconception and the facts concerning the topic. When they can differentiate between the facts and their misunderstandings, the new knowledge is not only acquired, but is shown to persist over time (She). The key element is allowing students to challenge the ideas presented and see how their misconceptions fail to explain the observed results. Computer based, real-time simulations can allow students to experience this cognitive dissonance between what they thought they knew and what they are directly observing, especially in novel or exotic circumstances. This allows them to learn a new concept and repair the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misconception they had at the beginning of the lesson. The ability to manipulate the simulation with different variables and see that the results are predictable provides immediate feedback that fosters learning (Sornkhatha & Srisawasdi, 2013).

Anyone who attended ATEC 2016 was awed by Boeing's multi-million-dollar maintenance trainers and their drive to bring simulation into the learning environment. But even Boeing is holding off on ordering Microsoft HoloLens at any useful scale until costs come down. How can Part 147 schools, especially non-profit or state/locally funded schools, even begin to get into computer simulations? To answer that question, we need to consider a couple of important things first.

IMPLEMENTATION

There are low-cost, and even free, simulation software packages available that can do some amazing things. Department chairs need to take stock of their situations if they are convinced that it is time to implement some changes to their Aviation Science curriculum.

In an excellent paper in 2007 on implementing new technology into the classroom, Marietta Del Favero & Janice M. Hinson provide a roadmap guiding department chairs and faculty through the process. Most useful is a seven-step scale showing the range of attitudes about implementing new technologies. Since substantial time might be needed to develop useful class material, especially if faculty do not have previous experience in the software, department chairs need to gauge faculty attitudes and readiness to take on such tasks. They must also be very supportive of the necessary development time to see fruitful outcomes (Favero & Hinson, 2007).

Another consideration is the school's relationship with its Principal Maintenance Inspector at the local FSDO. Interpretation of how much of the curriculum is considered subject to approval before implementation can be tricky, so communicate with your PMI about any planned changes well in advance. Bringing computer simulations into the classroom should not be any different than buying a new trainer board, but let the PMI be a part of that determination when it comes to altering your curriculum.

At TSTC, we have been working for a year on implementing simulations into our daily class environment, especially in the General Subject curriculum. We have developed over 20 simulations that we use in lectures, primarily in Aviation Science and Basic Electricity. To date, we have invested less than 60 total hours in development time, though the faculty working on these simulations are considered tech-savvy, highly motivated, and fully supported.

Our students have expressed that they enjoy being able to explore ideas presented in class and that changing up the variables and getting live feedback has improved their understanding of concepts. Early success in grasping key ideas will improve retention and completion rates as students enter their advanced classes with better understanding of fundamental subjects. They will spend less time needing to recall fundamentals and more time learning complex systems. This, in turn, will make them better prepared for certification testing and their awaiting careers.

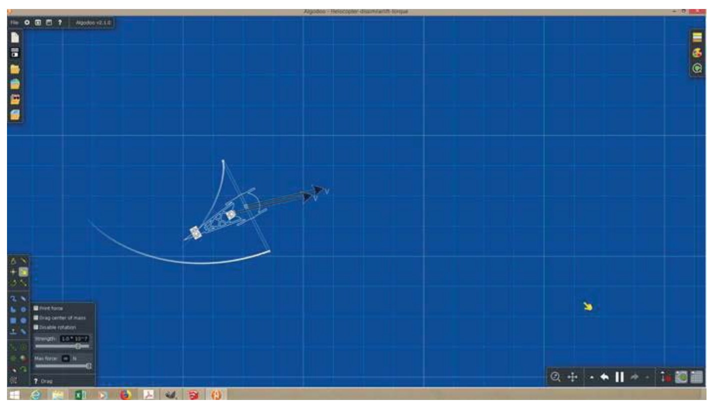

Figure 1. Dissimilar lift sim created in Algodoo - Helo in forward motion

Figure 2. Dissimilar lift sim created in Algodoo - Helo in hover

TABLE 1. Software used for simulation in TSTC courses.

