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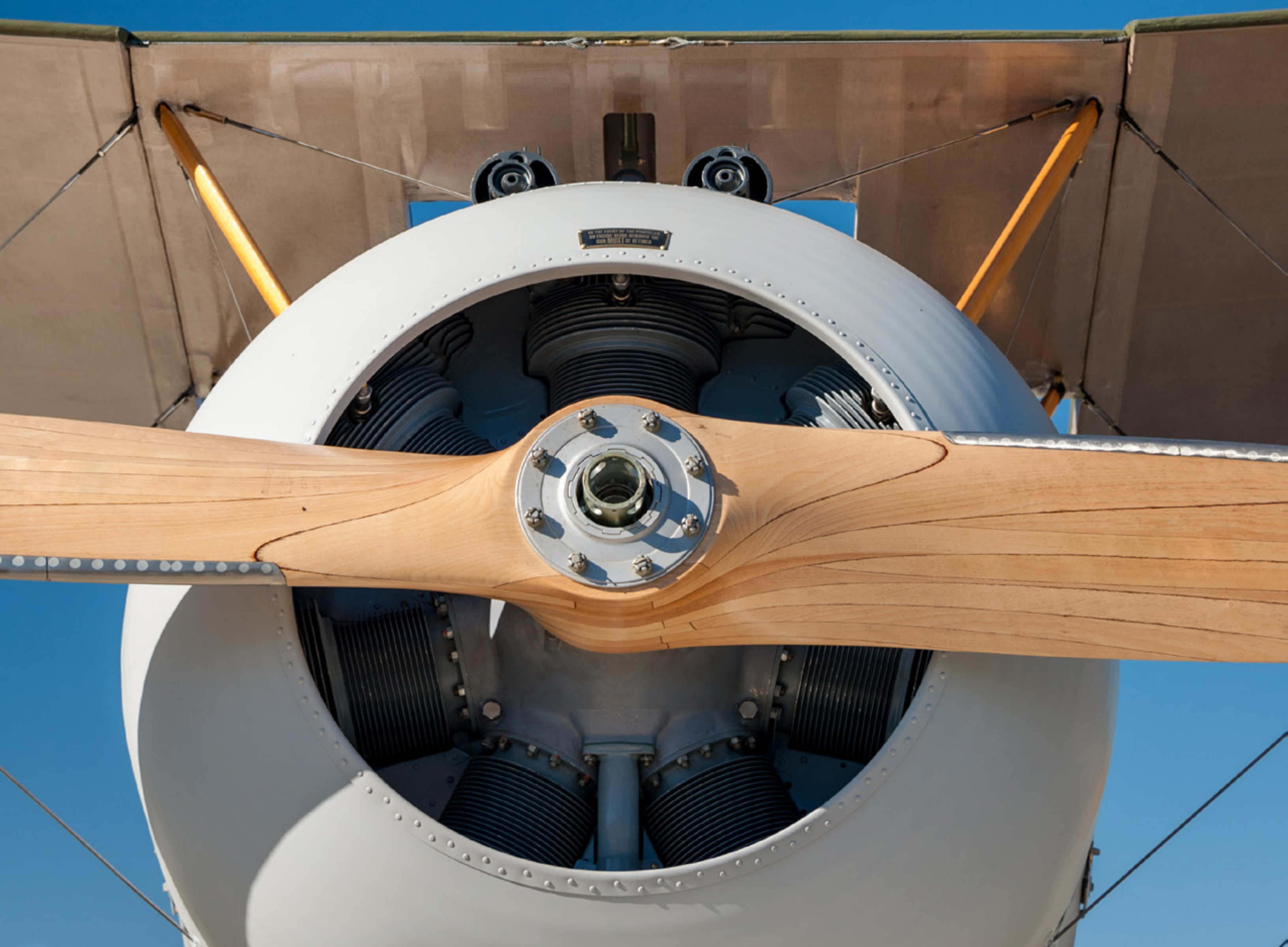

ATEC

About **the Council**

ATEC was founded in 1961. Its mission is to promote and support aviation maintenance technical education.

The council actively engages with regulatory and legislative bodies to advocate on behalf of the community, and provides resources, continuing education, and networking opportunities for our members.

Our membership is made up of employers, vendors, and educational institutions with aviation technical programs. The vast majority of member schools are certificated by the FAA to provide aviation mechanic programs.

Membership supports the following activities and initiatives—

- Advocating for sound regulatory policy, the development of clear and concise guidance, and consistent enforcement and application
- Participating on industry and agency committees to further aviation technical education and workforce development
- Fostering and supporting career pipeline partnerships between industry and educational institutions
- Facilitating networking opportunities through the annual conference, Washington fly-in, regional outreach meetings, and virtual webinars
- Enhancing aviation technical career awareness through support of ATEC's sister organization, Choose Aerospace

About **the Journal**

The *ATEC Journal* (ISSN 1068-5901) is a peer-reviewed, biannual electronic publication. The publication provides an opportunity for educators, administrators, students and industry personnel to share teaching techniques and research. Authors are encouraged to submit their articles for publication consideration, whether scholarly, research, application, or opinion, by using the submission form below. Papers supporting the council's regulatory and legislative agenda may be considered for presentation via online webinar and at the annual conference. Suggested topics include:

- Technical and soft-skills curriculum integration
- A history of legislative actions affecting aviation maintenance workforce development
- A study on implementing employer-education partnerships
- Funding implications stemming from Bureau of Labor Statistics occupational outlooks
- Highlighted innovations in the aviation maintenance industry
- A look at successful online teaching methods and subject matter in other technical fields
- Surveying currently used computer-based teaching across aviation maintenance training schools

SUBMISSION DEADLINES

Fall Issue Closing Date: October 1 • Spring Issue Closing Date: May 1

SUBMIT AN ARTICLE FOR REVIEW AT ATEC-AMT.ORG/THE-JOURNAL.HTML

from the EDITOR

As we all continue to become accustomed to the new FAA Part 147 and Airman Certification Standards and their implementation into our programs and classrooms, this issue of the ATEC Journal includes some applicable topics.

Richard Johnson from the Liberty University Aviation Maintenance Technician Program discusses how the new competency-based risk assessments and human risk factors from the Airman Certification Standards require a revision to our training and what those applications may look like.

Don Morris from the Aviation Technologies program at Southern Illinois University Carbondale provides an overview of a unique and innovative technique for the digital modelling of propellers and how this approach is currently being used in high quality content generation along with its implications in the classroom.

In this new curriculum environment that AMT programs are now in, it is exciting and refreshing to see a few of the new applications that faculty are bringing into the conversation. ATEC hopes that its members continue to move forward with innovative ideas and consider sharing them with the larger community through the ATEC Journal.

As always, thank you to the Editorial Board for their continued hard work, without which this Journal would not thrive. We are appreciative of your efforts.

Sincerely,

Karen Jo Johnson, Ph.D.
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Southern Illinois University Carbondale
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COMMITTEE UPDATES

Committee membership is open to all individuals employed at ATEC member organizations. Explore initiatives below and get involved! Email atec@atec-amt.org to join a committee.

MEMBERSHIP COMMITTEE

The part 147 community is growing, so far this year we've welcomed three new certificated programs to our group, bringing the number of FAA-certificated aviation maintenance technician schools to 195. The committee is focused on ensuring every one of these programs is aware of the benefits of membership, especially those that have not yet joined our ranks.

