The ATEC JOURNAL

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PLYWOOD ENGINES

BRIDGING THE GAP BETWEEN PAPER DIAGRAMS AND CUTAWAY MODELS

ENGLISH LANGUAGE TRAINING FOR AVIATION MAINTENANCE TECHNICIANS

THE CHALLENGE TO DO BETTER

A WORD FROM THE INDUSTRY

ADDRESSING THE SKILLS GAP

REQUIREMENTS FOR TRAINING AND QUALIFYING FUTURE TECHNICIANS FOR NEW TECHNOLOGIES IN AVIATION

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 tosubmit 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

In this fall issue, we are pleased to present to you a very diverse collection of articles that we hope you find to be relevant to you and your classrooms. It seems that our community has much to talk about as the aviation maintenance training environment continues to adapt to the advancements in our field.

Tracy Yother or Purdue University, Stephen Ley of Utah Valley University and Zack Nicklin of St. Cloud Technical and Community College explore the timely topic of how technician training will need to change to meet the needs of the many advanced technologies present in the growing advanced air mobility sector.

Don Morris of Southern Illinois University shares his experiences and insights on replacing diagrams with models for use in the classroom providing a more tactile approach to teaching mechanical concepts.

Denis Manson, AME (Australia), Anne Lomperise of University of Illinois, and Stewart Todhunter of Bond University, Australia outline an approach to English language training for the AMT based on English for Occupational Purposes principles.

Finally, John Gamble with Snap-on Industrial, highlights ways that his organization can work with FAA Part 147 programs to develop more effective pipelines to boost their enrollment to address the increased workforce need.

Thank you for your continued interest in our academic community and the innovative ways our members rise to meet the training challenges in this ever-changing world of aviation. And of course, thank you to the Editorial Board for the amazing efforts that keep the Journal alive.

Best,

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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.

Click here to view full committee rosters

CHOOSE AEROSPACE

ATEC's flagship initiative, Choose Aerospace, continues its mission to strengthen talent pipelines into aviation and part 147 programs. Since its inception in 2021, the Choose Aerospace general aviation maintenance curriculum has reached a total of 1,513 unique learners. For the 2024-2025 academic year, enrollment is projected at nearly 800 students across 41 programs in 15 states.

Choose Aerospace will host its annual teacher training from June 3-5, 2025 at TulsaTech, preparing both new and returning educators. We extend our sincere gratitude to the master A&P instructors who lead this "train the trainer" event, imparting essential knowledge for secondary and community-based aviation programs. Learn more about the training, which is free for Choose Aerospace teachers, at https://www.chooseaerospace.org/teacher-training.html.

For more information or to request a discovery meeting, please visit https://www.chooseaerospace.org/curriculum.html.

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REGULATORY COMMITTEE

ATEC is actively advocating for practical regulatory improvements with the FAA and Department of Education. Key priorities are updating Mechanic Airman Certification Standards to better align with industry needs, increasing access to FAA airman testing, and streamlining the certification processes by transitioning to online platforms and enhancing examiner discretion.

The regulatory committee is also seeking input from community members for the upcoming revisions to the FAA's Aviation Maintenance Handbooks (General 8083-30B, Airframe 8083-31B, and Powerplant 8083-32B). This is a unique opportunity to contribute your expertise to materials that set the training and standards for aviation maintenance students and professionals nationwide. The feedback deadline is December 2, and volunteers can select specific chapters to review, allowing you to focus on areas where you have specialized knowledge.

For more information about committee priorities, visit https://www.atec-amt.org/regulatory-priorities.

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LEGISLATIVE COMMITTEE

Earlier this year, Congress finalized comprehensive legislation reauthorizing the Federal Aviation Administration, addressing ATEC's top priorities: expanding the FAA workforce development grant, enhancing airman certification standards, and streamlining pathways for transitioning military personnel. The committee is now working to implement these initiatives in collaboration with the regulatory committee.

In September, ATEC members, industry partners, and federal officials gathered in Washington, DC, for the 2024 ATEC Fly-in to discuss FAA reauthorization and more. After policy discussions with the FAA and legislative briefings, ATEC representatives conducted over 75 congressional meetings across twenty-five states.

Thank you to everyone who participated. For more on committee initiatives, review the ATEC Legislative Priorities and stay tuned for 2025 Fly-in dates!

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ANNUAL CONFERENCE COMMITTEE

Registration is open for next year's annual conference taking place March 16-19 in Norfolk, Virginia! Aviation Institute of Maintenance will welcome attendees to its headquarters' city, alongside presenting sponsor Piedmont Airlines.

Next year's conference promises engaging sessions, delicious food, scenic waterfront views, and impactful tours.

The agenda is in development, look for it to publish in the next few months. Exhibitor and sponsorship opportunities are still available. Visit https://www.atec-amt.org/events/2025-annual-conference to learn more. We look forward to seeing you there!

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ATEC ACADEMY

The ATEC Academy, a board-led initiative, is committed to tackling the challenges of recruiting and retaining skilled aviation instructors in response to the increasing demand for technical expertise. Under the guidance of an experienced educator and supported by master A&P instructors, the Academy is currently running its second cohort of students and will launch a third cohort in conjunction with the annual conference in March.

This comprehensive program includes two days of in-person training supplemented by virtual modules over three months. Participants engage with key topics such as active teaching strategies, student behavior management, assessment methods, lesson planning, and current trends in technical training. While initially designed for new secondary and post-secondary instructors, the program has proven invaluable for both industry trainers and seasoned educators.

Facilitators have incorporated feedback and lessons learned from the initial course to enhance the curriculum, including a new section dedicated to teaching hands-on labs. To ensure a personalized learning experience, enrollment is limited to just 20 seats.

We are now accepting registrations for our third cohort, which will kick off on March 15-16, just before the ATEC Annual Conference in Norfolk. Reserve your spot today at https://www.atec-amt.org/events/atec-academy---spring-2025#overview.

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Plywood Engines: Bridging the Gap Between Paper Diagrams and Cutaway Models

By **Don Morris**

Don Morris earned his MAS in Aviation Education and Management from Embry Riddle Aeronautical University and his BS in Physics from Illinois State University. He has over 25 years of classroom experience and is an Associate Professor of Aviation at Southern Illinois University, Carbondale. Don has invested nearly $80,000 in the research, development, and equipment to make the models discussed in this paper. This has been largely funded through sales of model kits to the larger aviation community through Kickstarter, a booth at EAA Air-Venture OshKosh, and his own web site. He laughingly refers to himself as the world's leading authority on plywood engines.

ABSTRACT

Diagrams and cutaway models can both be used to explain the inner workings of complex machines. Cutaway models show the actual parts as they are inside the machine, but these parts are arranged in the best way for the machine to function and not for the process to be understood. Diagrams allow for the parts to be rearranged and shown for maximum comprehension, but lack the real world-tactile feedback that a cutaway provides. This article discusses a series of models the author designed to bridge the gap between cutaways and diagrams.

Over the past 6 years, the author developed increasingly detailed functional models of many types of engines. Designed in Autodesk Inventor, most of the parts were cut from Baltic Birch on a CNC laser cutter. Parts that did not lend themselves to being made by laser were fabricated from hardwood dowel rods. For the past 5 years, the author's Aviation Physics students at Southern Illinois University have each received a single-cylinder model kit to complete and to keep. They then used the completed models for lab projects involving gears and levers. The students also calculated pressure, force, work, and horsepower based on the models.

This paper presents the author's 6 years of experience with the designing, producing, and using these models in the classroom. It shares some of what the author learned as he progressed through three generations of models. It also includes selected student feedback.

I vividly remember trying to understand how the valves worked on a four-stroke engine. It was a different time, and I turned to the World Book Encyclopedia for guidance. I found a diagram not unlike Figure 1: a diagram of the intake stroke included in the FAA's 8083-32B (2023). The World Book said that the intake valve opened so air and fuel could enter the cylinder. I could observe the open valve on the diagram, but I could not see what made the valve open or figure out how it knew when to open.

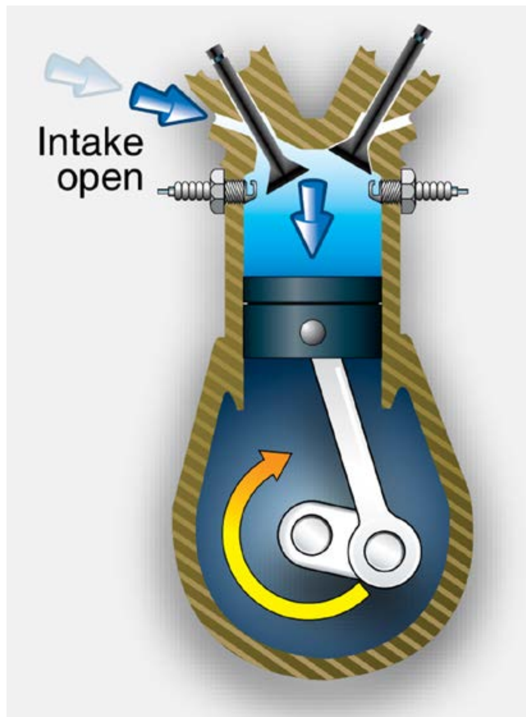

Figure 1: Diagram of Intake Stroke (FAA 2023)

The times have definitely changed, but beginning students still need the same answers. Like other teachers, I used to resort to diagrams and cutaway models to provide answers. That is how I know that diagrams are relatively useless unless students are provided with detailed explanations. Cutaway models require a lot of guidance as well, especially for students who have little experience with real mechanical systems. The engines that cutaways are made from have been laid out in the best interest of real-world function and not for basic student comprehension. Additionally, most cutaways are too expensive to give to students for home study. he aviation industry is best described as having a turbulent history with periods of advance and growth followed by setbacks and disruption. The Covid-19 pandemic illustrates that point. Commercial flight was experiencing steady growth, finally recovering from the negative effects of September 11th, 2001, and the great recession of 2008 (ICAO, 2022). Progress that took years was undone overnight as travel bans went into effect in early 2020. Airline revenue dropped from 248 billion dollars in 2019 to just over 130 billion in 2020 (Flynn, 2023). They had lost nearly half of their revenue in less than a year.