Software Information	Courses	Subjects
Algodoo 2D Physics Sandbox Free to anyone www.algodoo.com	• Aviation Science • Landing Gear • Assembly and Rigging	• Ideal gas law • Pascal's law • Helicopter dissimilar lift • Gear ratios (including planetary gears) • Density, mass, and gravity • Newton's laws of motion • Buoyancy in fluids • Air-oleo struts • Internally braced wings • Rigging systems
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X-Plane 11 Flight Simulation $775 for two commercial license keys (50% off for educational license pricing) www.x-plane.com	• Aviation Science • Weight and Balance • NavCom • Propellers • Ground Operations	• Aircraft design • Flight controls • Flight stability • Generating lift • Extreme loading situations • Instruments and their functions • Constant speed propeller operation • Ground starting and taxiing • Creating images for test questions

LOW COST SIMULATIONS

Table 1 outlines the simulation software packages we are using, costs at the time this article was submitted, and product location information. Courses and subjects where simulations have been developed are listed by software title.

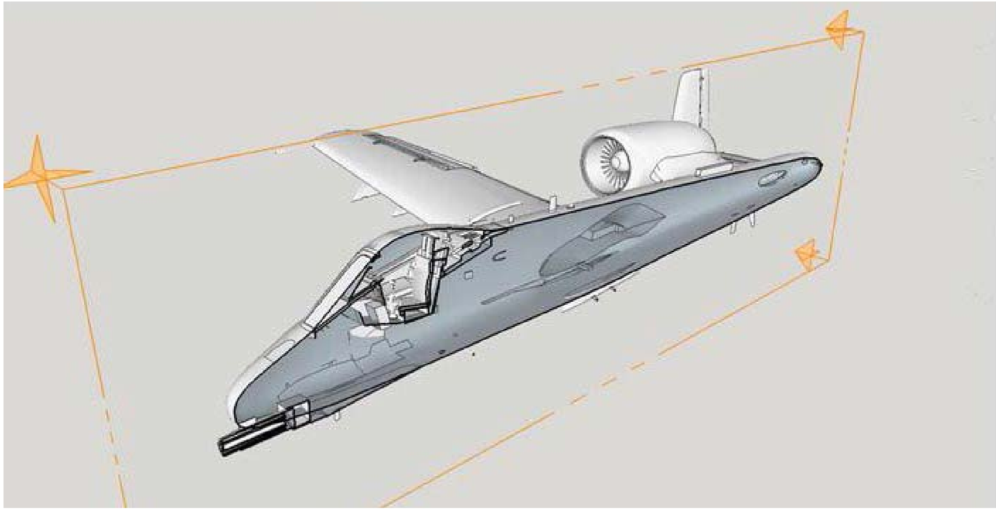

Figure 3. SketchUp showing how sectional views work

SUMMARY

The upcoming shortage of aviation mechanics demands that we provide new talent to the workforce in record numbers. Perceived differences in learning styles can cause conflict between students and faculty, leading to less prepared graduates or reduced completion rates. However, if we dig deeper, we find that we all learn best by correcting our lack of knowledge by taking things apart and putting them back together again. Creative use of simulations can bridge that gap in learning, especially with subjects that are not so easy to put our hands on. Computer simulations do not have to break your annual budget or take excessive amounts of time to implement. The breakthroughs experienced by our students are well worth the effort our schools will invest in adopting low-cost simulations in the classroom.

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INTRODUCING REVERSE ENGINEERING TECHNOLOGIES IN AN AERONAUTICAL ENGINEERING TECHNOLOGY CURRICULUM

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Ronald Strkenburg is a professor at the School of Aviation and Transportation Technology at Purdue University. He is a certificated Airframe & Powerplant mechanic (A&P), holds an Inspector Authorization (IA) and performs the duties as a Designated Mechanic Examiner. Dr. Sterkenburg's main research interests are in advanced composite materials for aerospace vehicles. He has published many articles, book chapters and books on all types of aviation maintenance topics.

ABSTRACT

Aerospace companies often develop and manufacture their products with 3D modeling technology. Reverse engineering laser-scanning technology can be used to create a 3D model of aircraft that were designed before 3D modeling became the standard. The 3D model can be used to recreate molds for new part manufacturing and repair of damaged structures. Graduate students at Purdue University developed a reverse engineering technology project that was added to the curriculum of the advanced composite manufacturing course. This project combines various composite manufacturing skills and technologies such as reverse engineering, 3D modeling and composite design, rapid prototyping with additive manufacturing, parts manufacturing with Computer Numerical Control (CNC), and 3D deviation analysis with 3D scanner.