One great way to learn more about the trade association, and influence our initiatives, is by attending an outreach meeting. The council will hold regional meetings in Oshkosh on July 26 and Seattle on August 8. Registration is free and available at atec-amt.org/outreach-meetings. We hope to see you there!

JAMES SMITH
MEMBERSHIP COMMITTEE CHAIR
AMT Director,
Marshall University
jsmith@marshall.edu

MEETING PLANNING COMMITTEE

Preparation for next year's Annual Conference is well underway. Last month, committee members descended on Tucson to plan the 2024 event, which promises informative sessions, good food, and some of the best aviation hot spots our great city has to offer. Don't miss out on the fun, mark your calendar for March 17-20. Registration will open this fall.

Early sponsor and exhibitor registration is open. Commit early to secure the best rates and reserve your chance to support aviation education's premier event atec-amt.org/annual-conference.

Responses to the call for presentations are due Oct. 1. More information at atec-amt.org/news/atec-annual-conference-call-for-presentations.

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LEGISLATIVE COMMITTEE

The committee developed and refined the council's legislative priorities and set an ambitious goal of addressing each issue in the next FAA reauthorization bill. Working with industry allies, the council obtained coalition support of the initiatives and successfully lobbied Congress to address each of the council's top priorities in the draft legislation, to include expanding the FAA workforce development grant, improving the airman certification standard system, and creating dedicated pathways for exiting military personnel. For a full rundown of the issues, see atec-amt.org/legislative.

The ATEC Fly-in will take a deeper dive into anticipated policy changes and provide attendees an inside look at how work gets done (or not) in the capitol. Plan to join us Sept. 19-22, 2023, registration is open at atec-amt.org/fly-in.

JARED BRITT

LEGISLATIVE COMMITTEE CHAIR

Director of Global Aviation Maintenance Training, Southern Utah University

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REGULATORY COMMITTEE

The regulatory committee keeps focus on providing continued support to the part 147 community as it embarks on new initiatives under a much-improved regulatory framework. After a successful and relatively uneventful transition to the new part 147, the council continues engaging FAA officials as we convert to a new testing system, one that will build on the foundations of the airman certification standards (ACS).

The committee's attention is also focused on petitioning the FAA for a change to part 65 that would allow for earlier access to FAA testing, expanding access to mechanic examiners, and engaging with the FAA to ensure common sense revision to the ACS and associated guidance and handbooks. Read more about those initiative and other regulatory priorities at atec-amt.org/regulatory.

SEAN GALLAGAN

REGULATORY COMMITTEE CHAIR

CEO/Founder,
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CHOOSE AEROSPACE

ATEC's sister foundation just wrapped its first full academic year, deploying aviation maintenance technical curriculum in 16 schools across the country. The majority of the 200 enrolled students were high schoolers, and prime targets for A&P programs looking to matriculate students that have successfully completed general curriculum based on the mechanic ACS.

ATEC provides initial funding for the foundation, and our member school instructors provide valuable expertise to support curriculum development and training resources for high school teachers across the country.

Our A&P programs are catching wind of the resource and finding creative and innovative ways to use it to increase awareness in their communities about their programs. If you are not familiar with the Choose Aerospace aviation maintenance curriculum, I encourage you to visit our website and/or contact me directly.

Applications are open to adopt the curriculum for the 2023-2024 academic year. Learn more at chooseaerospace.org/curriculum.

RYAN GOERTZEN

CHOOSE AEROSPACE PRESIDENT

Vice President Maintenance Workforce Development, AAR Corp

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ATEC CALL FOR PRESENTATIONS

The Council is currently accepting scholarly, research, application, or opinion articles for the ATEC Journal. Published authors are offered the opportunity to present the topic at the annual conference in Tucson. Submissions are due October 1.

SCAN OR CLICK HERE TO SUBMIT

A Parametrically Generated Digital Propeller Model

By **Don Morris**

In addition to being an Associate Professor in Aviation Technologies at Southern Illinois University Carbondale, Don Morris self identifies as an experimental aviation fanatic. When he was a middle school shop teacher with only a few flight lessons under his belt, an elderly friend gave him a partially built Pietenpol Aircamper. That gift helped change Don's life trajectory, spurring him onward as he earned his A&P, I.A., Commercial Pilot, CFI, and CFII. Don also added an MS in Aviation Education from Embry Riddle Aeronautical University to his existing BS in Physics from Illinois State University. Don is currently the faculty sponsor of the Southern Illinois Homebuilders student organization and an active member of the local Experimental Aviation Association (EAA) chapter 277.

ABSTRACT

The National Advisory Committee for Aeronautics developed mathematical models for airfoils nearly 100 years ago. These formulas were used to calculate tables of ordinate points for practical use. Modern computers along with 3D printers and computer numerically controlled (CNC) equipment allow the full mathematically defined curves to be properly incorporated into digital models and into the real world. This article explains the classic process of building a custom propeller out of wood, and then applies this process to digital modelling. It then details the creation of a digital model that can be infinitely customized to form almost any type of propeller. The digital model and its use are explained, and a link is provided to download the model. Our training environment increasingly depends on digital models for virtual reality, 3D printing, and high-quality content generation. It is hoped that this model will prove useful to others in the Part 147 environment.

Last year, one of my students asked for help carving a decorative propeller. Using a length of relatively knot-free construction grade lumber I found at the local home improvement store, I demonstrated some rough techniques that produced a delightful wall hanging. Spending a little more time, I have carved similar propellers for ground trainers and model aircraft — some of which have been able to taxi with the thrust produced by spinning these propellers with lawn-mower engines. However, these propellers are a far cry from a "real" propeller that could efficiently turn large amounts of engine power into thrust.

In its simplest form, a propeller is just a spinning wing. It produces lift, which is used to pull the aircraft forward. This lift is accompanied by its inherent induced drag, which absorbs the power of the engine and keeps the universe in its proper order. As with any spinning object, points near the center of the propeller travel at relatively low speeds and points near the outside edge of the propeller travel at much higher speeds. This means that the blade of a propeller will have a characteristic twist if the propeller is to maintain a similar angle of attack along its entire length. The twist allows the prop to slice evenly through the air.

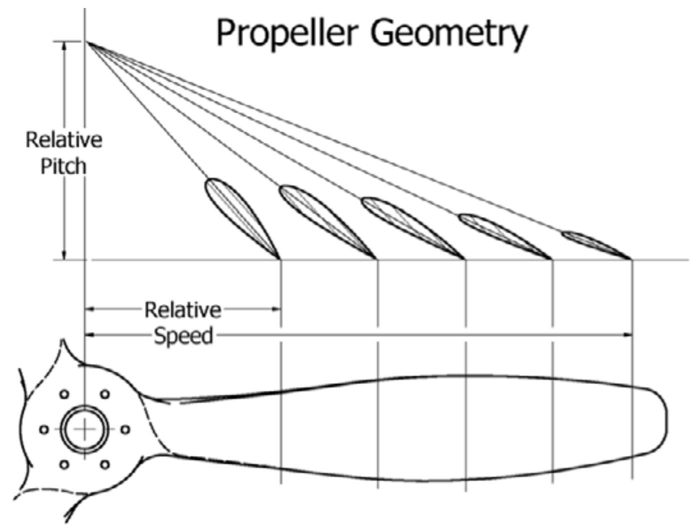
Figure 1 illustrates the geometrical basis for the twist. The pitch of the propeller is usually specified in inches, and it relates to how far forward the propeller would pull itself through the air with each revolution if the propeller were 100 percent efficient. The theoretical angle of incidence at any given point along the propeller can be calculated with basic trigonometry (equation 1).

$$\tan(\theta) = \frac{\text{Geometric Pitch (inches)}}{2 \times \pi \times \text{Distance from Center (inches)}}$$

Using this equation, the angle of incidence of any point on a theoretical propeller can be calculated. However, the angle of incidence is not the only important detail. Good performance requires accurate airfoils. Fortunately, the National Advisory Committee for Aeronautics (NACA) laid an incredible foundation nearly 100 years ago. Even more fortunately, the four digit airfoil series NACA created is specified entirely by mathematical equations (Abbot & Doenhoff, 1949/1959). These mathematical equations were difficult to visualize and use back when they were created. They were typically used to calculate ordinate tables that were used to draw approximate airfoil shapes. Today, these equations can be directly input into computers. This allows modern drawings and models to incorporate airfoil shapes with thousands of times more precision than those early drawings.