Diagrams (Figure 1) and computer simulations (Figure 2) are significantly less expensive and more versatile, but they lack the tactile experience of the real world. Though often highly experienced in digital worlds like Minecraft, many of today's students have relatively little experience in the tactile actual world they will need to master in order to safely repair aircraft.

Figure 2: Frame from a computer animation (Morris, 2014)

My Answer

In 2014, a Ukrainian startup called UGears began producing puzzle-type kits to build mechanical models (Ukrainian Gears, n.d.). Many of their models are complex and impressive. I pondered their models, and was fascinated by the possibility of creating similar but more technically accurate products. I had recently written an article for the ATech Journal about Autodesk Inventor and its usefulness in a Part 147 setting (Morris, 2018b), so it was natural that this was the software package I would use. I decided that a seven-cylinder radial engine would make a good test subject to assess the practicality of my idea.

Like the UGears models that inspired me, I made my designs to be cut from 1/8" Baltic Birch plywood. In the pre-covid era, it was relatively low cost and was easily available. It also is easily and accurately cut by laser. Better yet, I had several sheets in my garage. Borrowing from the alignment holes used in industrial manufacturing processes, I determined that the successive layers of my models would share small holes that would help align them with each other as they were assembled. This allowed fairly accurate alignment without a great deal of effort.

Creating my models was not very different from drawing a diagram. I made a two-dimensional sketch of the outlines of the crankshaft, pistons, and cylinders in relative position to each other. I thickened the cylinder walls around the pistons and added a crankcase around the crankshaft. I added cooling fins, taking inspiration from classic aero engines such as the Wright Whirlwind. I extruded the details of the walls and fins into a three-dimensional 1/8" thick layer, and its shape largely determined the remainder of the model. I added space for a cylinder head and added alignment holes wherever I felt that space allowed. Part of this layer is shown on top in Figure 3. Notice the "Birch Plywood" texture already mapped to the digital model.

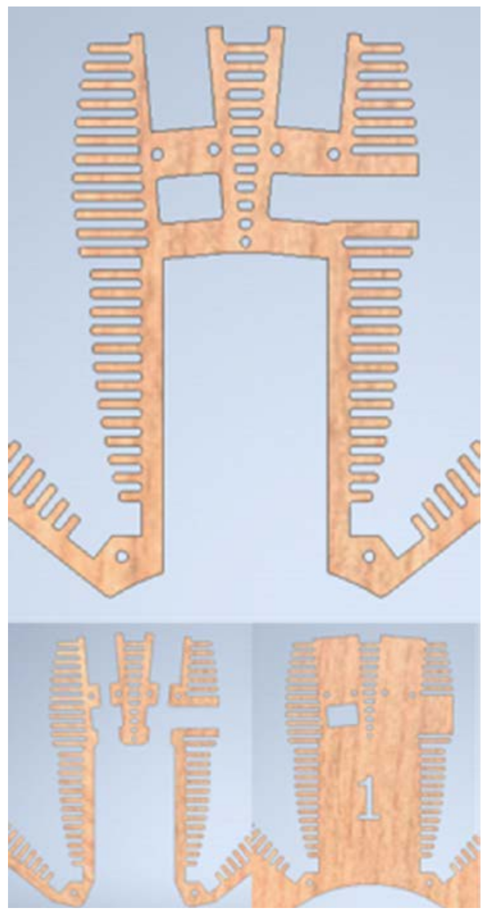

Figure 3: Cylinder layers described in text. Author.

Once I finished the first layer, I copied it. Working with the copied layer, I cut an opening for the valves to fit into and defined shoulders for the valves to seat against. This cut the layer into many pieces, but the computer did not care. I did not care, either. I had glue. I saved this as the second layer. Part of this layer is shown on the bottom left of Figure 3. Returning to the first layer, I copied it again. I added a rear cylinder wall to this new copy and filled in the appropriate areas of the cylinder head. Since this was intended as a teaching tool, I cut large numbers out of the cylinder walls to number each cylinder. Part of this layer is shown on the bottom right of Figure 3. Since all the layers are copies of each other, the alignment holes are in identical locations.

Following this same basic process, the other parts of the model were made up layer by layer. Anywhere a rotating shaft was used, I drew a small piece of hardwood dowel. To make these dowel shafts look more realistic, I cut holes through them. Figure 4 shows the master and connecting rods pinned together with 1/2" diameter drilled pins. I textured the pins as "walnut" in the computer to make it easier to distinguish it from a plywood part. The entire piston and rod assembly shown is about 3/8" thick. I created all the gears the model would need using Inventor's built in gear generation features. I manually created the cam plate, and designed a trailing arm valve lifter system to ensure that the parts would remain aligned as the wood cam plate made contact. Later experimentation showed that my trailing link system was not necessary and regular types of plywood lifters could be made to function. The whole assembly was designed, rigged, tested, and animated digitally before cutting the first model (Morris, 2018a). (Note that I got the cylinder numbers backwards on the digital prototype.) A local Experimental Aircraft Association contact provided access to a laser cutter, and in just a few days, the first model moved from a digital prototype to a physical reality. It was a rousing success and was admired by everyone who saw it.

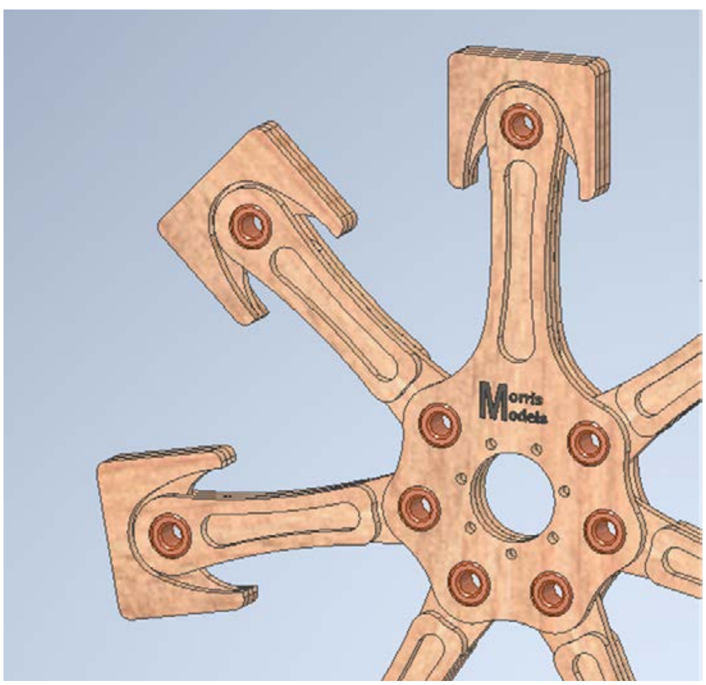

Figure 4: Pistons and rods. Author.

Development and Classroom Use

Once the first model was completed, I knew I was onto something special. I also knew I would need my own equipment to get anywhere near the full potential out of my idea. I decided to make another model to widen general appeal and drew a Harley Davidson(R) inspired V-Twin. This time, I even created the instruction manual before building the first model (Morris, 2019b). I posted the models on Kickstarter and sold enough pre-production kits to buy an industrial laser cutter (Morris, 2019a). Those kits were literally shipped all over the world, but they were far too complex for student assembly. For that I needed a single cylinder model. Because my models are flat (and because I have a sense of humor), I decided my single cylinder model needed to be a "Flat Flathead."

The traditional flathead engine usually has two valves on the same side of the cylinder. I rearranged the engine so that one valve and cam were on each side of the cylinder mimicking a diagram. Using a similar process to the one outlined above, I created the model shown in Figure 5. This was the first model that I had students put together. The students essentially assembled their own tactile moving diagrams for how an engine worked. I had my students assemble this model both that year and then next.

The feedback I received from the students was generally positive. That first year, one of my students was flight instructing for the university. She reported to me that her model went straight to her office, where she used it to teach flight students how their aircraft engines worked. The model seemed to be even better than a cutaway of a real engine for explaining how the Otto cycle worked.

Building on what I regarded as a rousing success, I continued creating more models. I modified my single-cylinder flathead into an overhead valve design with pushrods on each side. Then I made an overhead cam version with a gear train in the rear. I also made a WWI-era rotary engine and a Wankel rotary engine, and for the first time, I felt like I really understood the Wankel. I launched these additional models on Kickstarter as well. Experience with my students and with builders all over the world showed me where builders had trouble with my models. The most common problem was too much glue, which then got into places that engines should move. Builders also reported difficulties gluing the plywood parts to the dowel shafts, which created frustrating failures. I learned to design my construction manuals to push the glue away from important surfaces and to engineer joints where multiple plywood layers attached to shafts to increase longevity.