INTRODUCTION

In the past, it was very common to make a prototype of an aircraft or aircraft part using wood, clay or plaster. However, now a days most aircraft and aircraft parts are designed with a computer [1]. The introduction of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) technology has made it possible to create a 3D virtual model of the aircraft, and a physical mock-up is not necessary [2]. Reverse engineering technologies using a 3D scanner could be used to create a virtual 3D model of older aircraft that were designed before the introduction of CAD. The created 3D model could be used to create molds to manufacture or repair aircraft parts [3].

Reverse engineering is a technology that reconstructs the 3D virtual model from data that is collected (scanned) from an original physical model [4]. Reverse engineering technology is often used for rapid prototyping and an analysis of the shape geometry. It reduces reconstruction time and cost for part surface reconstruction [1]. Rebuilding the CAD model of the aircraft or aircraft part based on original drawings and measurements is very time consuming and expensive. However, using reverse engineering technology using 3D scanners makes this process much easier [2]. Since it is essential to have the ability to design a product quickly with better properties, reverse engineering technology has become more popular, and many industries use reverse engineering technology for their product design system [5]. Figure 1 shows the process of reverse engineering.

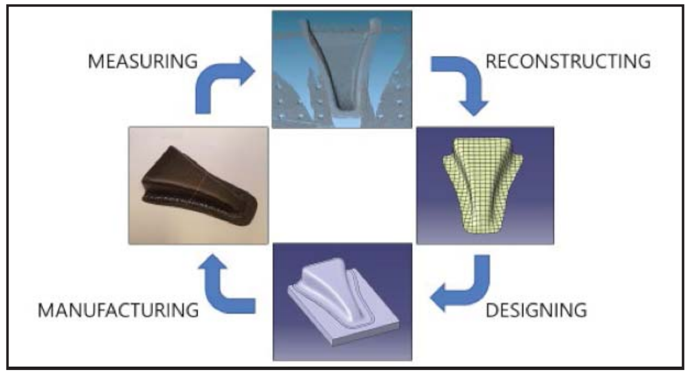

Figure 1. Process of reverse engineering.

Faculty at the Purdue University added an advanced Composite Manufacturing course (AT472) to the curriculum of the Aeronautical Engineering Technology program. The “toolbox” of future aviation professionals is changing, and new tools such as CAD/CAM software, CNC, and additive machining (3D printing) are added to keep up with the demands of a technology driven aviation industry. The purpose of this course is to introduce students to advanced composite manufacturing methods including the use of CAD/CAM, Computer Numerical Control (CNC), additive manufacturing, and reverse engineering technologies. This paper describes a project that was created by graduate students of the School of Aviation and Transportation Technology at Purdue University. Students that enroll in the advanced manufacturing course will learn all necessary skills such as CNC programming and machining, 3D printing, waterjet cutting, and composite design. For this project, reverse engineering technologies, rapid prototype processes, and part manufacturing technologies were used to reconstruct a 3D virtual model, rapid prototyping of the model, and manufacturing of a new physical model. The authors hope that this project will inspire others to incorporate new manufacturing technologies in their program curriculum.

PROJECT DESCRIPTION

The first step in the reverse engineering process is to create a 3D virtual model of an existing part. Purdue Pete, a mascot of Purdue University, was used as the original part. Students of the School of Aviation and Transportation Technology make several Purdue Pete heads and helmets each year for the cheerleading squad. The mascots are used for Purdue University sporting and promotion events. The design of the Purdue head is rather old and was created before the use of CAD software and no 3D model was available. This project started with measuring the original Pete head. The size of the part was approximately 316.16mm x 418.07mm x 443.08mm (12.45” x 16.46” x 17.44”). Since Purdue Pete has a complex geometrical shape, it was a good challenge for students to practice measuring skills and build valuable 3D modeling experience. Figure 2 shows the original part for this project.

Figure 2.
Original Purdue Pete.