Figure 1

Recreated Propeller Twist Diagram

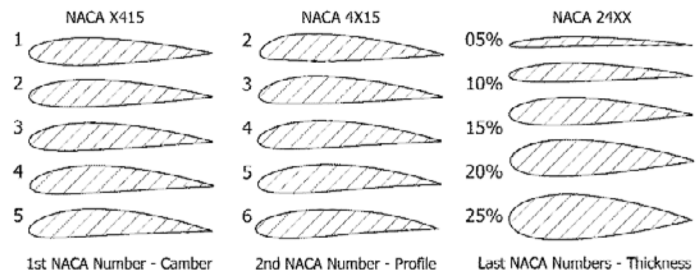


NACA Four Digit Airfoils

The four digits of an NACA airfoil number specify a fifth-order polynomial curve. The four digits that form the number specify the parameters of the airfoil. The first digit of the numbering system determines the overall camber of the airfoil — or the curve of the center line. Higher numbers have higher cambers. The second digit of the numbering system determines where the maximum thickness is along the chord of the profile. Lower numbers are thicker closer to the front of the airfoil. The third and fourth digits give the percentage of thickness of the airfoil as compared to its chord length (Abbot & Doenhoff, 1949/1959). Figure 2 illustrates how these numbers change the airfoil shape by systematically varying the each parameter. For familiar comparison, Cessna 172s feature a NACA 2412 airfoil. This is about halfway between the second and third airfoils in the last column of the figure.

Figure 2

Various Airfoil Plots (Author)



Practical experience shows that airfoils with less camber perform better at higher speeds. Airfoils with more camber perform better at lower speeds. Thicker airfoils allow for more rigidity, but thinner airfoils have less drag. Therefore, thicker airfoils are more frequently used in slower speed situations where their higher drag is less costly to performance. A fixed wing aircraft has a similar airspeed along its entire span, so a consistent airfoil across the wing span is reasonable. Propellers, you will recall, have high speed outsides and low speed insides. We have already mentioned that the angle of incidence should vary across the blade span. For optimal aerodynamic efficiency and weight savings the airfoil shape should also vary. Thick inner airfoils provide the propeller with strength and rigidity. Thin outer airfoils decrease propeller drag and weight. Other aspects of the airfoils can also vary. To see the various airfoil sections in a typical propeller, refer back to Figure 1.

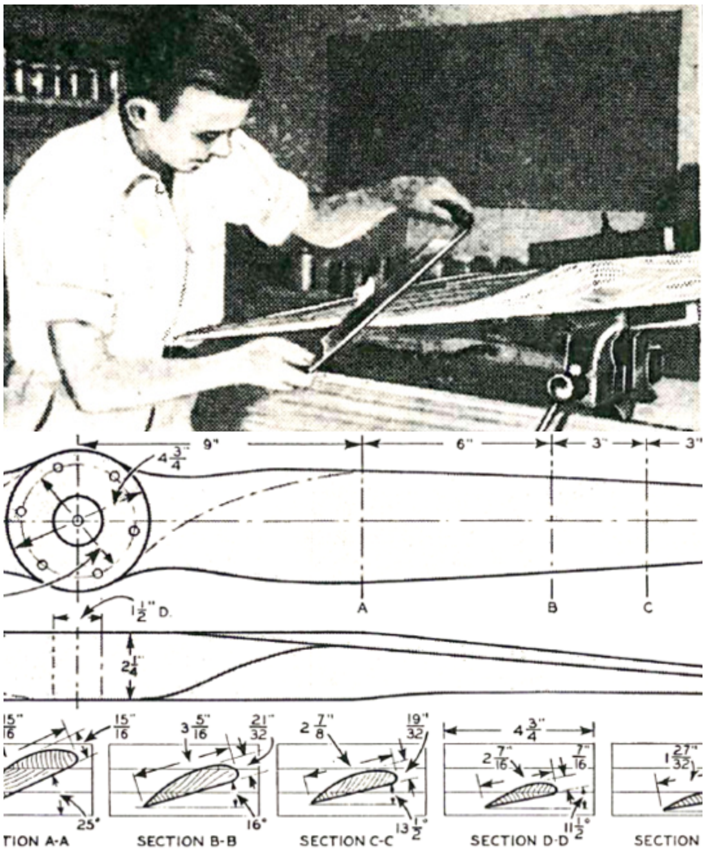
Carving Propellers

In the early days of aviation, propellers were all hand-carved from wood. They had multiple laminated layers that gave them strength and conserved material. As aviation technology progressed, most of the hand-crafted wooden propellers gave way to mass-produced metal propellers that were thinner, more efficient, and more weather resistant. The skills required to hand-carve wooden propeller blades were largely relegated to homebuilt airplane enthusiasts. Popularized by the EAA, these creative and brave individuals needed propellers of unusual specifications as they experimented with engines that were never really meant to fly on aircraft that had unique and unpredictable flight envelopes.

My first exposure to hand-carving propeller blades came from a 1933 article in the *Flying Manual*. Later reprinted by the EAA, the article describes the painstaking process of gradually shaping a laminated wood propeller blank into its required shape using carefully constructed airfoil templates and a great deal of patience (Dumas, 1933). The article illustrated, but did not explain, where to get the airfoil templates (see Figure 3). I tried carving my own pro-

peller with my own eyeball generated airfoils, but I was too afraid of it to attach it to an engine. This was probably a wise decision.

Figure 3
Illustrations from the 1933 *Flying Manual* (Dumas, 1933)



It was not until I ran across E. Alvin Schubert's self-published book *How I Make Wood Propellers* (1984) that I began to truly appreciate that an individual could create a flight worthy efficient propeller. Alvin describes the process of optimizing a propeller to a new aircraft. He details 21 hand-carved propeller iterations for his one-off self-designed and built aircraft *Die Fledermaus*. By his own account, his propeller designs were fairly heavily influenced by his own study of a damaged PT-19 propeller he was able to section and measure. He notes that the PT-19 propeller did not have an even pitch distribution across its diameter as calculated by equation 1. Instead, he noted that the tip had slightly more pitch than mathematically perfect, and the center had less.

Partly because of Schubert's book, partly because of my own love of carving things of beauty from wood, and partly because of my involvement with my local EAA community, I have spent a lot of time pondering the practical creation of custom propellers. As I learned how to digitally model, analyze, and CNC cut parts from the completed models, I have carefully studied the similarities and differences in creating real-world objects and their digital models. In the case of the propeller blade, the similarities are remarkable.