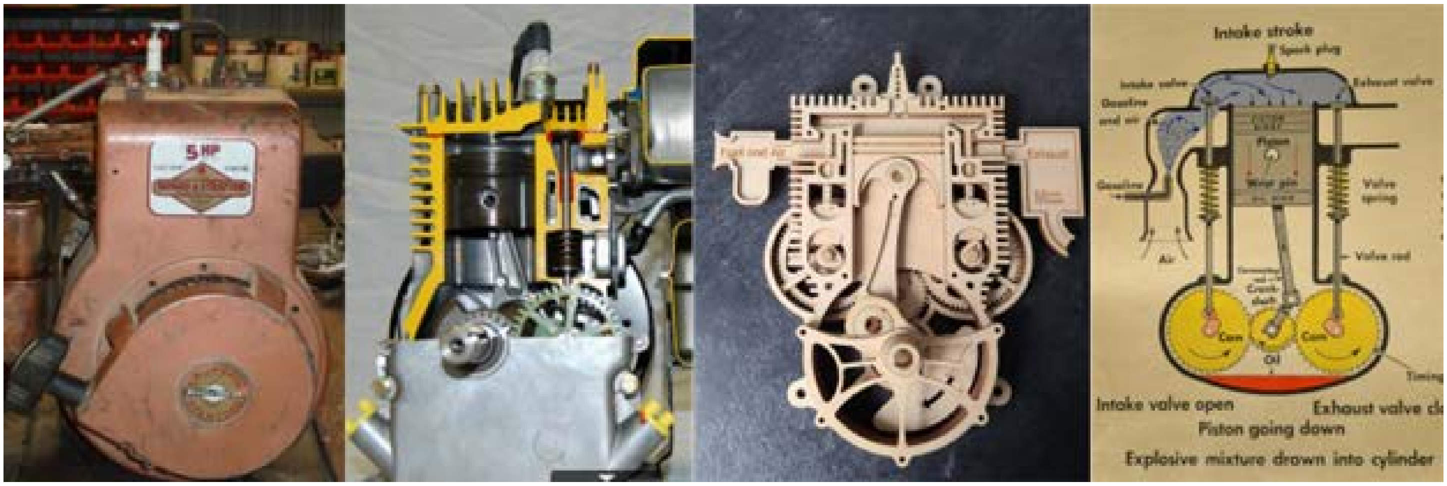

Figure 5: Flathead engine, cutaway of engine, my rearranged "Flat Flathead" model, and a 1955 diagram from my personal collection showing similar rearrangement. Image credit Author, Welch, 1955.

Designing for Repairability

As any experienced designer can attest, one of the hardest aspects of design is maintainability. This is especially true when it comes to permanently glued plywood models. My "premium" models became increasingly complex. My nine-cylinder radial model had over 1000 separate parts (Morris, 2022). It also had real roller lifters and a 35 page construction manual. This model was quite complex, and I had users glue it together into sections. These sections were then combined with AN hardware, allowing them to be disassembled and repaired if necessary. This feature was exciting, and allowed me to develop even more complex models. I added a skeletonized four cylinder Lycoming-styled engine and the five cylinder Kinner-styled radial shown in Figure 6. I called these engines my "series 2" models.

Figure 6: Kinner Style Face Cylinder Model: Author.

In the classroom, I redesigned my single cylinder engine to include more details and to get more kits from a piece of plywood, which was skyrocketing in price during the Pandemic. Figure 7 shows the resulting model on the left. It fit delightfully in a human hand. It also included enough detail to launch conversations about throttling, float bowls, and fuel metering. I had my students build this model for the next two years. The new model was cheaper and more detailed, but I still was not content. Too many students glued in parts of the engine incorrectly and were unable to make their models "run." I wanted the students to be able to take their models apart, repair them, and reassemble them. This past summer as I was preparing for a new school year, the answer hit me. I added hexagonal blanks to the appropriate layers and embedded nylon nuts in the model. The final layers changed from glue-on to screw-on and now can be easily removed if necessary. My third generation models were born, and the prototype "student" model can be seen in Figure 7 on the right.

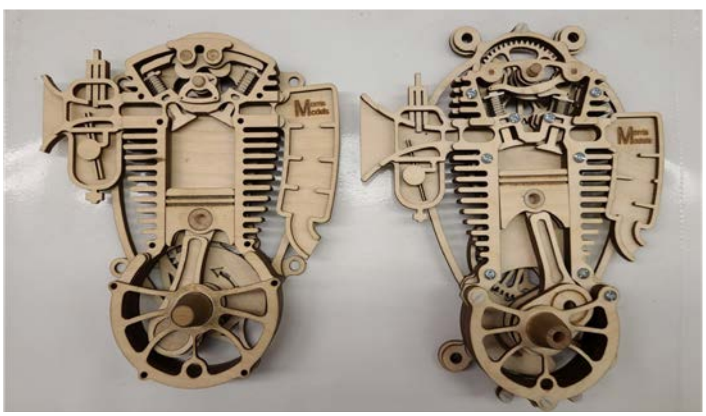

Figure 7: Single Cylinder Models for Classroom Use - 2022 - 2024. Author.

Classroom Feedback

Having the ability to disassemble and reassemble the engine made a huge difference in the classroom. Almost half of the beginning level students were able to assemble the engine during my three hour lab period with just the assembly manual. This was significantly more than before. Better yet, those who took the models home to complete them had a much higher rate of success than before. Students that assembled the engine without paying attention to timing marks were able to disassemble the engine and make it right, giving them an opportunity to learn from their mistakes. Figure 8 shows the grin of accomplishment as the assembly process is successfully completed and the model functions as it should. Figure 9 shows two students carefully calculating pressures, work generated, and power based on measurements from their completed models.

I believe that the natural conversations that flow as students build and answer detailed questions about my kits have helped me establish rapport and a trusting student-teacher relationship. It is good to see students interested and engaged. For many of my students, this is their first exposure to a detailed instruction manual, and it has been mostly positive. Better yet, my models create teachable moments. This year alone, I can recall discussions about how the float bowl works, the importance of timing marks, how a venturi allows the carburetor to meter fuel, why engines are designed with valve overlap, why there are baffle plates in a muffler, why ignition is measured before top dead center, and even the differences between a “class one” and “class three” lever (note the differences in the valve train between the left and right models in Figure 7). I do not know of any other tool that can naturally start so many conversations.

Figure 8: A grin of Triumph. Used with Permission.

Figure 9: Lab Work. Used with Permission.

At this point, I have watched hundreds of students build my models. I have seen more student social media posts about models than about any other activity I do with them. I have even seen my students engaging with my “premium” model builders online. A returning graduate recently shared that he used his model from my introductory class to verify what he learned as he moved on to the reciprocating engines classes near the conclusion of our A&P curriculum. Several of my students have enthusiastically regaled me with tales of members of their home aviation communities with my models, and how the people with these models are impressed that the students know the man who designed the models. Enthusiasm is a delightful lubricant for the tough daily grind of education.

Future Development

I’m not sure where the technical limits of my laser cut plywood medium lie, but I feel that I am approaching them. My current designs require tight enough tolerances that the inconsistent laser kerf due to slight plywood warpage is a limiting factor. My construction technique limits me to straight gears and short shafts. This means I am limited to short and flat models (which happen to display nicely on a wall). Radial engines are ideal. I have experimented with laser-cut nylon parts for greater durability, but feel that these parts introduce too much expense and complexity. I am guessing that most of my future development will be more about aesthetic improvements and leveraging my designs rather than technical improvements to technique.

I intend to incorporate my models into the Drawing portion of the Part 147 curriculum by challenging my students to improve on the drawings I provided in the manual. This could even allow them the chance to have their work featured in one of the manuals I distribute with my kits.

At this point, I welcome suggestions for additional models that may be made with this technique. I am also happy to discuss the technical aspects of my process with anyone who would like to create similar models of their own design.

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English Language Training for Aviation Maintenance Technicians – The Challenge to Do Better

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Director – Ten Hammers Pty Ltd, Brisbane, Australia

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Specialist in Language Planning and Language Policy for the Labor Force. Focus on developing countries; served across Asia, Middle East, Russia/Siberia, Central/South America, in a wide range of industry sectors.

Spearheaded initiative to develop and publish international standards in workplace language training with five co-authors and review teams in 45 countries.

Consulted with ICAO re: formation of Study Group for Proficiency Requirements in Common English (PRICE-SG) in early 2000s. Initial focus on pilots and ATCs; began addressing AMTs in 2017.

Committed to professional quality in AMT English training and teacher training.

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MBA Candidate, Melbourne Business School

Director – Ten Hammers Pty Ltd, Melbourne, Australia

MPhil Thesis: "Ability of Audio Feedback in E-books to Compensate for Haptic Attachment to Print Books," focusing on tangibility in virtual environments. Research featured at the ANZCA conference 2015.

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ABSTRACT

Worldwide regulations are inconsistent for language proficiency requirements in aviation. Yet Aviation Maintenance Technicians (AMT), when working in international aviation job roles, need proficiency in English to read, understand, and act upon work instructions. They must interact with co-workers, crewmembers, and passengers in English.

While the Aviation Maintenance Technician (AMT) cohort has specific language training needs, when teaching English to AMT, the principles of English for Occupational Purposes (EOP) should apply.

This paper discusses a proposed new methodology for English language training for AMT, while championing EOP principles. The focus must be firmly on realistic job tasks that hold the 'nuggets' of aviation terminology and grammar that are required for a new trainee to be successful in their new language.

AMT organizations have done great work in the past developing resources, such as illustrated dictionaries or glossaries that achieve so much in the overall teaching of aviation-related English language.

Now, to build on this work, newer digital media such as virtual environments can improve facilitation and student satisfaction as they exploit those natural tendencies for the new generations to explore and find out for themselves.

In reflection of the EOP principles, the time is ripe for us to:

- Define the need,
- Collaborate, and
- Customize, for the benefit of our industry.

Introduction

Despite guidance from the International Civil Aviation Organization (ICAO), worldwide regulations for language proficiency requirements in aviation are inconsistent. Yet, Aviation Maintenance Technicians (AMT), when working in international aviation job roles, need proficiency in English to read, understand, and act upon work instructions. They must interact with co-workers, crew-members, and passengers in English. Some members of the AMT community must be proficient in English for radiotelephony purposes, for safe maneuvering on the airport, just in the same way that pilots and air traffic controllers must be proficient for radiotelephony.