SCANNING OF ORIGINAL PART

Students used the FARO Edge ScanArm® HD scanning tool and CAM2 Measurement 10 software to create a 3D model. The Edge ScanArm® HD provides a very accurate scanning performance (ﬄ0.001 inch accuracy of measurement) and it is relatively easy to use. The students cleaned the surface of the part thoroughly, because contaminants on the part surface could cause noise and unwanted mesh while measuring with the scanner equipment. The part was fixed on a table and carefully scanned using the scanner arm. It is important to ensure that the entire surface is scanned to prevent missing data on the surface. Figure 3 shows the picture of the part scanning process.

Figure 3.
Part scanning process.

MESHING AND SURFACING

Since the data collected by the scanner is created as an unstructured point cloud, it cannot be used to make a CAD model directly and additional tasks need to be completed. Figure 4 shows the collected point cloud from the part's surface. The point cloud data was converted into a mesh form using CAM2 Measurement 10 and imported into 3D imaging software (Geomagic Wrap). Mesh imperfections were fixed using various mesh functions such as mesh doctor, fill hole, and rewrap. Figure 5 shows the before and after comparison of the meshing process.

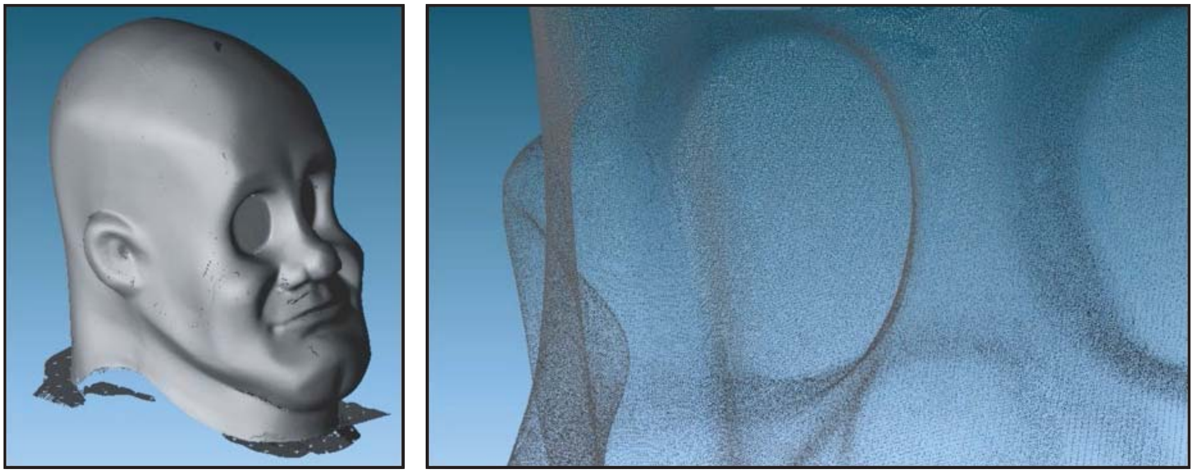

Figure 4. Collected point cloud from the part.

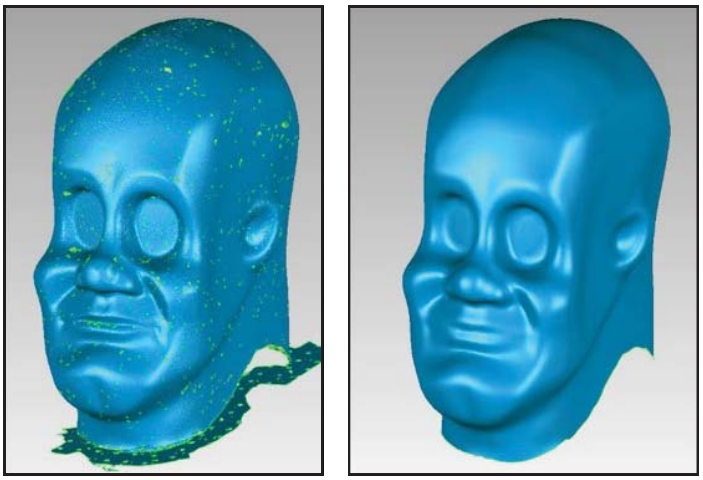

Figure 5. Before and after comparison of the meshing process.

After the students completed the meshing process, the mesh was converted into a surface. The mesh was imported into the CAD software, CATIA, and the surface was generated from the mesh. The generated surface was used to design the new part. Figure 6 shows the generated surface of the virtual model.