Both Schubert's booklet and that long-ago *Flying Manual* article agree that a hand carved propeller is defined by its airfoil shape at several positions along the blade, or stations. These stations are specified in inches from the hub. In the case of hand carved propellers, material is slowly and painstakingly removed from the blade until premade templates just fit over the propeller at each specified location. The shapes are naturally blended together as the person carving the propeller carves span-wise in long, smooth strokes across the blade. This is not a place where the hand-made propeller need be inferior to a factory produced one. A skilled craftsman can produce highly accurate contours — identifying irregularities of less than 0.00001 inch by touch alone (Skedung et. al., 2013).

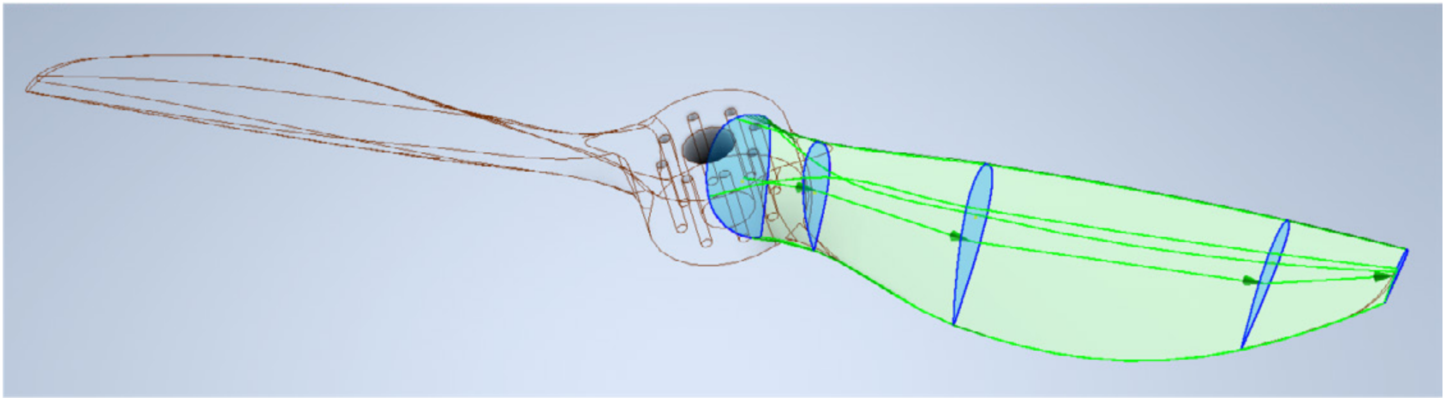
Once finished with the profile of each blade, the propeller is then carefully balanced by removing small amounts of material as required from each blade. Traditional wooden propellers were "tipped" in sheet brass along the leading edges and the ends of the propeller to reduce erosion (Dumas, 1933). The sheet brass was soldered onto brass screws embedded in the wooden blades. Modern wooden propellers are often covered by similar erosion protection. However, fiberglass and Kevlar coatings are now more frequently used. The entire propeller is then varnished or painted.

Modelling a Propeller Blade

Modelling a single propeller blade on a computer is remarkably similar to carving it from wood. Most 3D modelling programs feature some sort of blending "loft" command. This command takes a series of 2D profiles and smoothly blends them into a 3D shape. In theory, this is the same as a skilled artisan shaping the blade of a propeller from separate airfoil shapes at specified stations. In practice, the computer is much more precise. Most programs are capable of calculating spline curves that incorporate second derivative smoothness in all aspects of the infinitely varied cross sections they generate. Figure 4 shows the templates and the lofting process used to specify an example propeller blade. Notice the smoothly faired shape that is produced. The completed propeller made from this loft is shown on the right in Figure 5.

Figure 4

Computer Generated Airfoils Blended (Lofted) into a Propeller Blade



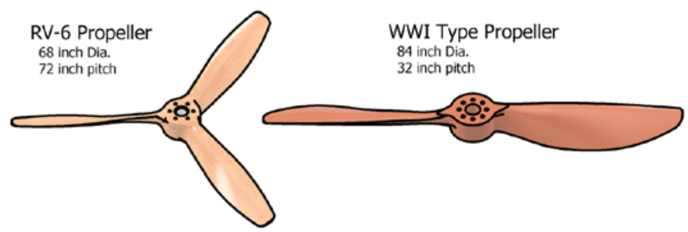
The similarities between working in digital bits and working in wood end here. Instead of templates, equations are used to define the airfoils. Each airfoil is generated from four separate equations (Abbot & Doenhoff, 1949/1959). In order for the equations to be understood by the computer, they must be functions with only one Y solution for each X value. This means the equations must be parameterized to express X and Y in terms of t. They also must to be scaled to the chord length. Finally, they have to be rotated by the angle of incidence of each station. The resulting equations must be input into the program in a format the program can understand. For most computer programs, this requires what to humans is an excessive number of parentheses. Equation 2 shows one of the 20 such parameterized, scaled, and rotated equations that are used to define the propeller illustrated in Figure 4.

X(t) = (((CD4*(t - 5*(N344/100)*(0.2969*t^0.5-0.1260*t-0.3516*t^2+0.2843*t^3-0.1015*t^4)*sin(atan(((2*(N14/100))/(1-(N24/10))^2)*((N24/10)-t)))))-CD4*N24/10-HS4)*cos(A4))-(((CD4*(((N14/100)/(1-(N24/10))^2)*((1-2*(N24/10))+(2*(N24/10)*t)-t^2)+5*(N344/10-0)*(0.2969*t^0.5-0.1260*t-0.3516*t^2+0.2843*t^3-0.1015*t^4)*cos(atan(((2*(N14/100))/(1-(N24/10))^2)*((N24/10)-t)))))+VS4)*sin(A4))

Once the blade of the propeller is been generated, the hub can be added. This is a relatively simple process. The blade must then be trimmed as necessary and smoothly blended into the hub. The computer can then copy the blade multiple times to make a digital model of a propeller with as many blades as requested. Figure 5 shows two such propellers with differing numbers of blades.

Figure 5

Examples of Highly Different Propellers Parametrically Generated Propellers



Parametric Generation

Building a single digital model of a propeller is satisfying, but it has only a narrow application. The goal of this project was to define the model parametrically. This allows the computer to repeat the required steps, making it much easier for iterative design and testing. The resulting models can then be analyzed via computer for strength and efficiency if desired. They can also be exported and 3D printed or CNC carved for models or decoration. They can also be used for technical illustrations, as seen in all the author's illustrations for this article.

The actual parametric model presented in this paper was created in Autodesk Inventor, my program of choice (Morris, 2018). The part is modeled using the described parameters, which are accessed by a menu (Figure 6). Using this menu, you can quickly and easily modify the parameters while observing the results in 3D space. The parametric model does not attempt to blend the blade profile into the hub, but a computer user with experience modelling in Inventor can manually blend the blade into the hub, trim the ends of the blade, and add any finishing touches desired to the parametric model.