While the Aviation Maintenance Technician (AMT) cohort has specific language training needs, when teaching English to AMT, the principles of English for Occupational Purposes (EOP) should apply. The principles of EOP provide a robust structure for any English language training activity within any occupation.

This paper discusses a proposed new methodology for English language training for AMT, while championing EOP principles. Although it is outside the scope of this paper, the same methodology may be used for other aviation job roles and for any other industry sector.

Improved English Language Training May Assist the AMT Employee Shortage

There is a great deal of current literature, from aviation Original Equipment Manufacturers, known collectively as OEM, (Boeing Commercial Airplane Company, 2024) through to academic papers, about the current and looming shortage of aviation frontline and technical roles.

The common theme is that a considerable number of new employees will be required in aviation technical roles over the next 10–20 years. The reason for this lies in several facts. Firstly, commercial aviation continues to recover rapidly from worldwide repercussions of the Covid-19 pandemic. A further factor is the progressive retirement of the baby boomer generation, the generation of workers who facilitated the growth of the aviation industry in the 1970s, 80s, and 90s. Concurrently, the world is experiencing population and economic growth in developing countries and a corresponding elevation of people from poverty into middle class (Wietzke and Sumner, 2018).

As Narayan, Sen, and Hull (2009) note, as people join the middle class, they move from a largely subsistence lifestyle into one where there are more economic choices. These economic choices influence peoples' propensity to demand and consume things like better infrastructure; better schools; better health care; better workplace health and safety standards; and faster, safer, and more comfortable means of travel. This includes safe and affordable air travel.

The OEM market forecasts highlight the large potential growth in emerging economies, such as China, India, and elsewhere in Asia. A higher demand for airline travel within, and flying out of, Asia will drive growth of the aviation industry in these regions, and, therefore, the purchase of new aircraft.

As the worldwide fleet expands, additional pilots, cabin crew, and technicians will be required.

Since English remains the lingua franca of international aviation (Estival et al., 2016), more people will need to learn English as a second language. Currently, 80% of aircraft mechanics worldwide are non-native speakers of English, and, in some jurisdictions, there is no formal requirement for aircraft mechanics to have a certain level of English proficiency (Korba et al., 2023). This means there are many technicians working in non-English speaking Maintenance Repair Overhaul (MRO) facilities and airlines who will remain isolated from international interaction and the use of English language in their day-to-day work.

But, as people wish to advance their careers in aviation, they tend to migrate from smaller, domestic carriers to larger organizations, where they are more likely to engage in international operations. This is especially true for pilots (Weigel, 2022), but in a market that is becoming more interconnected and globalized, candidates from all job roles can portray themselves as valuable assets who can contribute successfully by highlighting their English ability during a job interview (Ne'matullah et al., 2023).

Managers and staff in larger aviation organizations will commonly interface with English language speakers. English language skills then become necessary for maintenance staff to communicate with foreign pilots and cabin crew, to liaise with suppliers in other countries, and interrogate aircraft manuals and other documentation. In some cases, English language skills are needed for radiotelephony if AMT has the responsibility to tow or taxi aircraft on airfields where English is used for air traffic control and ground movements.

In some countries, English proficiency skills for aircraft technicians is seen as critical. For example, the Malaysian Civil Aviation Authority has adopted the ICAO language proficiency requirements, which are the same radiotelephony standard for international pilots and air traffic controllers, for Malaysian licensed maintenance technicians (Department of Civil Aviation Malaysia, 2014).

The adoption of English language standards for AMT within each non-English speaking country is one side of the coin. As organizations within English-speaking countries themselves struggle with the challenge of recruiting more employees, their outreach will inevitably include more and more non-native English speakers, as well. That is, aviation professionals will be tempted to pursue or further a career in aviation by migrating to English-speaking countries, or they will be employed by larger organizations in their own countries with the requirement that they communicate in English.

These global dynamics ensure that English language training will assume a more important role in aviation in the future, with the need for training effectiveness and efficiency also becoming more important.matching the learning styles of students and the integration of technology. Generational and learning style gaps makeup but a small portion of this growing disparity between current and future-state education and curriculum. Implementing cutting-edge technology within the classroom aimed toward the dominant learning styles of AMT students will pay huge dividends toward the success of the students.

A change in teaching styles to an application level and a shift toward CBT meet the AMT students where they operate most effectively. Furthermore, this change in traditional approaches also aims to submerse the students in realistic environments. This scenario-based training has proven to be highly successful in the pilot realm of operation, and logic that follows the same would apply to the AMT realm as well. Additional research is needed to assess the gender and minority talent pools while focusing on the dominant learning styles of each talent pool.

The Next Generation of Aviation Professionals (NGAP)

The International Civil Aviation Organization (ICAO) has coined the term NGAP, meaning the "Next Generation of Aviation Professionals" (ICAO, 2024). The ICAO NGAP 'Mission' is to implement strategies that assist the global aviation community in attracting, educating, and retaining the next generation of aviation professionals (ICAO, op. cit.). Thus, it is a forward-thinking approach to attract the additional labor force required to grow the industry. However, it also recognizes that new generations have different learning styles and prefer different training methodologies to previous generations (Symbiotics, 2024).

ICAO also emphasizes that there needs to be increased outreach from industry to this generation. ICAO, regulators, and companies are recognizing that there is also strong competition for labor outside the aviation industry. Anecdotal evidence suggests that, in many instances, young AMT graduates are being poached with greater offers of remuneration by other industries, such as mining, oil and gas, and wind turbine manufacturing and maintenance.

This paper briefly discusses the learning characteristics of the so-called Generation Z. However, these characteristics are, by now, well known (Johnson and Manson, 2020, and others). Aviation training organizations that aren't modifying their 'traditional' courseware to cater to these different learning styles are, or soon will be, in danger of losing market share.

It could be argued that the increase in training activity for aviation technical roles will ensure future profitability for most training organizations. Yet, the new generation is more discerning and less likely to put up with sub-standard situations, and their communication networks ensure that information spreads rapidly. Poorly performing training providers may be affected by a fast-spreading bad reputation via eWOM, or electronic Word-Of-Mouth (Salmiah et al., 2023).

Advances in Language Training and Training Delivery Methods

This paper advocates for these two advances:

- Applying principles of English for Occupational Purposes (EOP) in language training
- Aligning training delivery methods with the learning preferences of the Next Generation of Aviation Professionals (NGAP)

In terms of EOP, there is a need going forward for an increased, worldwide extent of English language instruction that is customized to AMT. Even if this need for customization in English for AMT is not widely recognized yet, it can serve as a model for adopting a better way more broadly over time. EOP for AMT is discussed specifically and in more detail in the next section.

In terms of training delivery methods, we must consider the best methodology to use when teaching the next generation of AMT staff who will need training in technical English language. The new generation has different needs and preferences; it is counterproductive to ignore these and make them 'fit in' otherwise.

A Proposed System of Language Training Delivery

As will be seen in this paper, the principles of EOP rely on job tasks. We need to engage trainees in representative job tasks so that they may progressively and effectively learn the new language they require for their employment.

A solution could be to take over part of an aviation workplace, so that dummy tasks could be devised, incorporating language elements, while being conscious of safety for the new trainees. This is impractical, though, as most aviation workplaces, even aviation training workplaces, are busy and potentially dangerous environments.

A newer way of replicating job tasks is proposed in this paper. It uses a digital aircraft maintenance environment, accessed via computer, or tablet device, in which trainees can self-navigate, explore, interact with objects, and gather information. At strategic points along the way, the trainee will be asked to perform realistic job tasks, ranging from BASIC through INTERMEDIATE and ADVANCED. During the pre-task instruction, during the conduct of the tasks, or at the completion of these tasks, the trainee will be exposed to language elements they will need to hear or read, decipher, and act upon, just like in the real world.

Being a 'digital twin' of an aircraft maintenance environment , the replica world will also be a place where real-world safety standards will apply. Therefore, each trainee will be expected to work safely and in accordance with accepted practices. Likewise, real, or 'near-real,' aircraft reference documents will provide guidance for carrying out the various tasks that are allocated. There will be verbal instructions, but trainees will always be encouraged to consult the correct Instructions for Continuing Airworthiness (ICA).

The Importance (and Difference) of English for Occupational Purposes (EOP)

EOP in the Context of General English and English for Specific Purposes

To elaborate on EOP for AMT, it is helpful to place it in a larger context. Language training overall, and English language training, in this instance, is best understood by the purposes for which a trainee wants to learn a language. Typically, there are two broad reasons trainees learn a language—for general purposes and for specific purposes. This is represented in Figure 1 as the first-level major delineation between General English and English for Specific Purposes (ESP).

on a qualifying English test for study in a chosen discipline. These pre-academic, preparatory English courses are offered through university Intensive English Programs (IEPs).

English for Specific Purposes (ESP), as the other main branch of English language training, is also divided into two sub-branches: English for Academic Purposes (EAP) and English for Occupational Purposes (EOP).