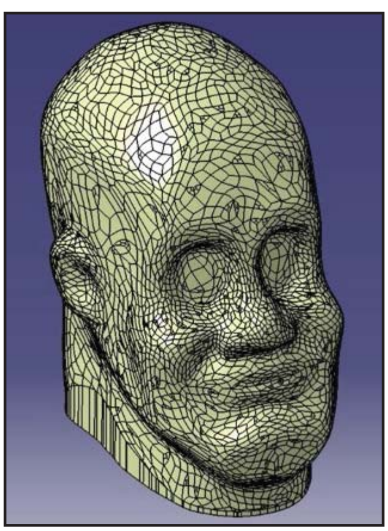

Figure 6. Generated CATIA surface of the part.

3D PRINTED PROTOTYPE

Students created a solid 3D model from the surface that was generated. A --scale prototype was created to check the final design before moving on to the manufacturing process. The students made the prototype with a 3D printer using PLA material. Building the prototype helped students to check the final design with the physical original model before the start of the actual manufacturing process. 3D printing is a fast and inexpensive way to verify a design. Figure 7 shows the picture of the prototype.

Figure 7. 3D printed prototype of the part.

MANUFACTURING USING 5 AXIS CNC

The students checked that the prototype accurately represented the original shape of the head, and the part manufacturing process was started. Students had learned how to program and operate a five axis CNC in class and applied their knowledge for the manufacturing process. Students first imported the 3D solid model into the CAMWorks® CAM software to generate the toolpath. Students used a DMS 5 axis CNC for the CNC milling process. In the CAM software, the shape and size of the stock material and milling bits were chosen to optimize the milling process. Five axis CNC programming is a complex task and

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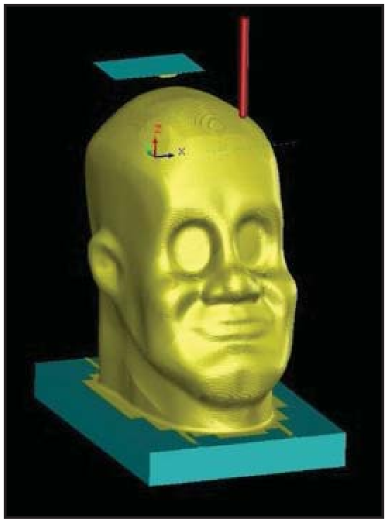


Figure 8. CAM software machining simulation result.

students had to explore many options to create the most efficient toolpath. The toolpath for this research can be divided into two main sections: The first one is a 3 + 2 rough milling process with removes large amounts of stock rapidly; The second one is a pattern project (planar or sweep) which finish mills the surface of the part with smaller tooling and step over distance to improve surface quality. The students simulated the complete milling process on the computer and on the 5-axis CNC controller to verify that the milling process was correct as shown in figure 8.

Figure 9. CNC milling Pete.

Students placed the stock material in the CNC mill and secured it in place. The milling process was started and the results are shown in figure 9. Figure 10 shows the completed part ready to be scanned to verify the accuracy of the milling process.

Figure 10. Finished milled Pete.

DEVIATION ANALYSIS

The graduate students performed a 3D deviation analysis to compare new part to the original one. The scanner equipment was used again to create a point cloud from the surface of the new part and used it for the analysis to determine if the new part was accurately made. Geomagic Wrap software provides a 3D deviation analysis function that students used for this project. The 3D deviation analysis showed that there was an average deviation of 1.7042mm/-1.8513mm across the entire surface. Figure 11 shows the 3D deviation analysis process between the original part and the new part.

Since there was a significant deviation between the original and the new part, students performed a 3D deviation analysis between each process to determine what caused the deviation. A 3D deviation analysis between original point cloud and mesh, mesh and generated surface, generated surface and machining simulation, machining simulation and point cloud of new part were performed and compared. Table 1 shows the results of the 3D deviation analysis average deviation between each process.

The one of the main reasons that caused the deviation was the choice of material. The foam that was used for this project has a porous surface. Therefore, the data collected from the scanned surface of the foam generated a lot of noise. A flat foam plate was milled and its surface was scanned to check how much noise the foam created. The average deviation between collected point cloud and flat plate model was +0.0779 / -0.1024 mm and the maximum deviation was +0.6162 mm / -1.0470 mm. If a different kind of material was used that has a non-porous surface, the deviation results could be reduced. Figure 12. Shows the 3D deviation analysis result of flat foam plate.