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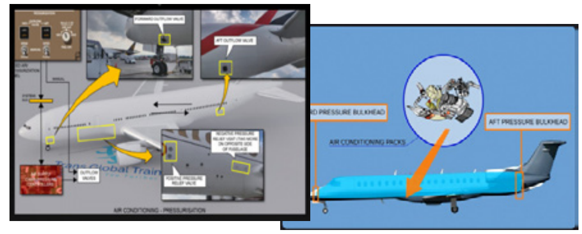

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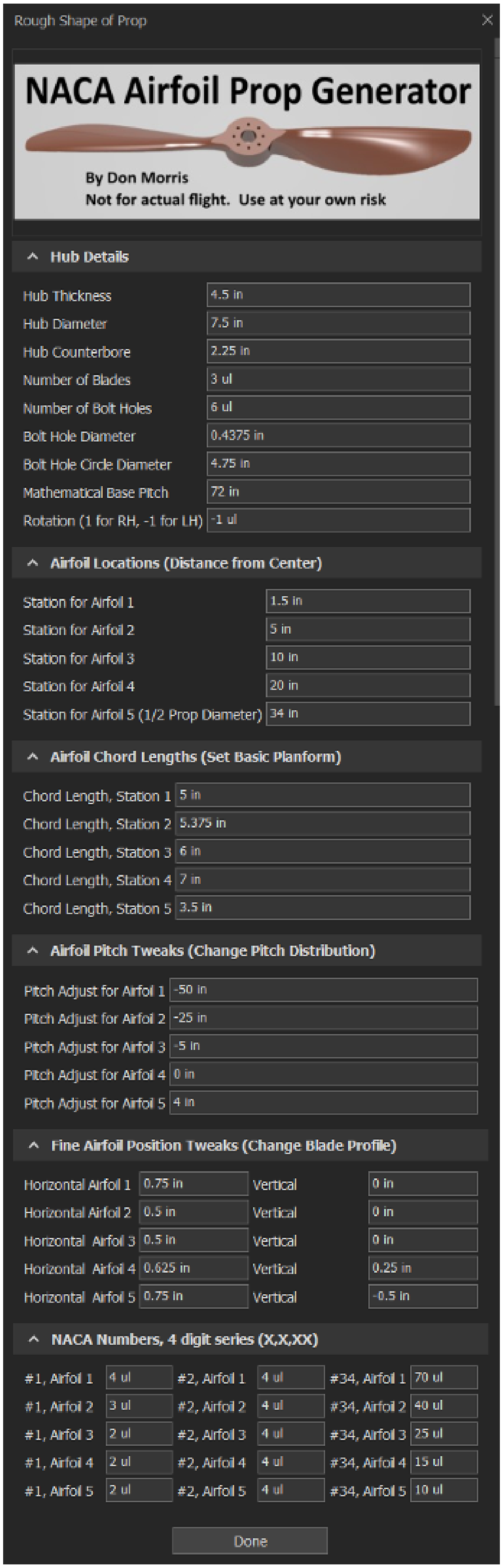
Figure 6
Parameters for Propeller Generation



The model specifies the hub with a diameter, a thickness, a bolt circle, a bolt diameter, and a bore. Each blade is described by five separate airfoil shapes that can be spaced at whatever distance from the center of the hub that you desire. The position of the first airfoil should be inside the hub, and the position of the last airfoil defines the diameter of the propeller. The precise airfoil shapes are specified using four-digit NACA numbers. The airfoils are automatically rotated to their mathematical pitch angles appropriate for their locations on the propeller blade, but you can manually tweak (make small adjustments to) their pitch to achieve a more optimum experimental pitch distribution. The airfoil positions can also be tweaked in horizontal and vertical position, allowing a variety of geometrical blade shapes to be modeled. Of course the number of blades can also be specified. Refer back to Figure 5 to see two very different propellers, both of which were created using this base model with only limited post processing.

Acquiring the Model

To use the model, you must have Autodesk Inventor (2022 version or newer) installed and running on a Windows computer (see Morris, 2018 for details). Download the main file from GrabCAD at the link that is provided in Appendix A. Open the iForm menu (shown in Figure 6), and modify the parameters as desired. A detailed explanation of the parameters and a demonstration of the model is available on YouTube. A link to this is also provided in Appendix A. Once you are satisfied with the propeller you have generated, you should save the file under a different name so that you can re-load the propeller you have created.

Going Forward

So far, my use of the propellers I have generated has been restricted to the artwork in this paper and a single 3D printed propeller for proof of concept. However, I am in the process of building an electrically actuated constant speed propeller to mount on the front of a stationary bicycle. The propeller blades will likely be cut from Styrofoam and lightly reinforced with fiberglass near the hub. I believe that this device will help students to develop an instinctual understanding of how a constant speed propeller governs the thrust and power output of a piston engine.

Appendix A

The model presented in this paper can be downloaded from GrabCAD — a service that allows CAD users to share their files. The direct link to this project is provided. The YouTube user demonstration can also be accessed through the GrabCAD link or directly at the second link provided.

Links:

- https://grabcad.com/library/parametric-4-digit-naca-aircraft-propeller-model-1
- https://youtu.be/wMKuH-RwJ80

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Competency-Based Human Factors and Risk Assessment Training in 14 Code of Federal Regulations (CFR) Part 147 Maintenance Schools

By **Richard L. Johnson**

Richard Johnson currently teaches within the Liberty University Aviation Maintenance Technician Program (AMTP) as an instructor. He is a United States Air Force-trained Maintenance Craftsman with almost 20 years of aircraft maintenance experience including duties as a KC-10 Crew Chief, Flying Crew Chief, Airframe, Powerplant, General (APG) Instructor, and Quality Assurance Inspector for the KC-10, C-5, and C-17 platforms. Richard possesses a bachelor's degree in Aviation Maintenance Management and a master's degree in aeronautics with a focus in aviation education, both from Liberty University. He also possess a Federal Aviation Administration Airframe and Powerplant License with an Inspection Authorization endorsement.

ABSTRACT

This paper addresses how Aviation Maintenance Technician (AMT) programs operating within the Code of Federal Regulations (CFR) 147 schools can meet the anticipated Federal Aviation Administration (FAA) change to competency-based Risk Assessment training as well as the implementation of the added Human Risk Factors requirements for Airframe & Powerplant (A&P) certification. The paper aims to develop and implement the new content for the certification program that complies with FAA regulations while incorporating the anticipated Risk Assessment Skills based on the FAA A&P Airmen Certificate Standards (ACS). The topic is critical to the advancement of CFR 147 operating maintenance schools, as the change will eventually occur. Being ahead of the curve for the anticipated changes will ensure the success of future maintenance programs and mitigate further transitional issues. The curriculum, measured against the FAA ACS supplied by the Aviation Technician Education Council (ATEC), ensured compliance.

A significant shift in teaching standards must occur from traditional delivery methods and focus on the predominant learning styles of AMTs. Data shows a difference between AMT dominant learning styles and non-maintenance students. The need to shift towards competency-based education and nontraditional approaches continues to grow. Additionally, technological advancements compound the issue; many students are often more adept with technology than the instructors. The paper sets out to address these issues.

Competency-Based Human Factors and Risk Management Training

This paper addresses how AMT programs operate within the 14 CFR Part 147 schools, how to meet the FAA change to Competency-Based Training (CBT), incorporating Human Factors, and the anticipated Risk Assessment Skill training. CBT is an educational teaching and learning assessment framework. The paper also investigates how to assess proficiency and implement the Human Risk Factors and Risk Assessment component requirements within the A&P program. A working definition of applying Human Factors can be defined as the potential risks inherent in each operation. Focus areas for potential risk and Risk Assessment Analysis include an example of an engine running operational checks and briefings for maintenance tasks requiring multiple individuals to ensure all members know the task at hand and the potential risks involved. A working definition of Risk is a future effect from an uncontrolled hazard that is not eliminated. The curriculum, measured against the FAA ACS supplied by the ATEC, ensured curriculum compliance. The Risk Assessment topic relates directly to the anticipated CBT Risk Assessment Skill standard the FAA uses to assess proficiency for prospective AMTs in the ACS.