Studying for academic purposes is markedly different from studying for occupational purposes. These different kinds of study may be taken in sequence. First, students may study their chosen academic disciplines, 'focusing on the language of academic performance.' Then, upon completion of the required

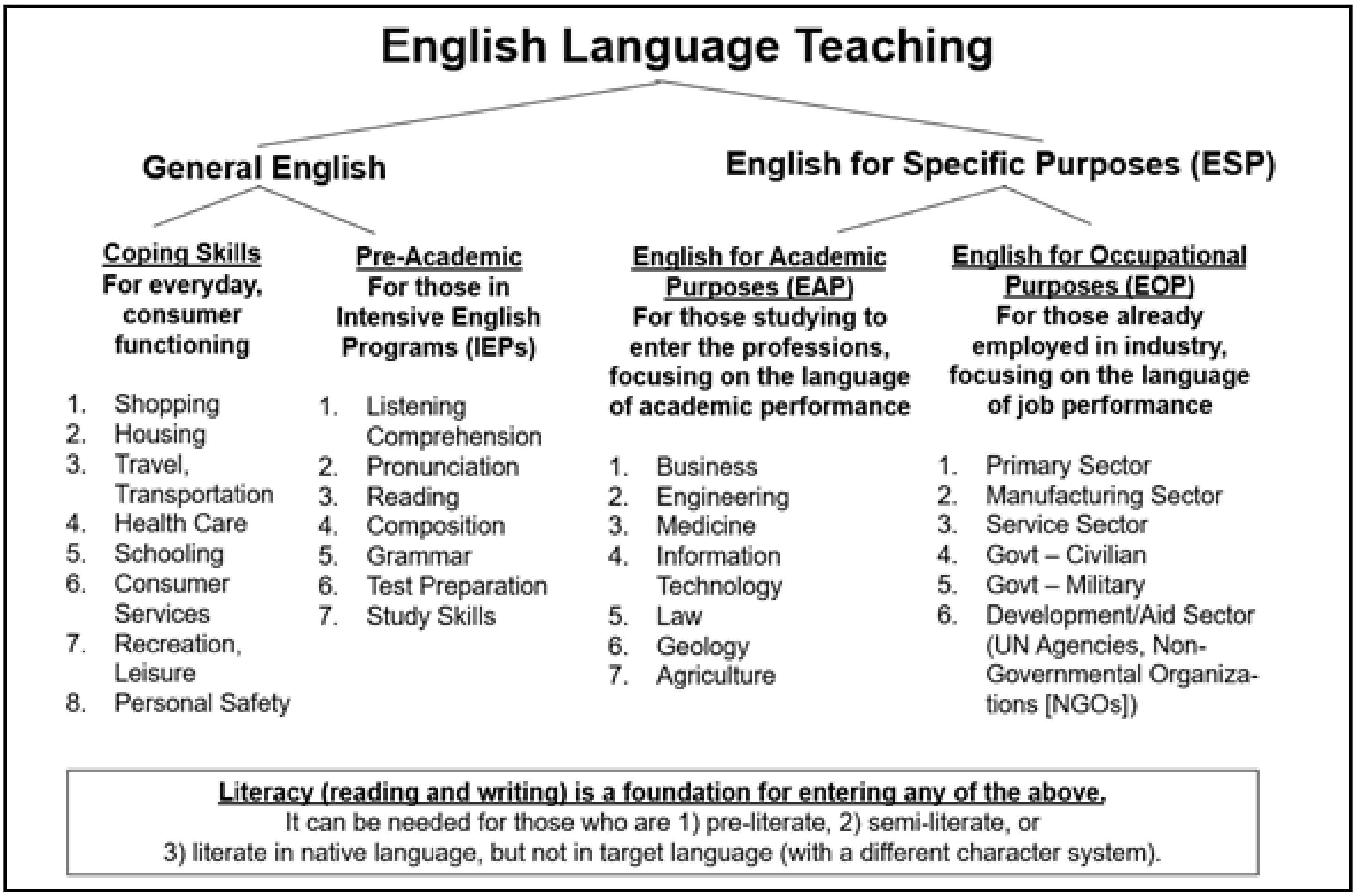

Figure 1: Broad Types of English Language Teaching

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General English refers to teaching those such as immigrants and refugees to become proficient in coping skills for integration into society as well-informed, functioning consumers. General English may also serve the purposes of an international student who needs Pre-Academic English to increase an entrance score

studies, graduates take qualifying exams to become certified or otherwise 'authorized' to go on to practice their disciplines as professional occupations. If occupational English is needed in these employment contexts, the professional 'focus[es] on the language of job performance' or the tasks of the occupation.

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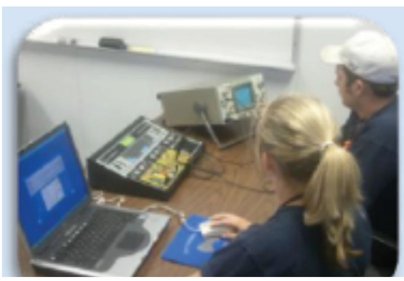

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Sometimes, the line between the two gets a bit blurred. If academic study includes practical internships, lab work, or real live job tasks in a workshop setting, then the trainee is crossing over into 'job performance.' It is helpful to distinguish the two by context and by language tasks and functions.

While studying under academic conditions, the contexts and associated language tasks and functions include understanding content, participating in discussions, taking notes in class (in person or online), carrying out short-term homework tasks, writing assignments that involve research and long-term manuscripts, and sitting for tests and exams.

For job performance, the contexts and the language tasks and functions of occupations are markedly different, as shown in Figure 2.

During their initial study, AMT trainees would fall into academic contexts and academic language tasks and functions. Then, when AMT trainees engage in activities in the workshop, hangar, or tarmac, they would fall into occupational contexts and occupational language tasks and functions.

Thus, the AMT trainee begins in EAP and progresses to EOP. Later, as an employee, the AMT continues in EOP and gains much more experience in EOP contexts and more complex EOP language tasks and functions.

In Figure 1, there is an important notation about literacy. Literacy is the concept that squiggles or symbols placed on a writing surface represent sounds and meaning. This can be quite a cognitive leap in the pre-literate mind. However, this basic literacy concept is a required foundation for learning General English or ESP. Further, literacy training may be needed at any stage: pre-literate, semi-literate, or literate in a native language but not in a target language with a different character system. This latter need may be the case with some EOP trainees.

Prerequisites for EOP – And for EOP Resources Within AMT

Just as literacy is a prerequisite for General English and ESP, a certain level of General English or Pre-Academic English is required before entering into English for Academic or Occupational Purposes. For example, if an enrollee begins studying EOP for AMT, it won't work if the trainee has zero or very low proficiency in English. Some level of prerequisite English is needed.

There are various international tests that may be used to establish this prerequisite level of English proficiency for EOP. However, some are less appropriate than others.

Context	Language Tasks and Functions
I. Administration	1. Writing documentation for ISO certification 2. Developing a proposal for project funding 3. Preparing a departmental budget 4. Submitting an expense report
II. Operations	1. Making a marketing presentation 2. Negotiating a client contract 3. Closing a sale 4. Writing correspondence and reports 5. Keeping records 6. Answering the telephone; taking a message 7. Ordering supplies and equipment 8. Reading manuals to maintain or repair equipment 9. Interacting with coworkers and superiors related to a specific issue or process 10. Participating in and/or leading meetings 11. Attending international conferences: presenting, handling Q&A, socializing
III. Social Responsibility	1. Warning others about a safety hazard 2. Documenting compliance with an environmental protection standard
IV. Human Resources	1. Interacting in a hiring or exit interview 2. Interacting in a performance appraisal 3. Participating in training

Figure 2: EOP Language Tasks and Functions

As many in AMT are aware, there is no dedicated AMT English test in the package of requirements for AMT certification at the end of the trainee's study. There are some partial exceptions, such as in Malaysia where, as noted above, ICAO language proficiency requirements, the same radiotelephony standard for international pilots and air traffic controllers (ATCs), are in place for Malaysian licensed maintenance technicians (Department of Civil Aviation Malaysia, 2014).

Note, however, that this test for pilots and ATCs only addresses these professionals' use of radio telephony (RT) for take-offs and landings. The focus is on listening and speaking skills between pilots in the cockpit and air traffic controllers in the tower. This lack of EOP testing for AMT job tasks, in particular, is, of course, a serious concern for the aviation industry, particularly as increasing populations of non-native English speakers enter this labor force.

AMTs may indeed need RT English for communicating with pilots (about mechanical issues, in flight and on the ground) and air traffic controllers (about movement on the airport). But they critically need an additional focus—and test— on speaking and listening for communication among themselves, such as during shift handover or to clarify instructions from a supervisor. They further need more dedicated AMT English testing for reading the ICA (Instructions for Continuing Airworthiness) and manuals and for writing about defect rectification in maintenance logs.

In order to develop such a more fully rounded AMT English test, a foundational AMT English curriculum is needed upon which to base such a test. The development of a professionally sound, comprehensive AMT English curriculum that is widely recognized around the world is therefore a high priority—and an a priori— goal for AMT EOP test development. Both curriculum and test are goals for AMT and the aviation sector overall.

Essential Principles of EOP

A professional AMT English curricula and testing regime will assist with conformance to the essential principles of EOP.

To put these EOP principles in context, comparison is helpful. General English is characterized by established content. Over time, the topics listed under the sub-branches of Coping Skills and Pre-Academic have become widely accepted and effective for achieving these two trainee purposes in learning General English. By contrast, the defining characteristic of English for Specific Purposes is that it is based on learner need. The profile of each EAP and EOP learner is going to vary, as are their exact needs for training in EAP and EOP. There is no 'established content' that can be 'universally' taught for each ESP learner, as there is in General English purposes and their associated topics.

Hence, in ESP, needs assessments must be conducted, and they must be conducted systematically in collaboration with academic or occupational (industry) experts. The goal of this collaboration between language trainer (i.e., qualified EAP or EOP expert) and academic or industry expert is to accurately customize the planned training to the academic performance or job performance needs of the learner.

EOP, with its service to industry sectors, is squarely placed in the larger context of the economy and economic development priorities and policies of any given country around the world. EOP therefore must align itself with, and support, economic development needs worldwide.