CONCLUSION

In this project, students of the School of Aviation and Transportation Technology of Purdue University successfully measured the existing physical model of the university mascot, and reconstructed a 3D virtual model using reverse engineering technology. A scaled prototype was made with a 3D printer, and a full scale model was machined on a five axis CNC. This project will be introduced in future classes so students have the opportunity to experience the complete engineering and manufacturing process including reverse engineering techniques to reproduce or repair parts that were designed a long time ago and for which no 3D computer model is available. Figure 13 shows the completely manufactured Purdue mascot, Purdue Pete.

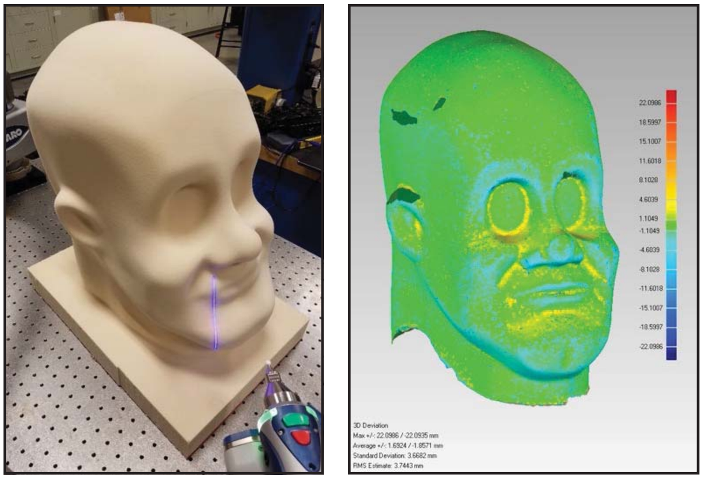


Figure 11. Before and after comparison of the meshing process.

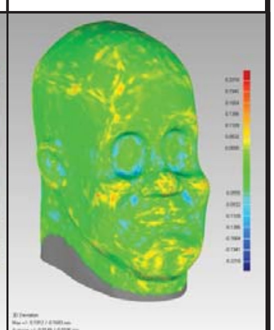
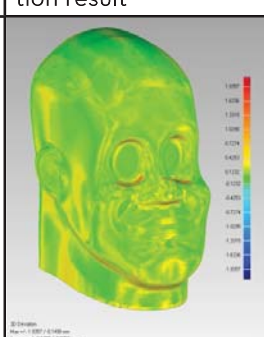
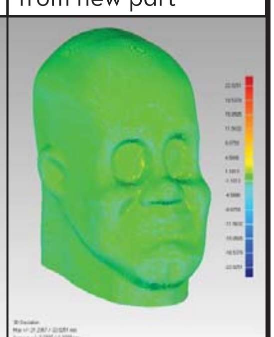
Process	Point cloud from original part vs. generated mesh	Generated mesh vs. generated surface
3D deviation analysis result		
Average deviation	+0.1354 / -0.1321 mm	+0.0149 / -0.0106 mm
Process	Generated surface vs. machining simulation result	Machining simulation result vs. point cloud from new part
3D deviation analysis result		
Average deviation	+0.1298 / -0.0306 mm	+2.2337 / -1.1609 mm

Table 1. 3D deviation analysis between each reverse engineering process.

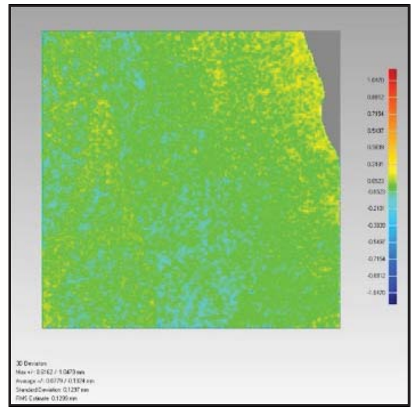


Figure 12. 3D deviation analysis of flat foam plate for noise detection.

Figure 13. Completely manufactured Purdue mascot, Purdue Pete.