A Risk Assessment, implemented in the subject area of Human Factors within the 14 CFR Part 147 Maintenance Schools, aligns with the functions of the Human Factors subject area. The incorporated Risk Assessment training lays the foundation for what can be built on in the following subject areas the AMT transitions through during the A&P journey to certification completion. Once students understand Risk and the proper application of a Risk Matrix to assess scenarios, the equipped AMTs may apply these concepts to the remaining subject areas. A Risk Matrix encompasses the likelihood of a given event measured against the severity or consequence of occurrence.

Furthermore, the framework for Risk Assessments for the AMT is based on the following: increasing aviation safety, Aeronautical Decision Making (ADM), sound logical and critical thinking skills, Risk management fundamentals, identification of personal hazards, making risk decisions, implementation of controls, and monitoring the process Jones, (2023).

An Aviation Maintenance Technician Program (AMTP) is an institution approved by the FAA to train and certify future aviation maintenance technicians. Prospective students must attend instruction covering 40 technical subjects. Each subject must meet a completion standard of 70% and pass oral, written, and practical exams to attain their A&P licenses. The way ahead removed the previous 1900-hour time component and allowed each 14 CFR Part 147 maintenance school to decide how to instruct future students. A CBT curriculum is the new standard.

A disparity exists between where curriculum, higher education institutes, and other 14 CFR Part 147 maintenance schools currently use and train students and the changes the FAA will require for A&P certification. This project can directly help AMT programs while setting a baseline for what CBT Risk Assessment training looks like within the field of aviation maintenance, as well as how to implement and integrate the required Human Factors component.

Regarding the present need within the aviation industry, this paper is not emergent in the sense of possible loss of life or equipment damage. However, the condition is urgent and new in focus as no one is sure how the FAA will officially implement the new CBT Risk Assessment curricula guidance. CBT is a predetermined competency focusing on outcomes and real-world performance. A proactive start and forward momentum in addressing the current scenario prove beneficial toward aligning new methodologies toward the anticipated curriculum change.

Identify the Problem

14 CFR Part 147 maintenance schools operate under the established standards set forth by the FAA. Previous standards needed to include the incorporation of Human Factors and Risk Assessment training. For years, the schools have anticipated a change to CBT and the inclusion of Human Risk factors and Risk Assessments. Schools must prepare for significant curriculum revisions without knowing how the FAA views the Risk Assessment changes. A disparity exists between how curriculum, higher education institutes, and other CFR Part 147 AMT maintenance schools currently train students and how the FAA is moving toward a CBT model.

This paper directly helps AMT programs by setting a baseline for what CBT looks like within the field of aviation maintenance, as well as integrating the required Human Factors and Risk Assessment components.

Human Factors and Risk Assessment

Just as learning styles vary among individuals, so do human factors. Various Human Factors have contributed to aircraft accidents and mishaps throughout the history of aviation. For example, a series of decisions discussed by Hoppe (2019) led to unfortunate events. Southwest Airlines flew affected aircraft, but the Principal Maintenance Inspector (PMI) did not require the withdrawal of affected Boeing 737 aircraft, Hoppe (2019). As presented from the National Transportation Safety Board (NTSB) findings, Boeing's installed software failed to function as advertised. Because the aircraft system was not working correctly, the pilots had to perform non-normal checklists to regain positive control NTSB, (2018). Human Factors play into scenarios differently, from decisions to reactions. Each has a profound impact on an aviation incident. In several cases, the issue highlights the need to find alternative ethical frameworks for the rule-making process and the oversight of the aviation industry, Hoppe (2019).

Human-Factor events are still a high percentage of key causal factors in aviation incidents and accidents Lawrence, (2007). The various operating environments and contributing factors for each circumstance pose significant obstacles in presenting a framework that can produce an influential safety culture. Previous data concerning safety cultures and environments paint an incomplete picture. Studies on safety cultures in aviation have focused on commercial aviation, military, and air traffic control environments.

A need to improve teaching HF courses at the undergraduate level exists. An improvement of principles and practices of Human Factors will carry over into the industry and beyond, Gibb (1998). Educators and instructors ensure that students learn at their best by implementing skills-based Risk Assessment and Human Factors in a CBT model that meets the learning styles best suited for AMTs. Investigation of possible intertwining learning styles, UDL, and advanced technologies in the context of technical training could be instrumental in creating frameworks for training solutions for the FAA, Kang et al., (2018).

Likewise, a robust safety culture begins with the fundamental

understanding of human error and both active, participatory, and latent factors; active failure and latent failures combine to produce an environment necessary for an accident to occur. The need to educate the individual of given human risk factors within a scenario must exist within the curriculum and throughout instruction to alleviate potential mishaps. Likewise, incorporating Human Factors, Risk, and Risk Assessment within the CBT model, measured against the FAA ACS, ensures compliance. The build can proceed with the Human Factors and Risk Assessments interwoven throughout the new curriculum. Once equipped with the baseline of Risk Assessment skills, the foundation is laid for the AMT students and instructors to build on. A reassessment of teaching methodology based on learning styles and the competency-based application level of learning must occur.

Competency-Based Training

The need for a CBT model exists, which drove the ACS change. Thankfully, AMTs are proficient in this domain of learning. Curriculum building should focus on CBT aimed toward student learning styles. The development of a new aviation maintenance curriculum is advancing faster than most institutions can keep pace. The need to adjust, evolve, and change is paramount to the future success of the aviation industry.

Curriculum Build

The above-identified learning styles, Human Factors, and Risk Assessments differ from the current curriculum. The curriculum development must have a framework based upon set milestones that will proceed toward the desired outcome. A successful curriculum development begins with the end in mind first and works backward to fulfill the desired result. The curriculum construction is like an expedition and how to best prepare, Mackh (2018). Curricula build must include lectures, training aids, projects, and accurate assessment tools, like the Risk Assessment Matrix. The potential risk inherent in each operation sums up a working concept and definition of the application of Human Factors as focus areas for potential risk, including engine-run operational checks and briefings for maintenance tasks, which require multiple individuals. This approach ensures that all members know the task and potential risks involved. The projects must successfully mitigate all identified Human Factors for the subject area, which promotes high student engagement using Risk Assessment Matrixes to manage risk. The equipped AMT utilizes the Risk Assessment Matrix and identification of hazards to mitigate potential threats and hazards best. This skill set is significantly valuable to newly certificated A&P, as they utilize these skills for the remainder of their careers.