Already discussed in this paper is the priority of addressing the global economic issue of the labor shortage in the aviation sector—and in AMT, in particular. But there may also be other priorities and policies in economic development that should be taken into consideration. These include the need for employment of target populations, such as women, the rural underemployed, and the urban poor. This need is closely tied to the need for increased training—and access to training—for these target populations. Economic priorities and policies also include fair labor practices and adequate EOP AMT training at outsourced facilities that provide services to developed countries and their multinational corporations. In the AMT context, this must be addressed at MRO facilities. For a fuller discussion of aligning EOP with economic development priorities and policies, see Lomperis, 2020:182–184.

The next level of need at which EOP must concern itself within the national economy is the individual corporation. Companies are not always aware that they are sustaining costs because of insufficient English proficiency of some of its labor force. These costs typically relate to time and materials, but they could also involve damage to or loss of equipment, or lives, or reputation, or market share. In AMT, deficiencies in language and communication can contribute to costly Human Factors issues.

These costs, however, can typically be addressed by well-customized EOP training. The more EOP training is customized to desired improvements in job performance, the lower the costs will be to the company. EOP, well done, usually yields compelling return on investment (ROI), as high as 531% (Martin & Lomperis, 2002).

To summarize the essential principles of EOP:

- They involve needs assessment of economic development priorities and policies at the worldwide and nationwide economic level.

- They involve needs assessment of costs to be addressed at the individual corporate level.
- They involve needs assessment of job task language and other work and workplace factors at the level of curriculum development for target learners in the corporation.
- At this curriculum level, these principles also include:
  - Collaboration between language trainer and industry expert, and
  - Customization of the curriculum to produce desired results and potential for high ROI.

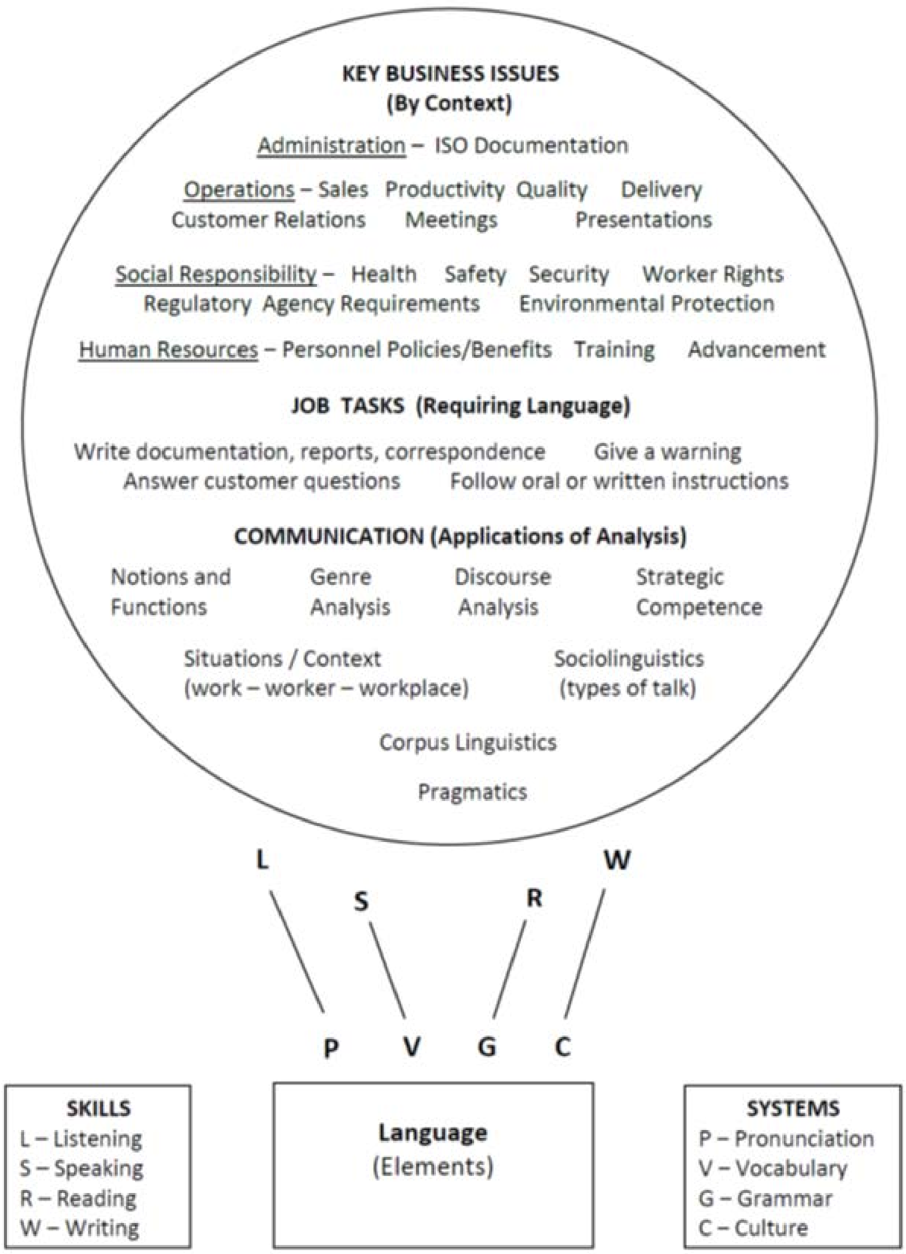

Figure 2: EOP Curriculum Concepts and Lesson Framework
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EOP for AMT Curriculum and Lesson Framework

When designing the curriculum level, it must be remembered that a professional quality AMT EOP curriculum is needed not only in its own right, but also as the basis for developing dedicated AMT EOP testing resources.

What, then, would a lesson framework for such a curriculum be based upon? Refer to Figure 3.

From conducting needs assessments at the corporate level, the following Key Business Issues have been identified as broad domains that encompass need. These are listed at the top of the 'balloon' in Figure 3:

- Administration
- Operations
- Social Responsibility
- Human Resources

In the balloon, some examples are provided under each domain. Note that these domains are where we start our needs assessment. This is the largest context with which we should start in understanding the overall concept for a curriculum.

Within each of these domains, we are looking for the all-important job tasks and the language use they require. The job task is the dominant consideration in all EOP curricula and in the EOP lesson framework. The job task determines the selection and treatment of all other categories of communication analysis, as well as language skills and language systems. Not the other way around! We start at the top of the balloon and work down. We don't start—and stay—at the bottom—only in language skills and language systems.

So again, moving down from the top of the balloon, once the job task is identified, the EOP specialist analyses it for communication applications, as listed below. Not all of these applications will be relevant for a given job task, but it is important to analyze which of them are, in fact, relevant:

- Notions and Functions
  - The purposes for communication
- Genre Analysis
  - Written formats (e.g., email, reports, manuals, bulletins)
- Discourse Analysis
  - Oral formats (e.g., in person, telephone, radio / RT)
- Pragmatics
  - Factors that govern choice of language based on relationship of parties; power-distance is especially relevant in social and workplace hierarchies
- Sociolinguistics
  - Closely related to pragmatics, the study of the interaction between language and structure and the functioning of society
- Situations / Context
  - For example, work-worker-workplace
- Corpus Linguistics
  - Language patterns – research and identification of highly productive language patterns by industry sector
- Strategic Competence
  - Terms, phrases we use to manage language learning (e.g., repeat, say slowly, sorry to interrupt, what does X mean?)

Only after all the above analysis, do we then know what language skills will be relevant to address for this job task, under the broad and well-known categories:

- Listening
- Speaking
- Reading
- Writing

Likewise, only after all the above analysis, do we know what language systems will be relevant to address for this job task:

- Pronunciation Every language has a system of sounds.
- Vocabulary Every language has a system of meaning.
- Grammar Every language has a system of structure and word order.
- Culture Every language has a system of cultural usage.

Vocabulary and Grammar

The role of vocabulary and grammar warrant a little more discussion. General English lessons often revolve around vocabulary and grammar. Hence, people who are only familiar with General English may think all language lessons should revolve around vocabulary and grammar. This may seem reasonable and logical because vocabulary is the easiest and most obvious element of language learning to present and grasp. Vocabulary is often equated with a noun (a person, place, or thing), and, as such, is the easiest to point to and associate with a new word in a new language (e.g., table, apple, tree – or, in AMT, wing, engine, fuselage).

However, we soon run out of things we can do in language if we only have learned vocabulary. We need to be able accomplish things, which is when we begin to need grammar. We need to be able to ask questions, direct action about the relationship between vocabulary items (for example, clean the windscreen with soap and a rag), or manage conversation (interrupt, clarify, redirect the topic, apologize, offer help, express thanks). So, grammar becomes important.

Yes, vocabulary and grammar are certainly important in an overall way. AMT organizations have done great work in the past developing resources, such as illustrated dictionaries or glossaries which achieve so much in the overall teaching of aviation-related English language. These resources will be invaluable also in the future, when matched up with a new way of replicating job tasks.

But ‘overall’ is not efficient for teaching EOP. We don’t need a generalized grasp of vocabulary and grammar from which to try to find what we specifically need to carry out a particular job task. Such generalized vocabulary and grammar are fine for General English. And for achieving the prerequisite level of English proficiency to qualify to start learning AMT English.

But in EOP for AMT itself, we must identify, within the language systems of vocabulary and grammar – and pronunciation and culture, as well as within the language skills of Listening, Speaking, Reading, and Writing, what more precise content we exactly need in order to succeed in carrying out a specific job task. So, as above, the job task is the most important consideration for what we need to teach. And also as above, after identifying the job task, we must next analyze and identify all the areas of communicative competence that are needed to carry out that given job task (Friedenberg et al., 2003).

Then only do we select those elements of the language systems (pronunciation, vocabulary, grammar, culture) and the language skills (Listening, Speaking, Reading, Writing) that are particularly needed to carry out that specific job task. As above, EOP is based on specific need. The lesson for the given job task is efficient to that task. Over time, we will gather more and more proficiency as we learn to carry out job task after job task after job task. Yes, accomplishing job tasks is what EOP is all about.