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UNMANNED SYSTEM PROPULSION:
TYPES, OPERATING CONSIDERATIONS, AND ATTRIBUTES

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ABSTRACT

This paper will explore the various powerplants used on small unmanned aircraft and their operational characteristics. The advantages and disadvantages of each will be examined. Understanding the propulsion systems used in unmanned aircraft is essential to safe and reliable operations. The propulsion system determines duration, effects sensor payload performance, and will affect the weight the unmanned aerial vehicle (UAV) can carry. Proper selection, service, and operation of the propulsion system will minimize unscheduled repairs, unnecessary costs, and potentially crashes related to loss of power events.

INTRODUCTION

The modern UAV is designed with a set of mission requirements and payloads in mind. Aircraft of all types are a series of priorities set to achieve specific goals and unmanned aircraft are no exception. As an example, if stealth operation is a mission priority, such as in wildlife observations or surveillance applications, this would dictate electric propulsion be chosen over fuel burning engines due to their noise while operating. If extreme duration is a mission priority than a system that has a liquid fuel engine may be appropriate. Each propulsion type will be discussed in the following paper with its specific attributes explored so that an informed decision can be made in light of mission priorities.

ELECTRIC MOTORS

Electric motors in modern unmanned aircraft are typically of the direct current (DC), brushless, outrunner type. There are exceptions to this generalization, however, as brushed motors still have applications in some smaller rotorcraft. This particular type of electric motor is well suited to producing substantial torque to turn larger propellers or rotors without the requirement of an additional reduction gearbox or belt driven reduction system. It has the further advantage of eliminating the brushes formerly used to transmit electrical power to the rotor. Eliminating the brushes not only eliminates a wear and service requirement, but has the further advantage of eliminating brush sparking, which can cause electrical interference in sensitive autopilot and electronic components. Electric motors are low vibration, low noise, and virtually service free due to the brushless design. A further advantage is the 100% reliability of restarts and the highly predictable and controllable power curve.

Electric motors are selected based upon the power they are required to produce, just like the other forms of propulsion. The Kv rating of an electric motor is often listed as a specification to be used in selecting motor performance. Kv is the revolutions per minute (rpm) a given motor will produce when 1 volt is applied. In general, the smaller the Kv rating of a motor, the larger propeller or rotor it is designed to turn at a lower rpm. A more useful measurement of motor performance is the watt rating. The watt is simply the voltage multiplied by the amperage. A motor rated at 900 watts will consume 75 amps at 12 volts (11.1-12.4v lipo). This watt rating can serve a couple of purposes. Firstly, it can help in selecting the amperage capacity of the electronic speed control (ESC) and battery required for the motor. Secondly, the watt rating can be used to estimate weight carrying capability of the aircraft. An unmanned, fixed wing aircraft will fly marginally at 50 watts per pound flying weight. If a hand launch is required, the watts per pound should be closer to 100. If exceptional climb is required, 150 watts per pound is considered adequate. In the example above, a 900-watt motor would be adequate for a 9-pound fixed wing aircraft in most cases.

Multirotor unmanned aircraft primarily use thrust to determine their flying ability. The thrust will vary with motor selected, voltage applied, and rotor size. Thrust ratings are available from most motor manufacturers for various rotors installed. A 2:1 thrust to aircraft weight ratio is considered adequate. If this balance is not maintained, the rotorcraft may not have adequate reserve thrust for maneuvering and will eventually become unstable as weight is increased. Electric propulsion sizing requirements are influenced by many factors. Several online calculators have been developed to address these variables and predict performance as well as other factors such as duration, heat generation, and expected thrust of electric powered aircraft.

RECIPROCATING PISTON ENGINES

The reciprocating piston engine in unmanned aircraft have historically taken two forms: the glow ignition engine and the spark ignition type. They are available in two stroke, four stroke, and multiple cylinder configurations. The methanol burning glow ignition type is no longer commonly used. The modern spark ignition type is typically two stroke and incorporates an electronic ignition system for ease of starting, reliability, and maximum power. The fuel is mixed with a small amount of oil for lubrication much the same as a residential mower or chainsaw. The primary disadvantages of the piston engine include noise, vibration, and exhaust plume residue that may interfere with sensitive cameras and sensors. The primary advantage of the piston engine is relatively low cost and exceptional thrust to weight ratio. Long duration flights favor the efficient piston engine as well. Multiple cylinder arrangements can mitigate vibration. Installing the engine at the rear of the aircraft (pusher), far from sensors and avionics is a common design strategy. Because piston engines vibrate, and are composed of multiple close fitting parts, the maintenance requirements for these engines exceeds that of most other powerplants. Piston engines are traditionally rated in horsepower and/or thrust produced.