Educational Reform

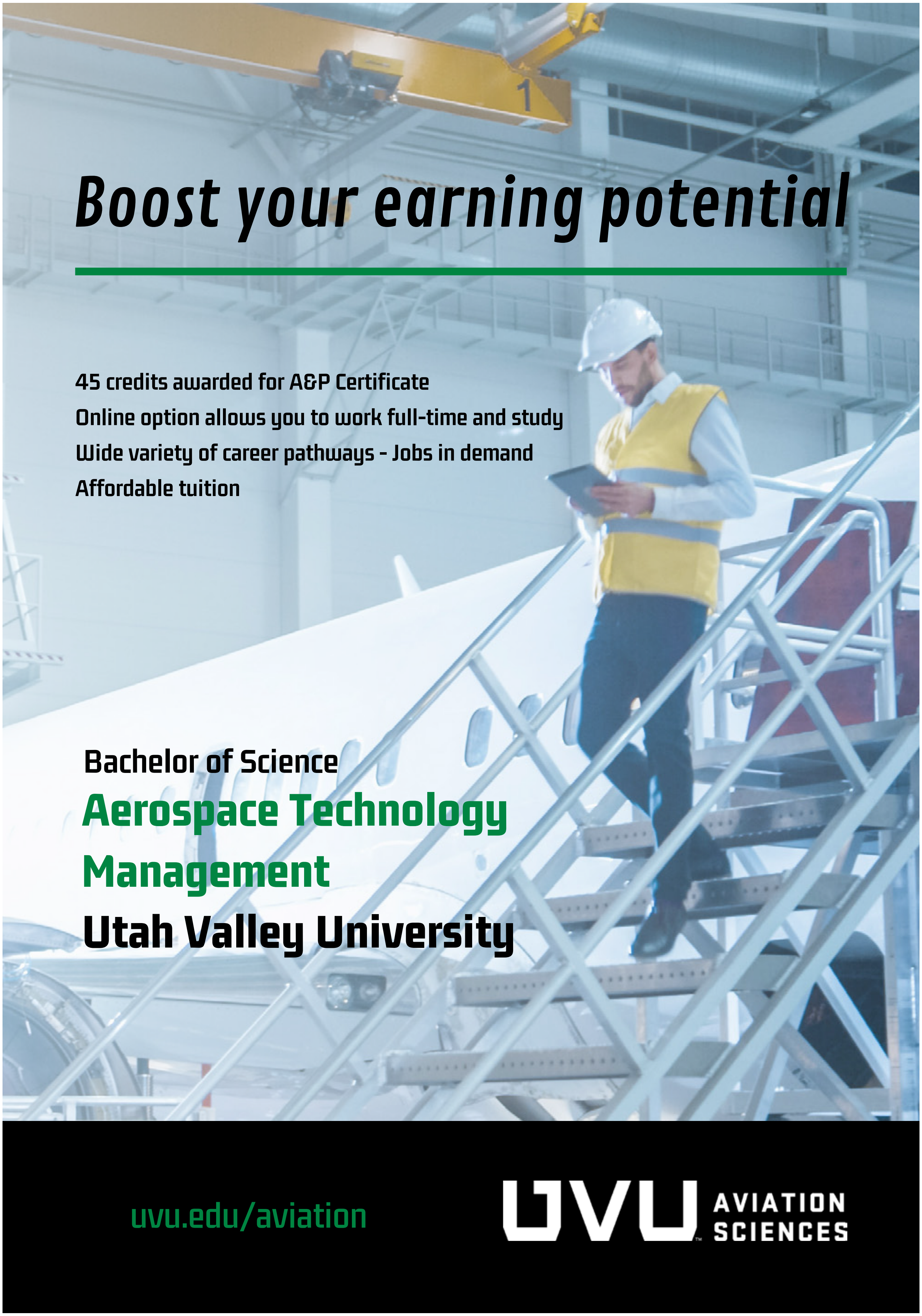
As the aviation industry evolves and the curriculum changes to meet the airline industry's needs, a need for educational reform follows. Researchers can learn significantly from observing current maintenance practices, trends, and data analysis. Interpreting aviation maintenance on jobs offers valuable information for the educational reforms necessary in the field and the industry, Szegedi et al., (2017). The students become more engaged by further establishing the direct correlation between the classroom and the real-world environment, promoting deeper learning. As adults, many aviation students aim to further their careers. As such, many adult learners are intrinsically motivated, seeing learning as a utility for application Brady et al., (2011). Positive educational reform can come in different forms. The end goal is to encourage active participation that enables progressive learning positively. By creating a similar environment, the instructor can draw interest from students, Santonino (2016). Flipping the classroom and traditional learning approaches correlate positively to student learning objectives and information retention. In a nontraditional age of technology, a call to nontraditional teaching remains. Best teaching methods should challenge and support individuals through various instructional formats Fanjoy & Young, (2004).

Learning Styles

The needs of the Aviation Industry to meet the FAA requirements should be an opportunity to serve. The curriculum build aims toward individual student learning styles at the applied level of learning. In meeting the needs of the students, Kang et al. (2018) propose the concept of Universal Design for Learning (UDL), which provides as many diversified teaching methods as possible on three classifications (i.e., information display method, action, and expression methods, and engagement methods), Kang et al., (2018).

The application-level competency-based, hands-on learning style is the dominant learning style of AMTs. Many studies speak to aviation concerning pilot training and learning styles. Evidence supports the assumption that AMTs learn at the applied level of education. AMT students can typically struggle in the traditional classroom setting, but most often thrive in the hands-on, application-level shop environment. Additionally, students further excel once they see the correlation between what they have learned and how the concepts apply to their career field.

Furthermore, self-regulation is an individual's ability to self-talk, motivate and learn in each environment under one's abilities. By knowing themselves, students can improve their study habits, assessment scores, and knowledge retention by understanding how they learn individually.



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Educational Change

As noted within the applied learning context, a further focus on the educational environment may be outside the traditional classroom. Santonino (2016) reports that an instructor at the Embry-Riddle campus in Singapore stresses that educational reform in the standard delivery methods for higher education students must coalesce. A significant change in educator methods to meet student learning is urgent Santonino, (2016). One method to meet the need for methodology transition is that of simulators. Flight simulators and other advanced, immersive technology are practical tools used in pilot training. An enormous benefit exists to the student who can tangibly see how items work together is invaluable. The experience gained from immersive training is valuable to the students. The added benefit of simulators to pilots must be utilized for maintenance students.

The awareness of variations of learning styles within the pilot and maintenance training programs is well-known among pilot and flight students. As demonstrated among flight faculty members must be sensitive to different learning styles among their students Fanjoy, (2002). AMTs often must wait until an aircraft part fails to begin troubleshooting when a maintenance fault or action occurs. Simulation components allow individuals to experience and learn from situations they may not have directly experienced otherwise. Educators may adopt artificial conditions to enhance several learning experiences Ruiz et al., (2014). To this end, simulators could vastly aid AMTs in understanding theory and system operations and increase troubleshooting skills and capabilities if adapted into the maintenance sphere of responsibility.

By programming a fault into the simulator, the AMT can isolate the maintenance issue and troubleshoot to fix the failed component. This approach leads to better system understanding and saves valuable time. Different approaches to teaching methods, such as the course of instruction, and mode of delivery, can be beneficial to meet the new age of technology and promote further student engagement. Using an unconventional teaching approach, the instructor can break traditional classroom lecture learning methods and redirect them toward an applied learning methodology, Santonino (2016).

An often-overlooked form of immersive training is the approach of a real-world field trip. A visit to the airport maintenance facility can provide a tremendous amount of information to the student. They are simultaneously appealing to the anticipation of the student and enabling the student to connect the dots to the real world. A divergence from traditional classrooms is field trips, which offer an opportunity to communicate with students and increase their knowledge foundation, promoting further learning and higher-level thinking strategies Santonino, (2016). Likewise, an immersive environment with high realism for aspiring remote pilots and sensor operators to a resounding success, Macchiarella & Mirot (2018) has yet to translate to maintenance.