Job tasks, well done, improve overall job performance. That serves the needs of the learner / trainee and the overall organization.

Example Case Study

These principles may be illustrated with a brief case study for an AMT trainee.

Note, while the example given below assumes the trainee has a certain level of familiarity with the tasks and the environment, we could just as easily assume that the trainee has zero previous knowledge or experience; i.e., it is the trainee's first day on the job. In this case, we would have to allow for this by explaining every task and sub-task in more detail in anticipation of questions and confusion.

In the example given below, we provide the Job Task Breakdown. It is a BASIC task that includes instructions and a short interaction between the trainee and the supervisor.

Note also that, in the complete training solution that this paper advocates, the role of the supervisor may be played by an artificial intelligence entity. In that instance, the entity would be trained to answer all possible questions.

Thinking now of transferring this lesson into the technology format— to create the job task, the user experience, and the user interaction for the digital platform—it is necessary to closely identify the job task and a likely key exchange between the AMT trainee and supervisor. (See third row from bottom of table.)

When creating the job task for the digital platform, to make the action as realistic as possible, additional methods of task analysis, or clarification may be used. These may include the PEAR Model, commonly used in aviation Human Factors training to analyze the People, Environment, Actions, and Resources that will interface with the trainee when conducting the task.

Another analysis could be a simple Who?, Why?, What?, Where?, When?, and How? These analyses are just to gather as much

Task Categorisation	Job Task	Further Information	Instructions from Supervisor	Clarification Questions from Trainee	Response from Supervisor
BASIC	Clean the aircraft windscreen	Captain (L/H) side	Check the ICA. (For example, B737-300 Aircraft Maintenance Manual 12-16-02-100-801)		
			Get the appropriate soap and rags from the Tool Store.		
			Find an appropriate size (height) stand.		
			Be careful bringing the stand across the hangar. Ask for help if needed.		
			Position and secure the stand near the aircraft. Ensure it doesn't touch (or scratch) the aircraft skin. Allow for movement of the stand and the aircraft.		
			Put on gloves and safety harness, if required.		
			Climb stand with soap and rags. Attach safety harness to stand.		
			As per AMM instructions, when cleaning the windscreen, don't press too hard on the surface of the windscreen.	Some of the dirt and bugs won't come off. They are stuck on hard. What should I do?	Just use your fingernail. The windscreen outer surface is glass, so it won't scratch easily. Or place a rag over the tough spots, soak the rag in water and leave it for 10 minutes
			When finished, return stand to its location and throw away used rags.		
			Report to supervisor when task completed, and supervisor will explain log entry or task card.		

Figure 4: Example of Job Task Breakdown Template
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information as possible about the job role and what the trainee needs to consider.

The next step is to list the full framework for a lesson plan for this job task below.

Lesson Objectives	
Key Business Issues: Administrative, Operations, Social Responsibility, Human Resources	**Operations:** Read manual to maintain aircraft – clean windscreen **Social Responsibility:** Follow safety protocol – wear safety harness, starting at 2-metre height
Job Task:	Clean windscreen

Communication analysis:	• **Notion:** Relational meaning
	  o Agent (AMT), object (windscreen), instruments (soap, rags) (Van Ek, p. 39, 41; Wilkens, p. 34–35)
	• **Function:** Getting things done (suasion)
	  o Instructing others to do something
	  o Requesting assistance (Van Ek, p. 38)
	o **Discourse analysis:** In-person oral communication
	o **Genre analysis:** Reading manual; writing task completion card
	o **Corpus linguistics:** Productive language patterns
	  o Describe circumstances of problem – Some of the dirt and bugs won't come off
	  o Identify cause – They are stuck on hard.
	  o Ask for guidance – What should I do?

Language Skills:	• **Speaking and Listening:** Between supervisor and AMT • **Reading:** ICA (Instructions for Continued Airworthiness) • **Writing:** Log book or task completion card

Language Systems:	• **Pronunciation:** Will depend on L_1 of AMT – for languages without initial consonant cluster, two syllables will be created /stuck/ → /is-tuck/
	• **Vocabulary:** Windscreen (windshield), skin (of aircraft);
	Position and secure (the stand)
	Technical terms in ICA or on task completion card
	• **Grammar:** Imperative (command) sentences (subject is understood)
	  o Verb + object; Verb + adjective, adverb, prepositional phrase
	  o Past participle: (when) finished; (task) completed
	  o Information question: What + should do (modal + do);
	Modal and subject are inverted (should I do; not – I should do)
	• **Culture:** Work safely; avoid damage to aircraft skin; problem solve by being quick, simple, practical, flexible

Figure 5: Example of Lesson Objectives Template
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Important content to identify among these lesson objectives is the Corpus Linguistics of the highly productive language patterns and their sequence, as listed below.

(This is just one example from this lesson based on AMT communication. Another example would be language patterns based on exchanges between the AMT and supervisor.)

Key Language Patterns — Trainee Sample Language for BASIC Task

- Describe circumstances of problem.............Some of the dirt and bugs won't come off.
- Identify cause ....They are stuck on hard.
- Ask for guidance ....What should I do?

It is highly likely that these language patterns and sequence will be useful and effective for the AMT trainee in a great many exchanges with supervisors and co-workers alike. Learning them here in a beginning lesson makes them a productive set of language patterns to master because they can be applied (used) again and again throughout AMT training—and in AMT employment.

Now see also how this pattern sequence, as used in the exchange with the supervisor above, may be inserted into the technology platform for deliver of training.

Lesson Plan	
Preliminary safety and other regulations to comply with	
Review from Last Lesson	
Introduce New Job Task	
Practice the New Job Task	
Apply New Job Task to Additional Circumstances:	Function/operation of windscreen wipers, Function/operation of windscreen heat, Cleaning a helicopter windscreen
Review, Summary Quiz	

Figure 6: Example of Lesson Plan Template ©Lomperis and Manson, 9-29-2024

An important thing to remember is that one size does not fit all. AMT language differs from other aviation job roles. That is why the needs assessment is such an important underlying principle of EOP. It identifies individual need that is not one-size-fits-all.

Proposed English Language Training Delivery Methodology

As speculated, a replica digital workplace shows great potential for being able to recreate meaningful job tasks and, therefore, meaningful and progressive language learning.

One characteristic of the digital twin, as further explained below, is that it encourages repeatability and practice until the right standard is achieved, if this is an appropriate learning strategy. In the solution proposed, there will be free navigation and self-exploration to a certain extent, so trainees may back-track at any time and revisit the language from earlier lessons. When a trainee successfully completes a series of job tasks and language acquisition at a certain level, then there will be an opportunity to 'level up'.

Within each job task are the 'nuggets' of aviation terminology and grammar that are required for that level.

The Power of the Digital Twin - A Replica Workplace

A potent solution for recreating job tasks in a controlled setting has emerged in the form of digital twins—virtual simulations of physical subjects used in training and familiarization. Reminiscent, but not merely imitative, of three-dimensional displays seen in science fiction media, these digital twins can take many forms, from individual parts to complete workplaces, including the people that comprise them. The unprecedented flexibility in simulating work scenarios promises to alleviate the need for training in physical circumstances that might otherwise be im-

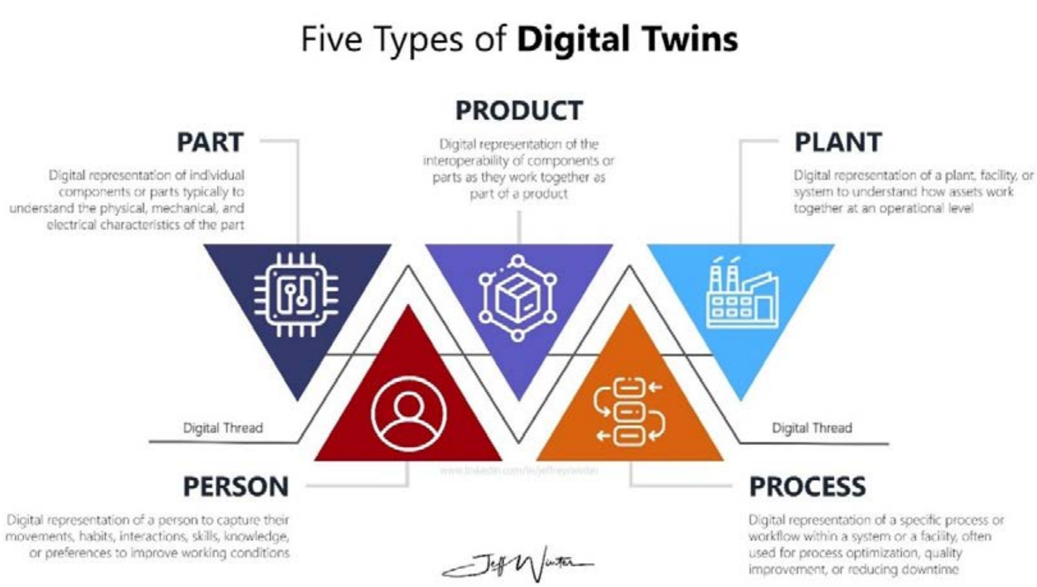

Figure 7: Five Types of Digital Twins (Source: Adapted from IoT Analytics, 2023)

practical, cost prohibitive, or even hazardous (Madni et al., 2019; Alomar & Yatskiv, 2023). The subsequent benefits to trainees and training providers are both obvious and intricate.