GAS TURBINE

In recent years, the gas turbine engine has become practical for unmanned aircraft use. The ignition of the combustible fuel and the rotation of the internal parts are continuous, therefore, the vibration is dramatically reduced over the piston types. Turboshaft types have also been developed to power small unmanned rotorcraft and helicopters. Gas turbine engines, like their manned counterparts, have the most advantage over other types during high altitude operations where the atmosphere is thin and piston engines struggle to produce horsepower. This attribute has not been fully realized as current regulations, in most cases, limit operations to visual line of sight (VLOS) and therefore limit the speeds and altitudes achievable by the turbine type. The three main disadvantages of very small turbine engines are cost, noise, and the skill required to operate them safely. Turbine engines are normally rated in thrust produced.

SUMMARY

Selection of the proper propulsion system is critical to mission success. The disadvantages of each type must be minimized to provide the best set of compromises based upon mission requirements. Engines designed specifically for unmanned aircraft, especially in the larger thrust categories, are rare. Most smaller propulsion systems have been borrowed from the recreational radio control hobby. Very large unmanned aircraft will find suitable options in the manned, experimental aircraft, or ultralight market. The unique nature of unmanned flight will see the future development of propulsion systems that are tailor made to work seamlessly with airframe and avionics of specific unmanned aircraft.

Figure 1. 5.5 Horsepower, twin cylinder opposed, electronic ignition, two stroke gasoline engine

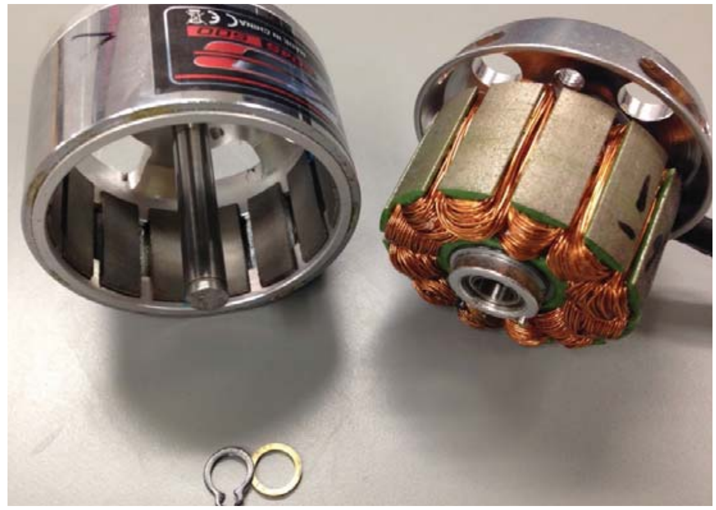

Figure 2. Brushless, outrunner electric motor disassembled to show stator and rotating magnets

Figure 2. Brushless, outrunner electric motor disassembled to show stator and rotating magnets

BIO

Michael Leasure teaches at Purdue University at the level of Associate Professor in the School of Aviation and Transportation Technology. His unmanned interest and activities span over 4 decades including the design, test, and publication of multiple unique model aircraft designs beginning in 1984. His federal licenses include FAA airframe and powerplant, Inspection Authorization, remote pilot, and private pilot. His professional unmanned activities began in earnest in 2002 with the construction and flight test of a precision agricultural UAV with autopilot and dual camera installation. The aircraft spanned 10 feet and was flown successfully for over 12 years. Subsequently, he has flown and tested multiple unmanned systems including rotorcraft, as well as fixed wing designs. Current efforts involve the development, and delivery of unmanned aircraft instruction at Purdue. He has published a textbook on the subject: Leasure, M.L. (2016). Unmanned Aerial Systems: The Definitive Guide. (2nd. edition) Tabernash, CO. Aircraft Technical Book Company. This is a comprehensive textbook of unmanned aircraft science that is utilized throughout the major plan of study in unmanned systems. He is also the acting Director of unmanned aerial operations for the Beck agronomy center at Purdue

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