Safety Culture

As discussed with the varying and wide variety of experiential training, a safety culture can vary just as widely. Companies with the highest safety records hold a robust, safety-minded, and proactive safety culture model. Organizational safety requires elaborate safety management techniques to hone safety Lawrence & Gill, (2007). Safety must be the mindset of the entire organization from the top down. The safety culture will inherently follow suit if standards, operating procedures, and protocols are lacking. When policies are lacking, low accountability is present, as well as a lack of standard operating procedures; it is only a matter of time for an accident to occur. A positive safety culture begins with a safety conscience mindset.

There are latent risks that may be inherent in the design of a part or specific operation, and there are active components an individual must “act” upon to trigger an accident. Many methodologies are in play, from Crew Resource Management (CRM) to Human Error Risk Management in Engineering Systems (HERMES) methods. Regardless of the assessment tool employed, safety comes down to mitigating variables and dealing with the unknowns to the best extent possible. Do the benefits outweigh the risks? From this vantage point, one can more effectively reduce the inherent dangers present to the student. Likewise, proper education on Risk Assessment aids the AMT in mitigating risk best and driving risk factors to a tolerable or acceptable level of risk Jones, (2023). As the landscape of higher education changes, a professional mindset and what will be most effective for the workforce may be valuable in shaping future training. An individual who possesses professional competency has the necessary knowledge, skills, and attitudes to exercise their work, to solve problems creatively and with independence, and that can contribute to their work environment and work for an organization Ruiz et al., (2014). These competencies are crucial to the future success of the aviation industry.

Crew Resource Management

Prior research cannot satisfactorily deduce traditional Crew Resource Management (CRM) frameworks and the implemented effectiveness. A result cannot be determined with certainty that CRM training affects safety Salas et al., (2006). For years, the employment of traditional forms of CRM was the gold standard, but the assessment methodology operates within a strict framework. Both commercial and military aviation have utilized CRM for decades Salas et al., (2006). But there still needs to be the issue of deducing an accurate tool for assessment to measure CRM's effectiveness accurately. Fault tree analysis breaks down more significant components and systems into smaller portions useful for troubleshooting and fault isolation. Due to limitations, fault tree analysis is most suitable for logically determining a system's critical components Lawrence & Gill, (2007).

Motivational Factors

Just as members within an organization must buy into the safety culture to effectively promote a positive and safe working environment, an individual must want to be safe, and an internal or motivational factor may aid in promoting a safer operating environment. Participation in meaningful work is a deeply personal experience that may have far-reaching positive impacts on one's life, Steger & Dik (2009). An ingrained safety culture becomes second nature to the individual who feels connected. The Human Risk Factors curriculum must successfully tailor risks to the given subject. Additionally, AMTs must positively identify and assess risk within the subject. The curriculum must aim towards the experiential and immersive realm, focusing on advanced technologies. Previous studies have demonstrated that lecture-based learning is inferior to active, collaborative, problem-based learning methodologies Santonino, (2016). The most highly desired skills for military aircraft maintenance are detailed knowledge, a substantial understanding of systems and components, creativity, physical strength, and problem-solving skills Szegedi et al., (2017).

Technological Advancements

Just as internal and external motivation can help students engage within the classroom environment, new technologies peek their interests and drive them to engage. A comprehensive curriculum prepares professionals to apply the results to a real-world (authentic) situation, Moye (2019). Likewise, risk identification and assessment within the educational framework translate to the AMT knowledge baseline when entering the aviation industry. The more realistic, immersive, hands-on environment, the more likely the student will succeed. With the curriculum tailored to the predominant learning style of the AMTs, the student's grades and overall success will improve. Most collegiate flight programs believe flight automation training is critical to student success. However, only some programs apply comprehensive training in aircraft maintenance in this manner Fanjoy, (2004).

Experiential Training

As technologies advance, on-the-job and experiential training may be on the cutting edge of educational reform. Experiential and immersive training adds to realistic and tangible scenarios to which the students can relate. In a recent immersive, scenario-based environment concerning unmanned aerial vehicles (UAV) and unmanned aerial systems (UAS), new knowledge from experiential learning yielded significant results, an experience during simulator training related to widely practical application in the real world. The individuals involved developed new ways of thinking, new skills, and attitudes Macchiarella & Mirot, (2018). Employed mainly within pilot training, UAV, and UAS operators, the approach still needs implementation in the aviation maintenance field. Preliminary data which supports pilot, UAV, and UAS training would be like that of AMTs, which supports a positive correlation to learning outcomes. However, no such implementation exists in AMT training.

Students can also participate in a once-experimental Geographical Information System (GIS) course spearheaded by Embry-Riddle Aeronautic Institution. The overwhelming success of the trial course has led to the implementation of additional courses. Observing data significantly affects decision-making and drawing connections and conclusions Snow & Snow, (2004). The information gained through this course approach can apply to government, industry, and academia to advance spatial data analysis and enhance decision-making capabilities at all levels, Snow & Snow (2004), which will genuinely aid prospective students within the aviation discipline.

New Technologies

Factors that minimize the resistance to change include a professional mindset, a positive attitude, and an approach of willingness. The educational realm could keep pace with technological advancements if specific technology and software were available to AMTs. By effectively incorporating new modes of lecture and the latest technology, students are in a better position to meet the demands of the workforce, being adept with software and technology ahead of their potential employment.

Additional Findings

Interesting items came to light that concerned the qualifications of personnel for positions within a 14 CFR Part 147 Maintenance school which is rather significant and beyond the scope of this paper. Further research and development in qualifications or certification for 14 CFR Part 147 Maintenance school instructors also came to light and are as follows; years of industry experience, subject teaching assignments aligning with industry experience, and an instructor endorsement similar to that of a Certified Pilot Instructor (CFI) for pilots, but one which correlates to aviation maintenance would undoubtedly benefit from additional research. Lastly, roles within a 14 CFR Part 147 maintenance school would be worth pursuing.

Conclusion

The research and data collected presented a gap between the higher education curriculum and teaching at the application level for CBT. The direction in which higher education must focus on the change in teaching methodologies is vast. A divergence from traditional teaching methods, assessments, and delivery modes are paramount to successfully matching the needs of future students and the advancements in technologies and educational frameworks. An aim toward implementing state-of-the-art, cutting-edge technology within the classroom which mirrors the modern work environment students will operate, will pay huge dividends toward the student's success. A change in teaching styles to an application level and a shift toward CBT meets the AMT students where they operate most effectively. The change in traditional approaches also aims to submerse the students in realistic environments. The paper addressed the FAA change to CBT while incorporating the Human Factors and Risk Assessment components for the A&P certification. The new curriculum, assessed against the FAA ACS, ensured compliance. The future of the aviation industry depends upon the successful transition to CBT.

Ultimately, the future of aviation rests upon the shoulders of the trained younger generations. Throughout the discussion of learning styles, the curriculum builds, CBT, Human Factors, Risk Assessments, educational and evaluation assessments, the need to change traditional approaches and theories of higher education, and modes of delivery are present. The change in direction from the standard classroom environment to interactive environments, technological advancements, and immersive training have higher levels of effectively demonstrating course learning outcomes. Tailoring curriculum approaches to the upcoming AMT cohorts while addressing experience and technology disparities is paramount.

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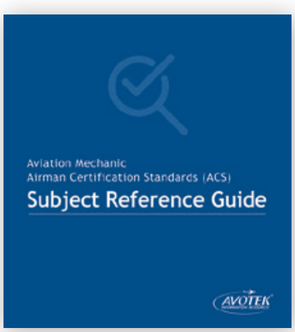

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