One of the primary benefits of digital twins is their propensity for attracting and engaging the new generation of learners in technical fields. With Generation Z, we are now long past the emergence of so-called digital natives, having now entered an era of digital immersion where platforms are more than mere tools or communication channels that are nonetheless novel or separate from real life. Rather, these platforms are now seamlessly integrated into the lived experience of the young adult workforce. Strong preferences for remote work among the Gen Z workforce, lingering since the COVID19 pandemic, provide emerging evidence for this trend (Bińczycki et al., 2023). The demand for interactive, immersive, and self-directed learning experiences is only further indicative of this preference (Hendrastomo & Januarti, 2023). Enter the digital twin: training artefacts that facilitate exploration of virtual work environments and learning through hands-on experience within a safe, consequence-free setting (Vasco, 2023; Hagedorn et al., 2023).

Digital twins are versatile tools that have seen use in a variety of education and educational settings. As illustrated in Figure 7, digital twins can be categorized under five main types: Part, Product, Plant, Person, and Process. Each of these serves a specific purpose, which may range from representing individual components to simulation of entire facilities and complex human interactions within a broader system. This comprehensive approach allows for a holistic representation of complex systems, lending themselves particularly valuable to aviation maintenance training, a domain where understanding interplay between parts, products, processes, and people is crucial. Realizing their potential is a matter of leveraging digital interactive technology in such a way that creates engaging, optimal experiences for learners.

The control over the training environment afforded by digital technologies presents key opportunities to counteract any engagement loss in the transition from physical to virtual settings. Namely, the loss of physical sensation—critical for precise hand-eye coordination— can be compensated with effective audio feedback from interaction. Responsive audio cues contribute to a sense of presence in the virtual environment, while also playing a crucial role in task comprehension and simulating workplace communication scenarios (Loureiro et al., 2020). Language training, where understanding and responding to verbal cues is a fundamental skill, is just one example of this, representative of the broader potential for digital twins to engage multiple senses and learning modalities. Philippe et al. (2020) reviewed how such multimodal teaching in VR can enhance learning outcomes. In AMT training this could relate to visual inspections, auditory cues for equipment status, and haptic feedback for tool usage. The combination of these sensory inputs contributes to a more comprehensive learning experience.

Other engagement tactics afforded by digital twins include the incorporation of adaptive learning techniques and 'gamification' elements that have matured in other digital training domains. For instance, challenge difficulty can be automatically adjusted to sustain an appropriate level of challenge (or flow) for trainees, ensuring continuous engagement (Koivisto & Hamari, 2019). Such personalization ensures that learners can be challenged to improve their competencies without becoming either overwhelmed or bored (Csikszentmihalyi, 2014). The integration of such features can significantly enhance motivation and learning outcomes. According to Koivisto and Hamari (2019), overtly gamified elements like point scoring, badges and leaderboards can be particularly effective at this.

The benefits are compounded by a key advantage afforded by the control over the training environment made possible by digital twins: unlimited repeatability. These systems allow learners to practice tasks as many times as necessary without the inherent friction of finite physical resources or the risk of equipment damage. Repetition, being fundamental to skill acquisition and mastery, is facilitated in these systems, allowing trainees to build confidence and competence before their skills are applied in real world scenarios (Checa and Bustillo, 2020). Additionally, the safety of digital environments encourages experimentation and learning from mistakes—vital characteristics of effective learning that are seldom feasible in actual workplace settings where genuine mistakes may be too risky or costly to be tolerated (Hagedorn et al., 2023).

In the specific context of English Language Training for AMTs, a detailed digital twin of an aviation workplace can facilitate unparalleled opportunity for self-exploration, discovery, and practical application of language skills. The technology represents an approach to language training that bridges the gap between theoretical knowledge and practical application in such a way that traditional training methods struggle to match (Lan, 2020). By providing an environment for trainees to safely and cost effectively interact with virtual aircraft, tools, and personnel in simulated environments, these digital twins can develop both technical vocabulary and communication skills in context. Furthermore, as a realm where clear and consistent communication is particularly essential, mastery through repetition would be another instance in which digital twins can provide a significant advantage over traditional methods for language training. Lan

(2020) demonstrated how immersive VR environments are one such effective tool for enhancing language acquisition in technical contexts. For AMTs, this might mean practicing aviation specific English terminology within the context of virtual scenarios—such as routine maintenance checks to emergency situations—potentially addressing both language skills and procedural knowledge simultaneously.

With these benefits in mind, the development of digital twin technologies presents as a promising solution for training the next generational of aviation professionals, not the least of which pertain to English language training. Not only does this approach align with the learning preferences of the emerging technical workforce, and but holds promise as a more comprehensive, practical and engaging training experience. In addition to potential increased cost effectiveness, these technologies can lead to better prepared, safer, empowered, and more confident AMTs in the global aviation industry (Legaki et al., 2020; López-Jiménez et al., 2022).

A Progressive Learning of Technical Language (Similar to How Apprentices Learn Their Trade)

Anecdotal evidence suggests that a large component of current technical English language training programs involves the provision of a vocabulary list in the early stages of the training or, in some extreme cases, as the sum total of the training.

As previously mentioned, while vocabulary is an obviously important part of learning any language, it is important for vocabulary items and grammar conventions to be presented in a contextualized manner. The ideal way to do this is as part of a realistic job task that a trainee needs to achieve. To achieve the task, the trainee needs to interpret instructions, carry out the task, and report back.

The 'digital twin' work environment is an ideal resource to use for this challenge. This realistic but benign environment will allow replication of job tasks with recognizable equipment, consumables, and processes, but also ensures trainee safety.

For AMT, the details of job tasks may be communicated verbally, but are also found via written reference, perhaps with pictorial supplement. Often there is cooperation between multiple people, or between multiple teams, for example, shift handover. Communication and language proficiency in this context has a different profile, and assumes a greater importance, as miscommunication can have a dangerous consequence.

An ideal training environment for AMT technical language training is proposed where there is progressive complexity in job tasks and, therefore, progressive complexity in language requirements. This is not dissimilar to real life where, for example, an apprentice will be allocated simple tasks until the supervisor gains confidence in the trainee's skills and ability to follow instructions. Gradually, the trainee is allocated more challenging tasks until, near the end of the apprenticeship, the trainee hopefully has the knowledge, skills, and attributes of an accredited tradesperson. And, most importantly, because of that knowledge, those skills, and that attitude, the trainee has the trust of supervisors and peers.

A typical apprenticeship, or traineeship, in AMT is a duration of three or four years. Therefore, it is proposed that the replica AMT environment will have three broad levels, which each represent a stage of apprenticeship. Trainees must complete each level before moving on to the next. The program will be self-paced, but it is expected that a typical trainee will complete each level in two-four weeks, with the ability to backtrack and revise at any time.

To fit in with this progressive structure, job tasks designed for each level will be classified as BASIC, INTERMEDIATE, and ADVANCED. Correspondingly, the language used in each level also increases in complexity.

In the first year, only simple, BASIC tasks are given. The trainee learns the layout of the workplace, they learn the scope of tasks undertaken in the workplace, and they achieve familiarity with tools and resources at their disposal. As in real life, there are simple tasks, and there is a focus on workplace health and safety in the early days, encouraging the trainee to identify and report workplace hazards.

To graduate further in the apprentice levels, the trainee needs to successfully complete all the tasks and demonstrate competence in the level of language used.

In the second / third 'year', the tasks become increasingly detailed, up to an INTERMEDIATE level. It will become obvious that the trainees are developing more confidence and that they are working safely and learning language on the job.

In the fourth year, the trainees need to graduate as bona fide tradespersons at the end of this year. So they are involved in much more ADVANCED tasks, collaboration, teamwork, and decision-making.

To allow and manage the progress of trainees from one level to another, there will be gameplay techniques whereby a trainee scores points by earning the trust of the 'supervisor'. They do this by completing tasks, by following health and safety instructions, observing housekeeping standards, collaborating and reporting hazards. Importantly, the trainees must demonstrate proficiency in the language tasks at all levels prior to moving on.

Supervision and Mentoring Within the Digital Training Environment

To compensate for the support that would otherwise be provided by a human supervisor in a physical environment, a key characteristic of the proposed digital training environment is an AI driven digital mentor. As an ever-resent resource within the simulated workplace, this AI agent is designed to be capable of providing meaningful supervision and guidance to trainees, summarizing the knowledge and experience of a mentor figure or experienced colleague.

By leveraging contemporary advances in natural language processing and machine learning, the digital mentor is designed to enhance the learning experience through providing immediate, contextual assistance to trainees. Like a human mentor, this technology is capable of understanding and responding to trainee queries in real time, offer explanations, clarifications, and suggestions based on the associated tasks and scenarios (Köbis & Mehner, 2021). By drawing on information from a comprehensive knowledge base, the digital mentor may answer questions on a wide variety of topics — such as task procedures, safety protocols, or technical language. This constant access to expert guidance is effective for facilitating self-directed learning and problem-solving skills (Chine et al., 2022). Furthermore, the digital mentor can proactively refer trainees to additional resources where appropriate. These references may include aircraft maintenance manuals, safety guidelines, or supplementary learning materials — ensuring that trainees continue to develop the research and information seeking skills essential in the field of aviation maintenance (Homitz & Berge, 2008).

It's important for ensuring consistent engagement that the AI mentor can adapt its support based on a trainee's progress and performance. As they progress through BASIC, INTERMEDIATE, and ADVANCED levels of the program, the digital mentor's guidance can become more sophisticated. As a result, trainees are challenged to think critically and apply their growing knowledge and skills to increasingly complex scenarios (Seyed Alitabar & Zadhasn, 2023). Combined with data collected from assessment and progress tracking, the digital mentor can provide valuable insights into areas of weakness for trainees where additional practice or instruction will be beneficial. The result is a data driven approach for a more personalized and supportive learning experience for each trainee (Bagai & Mane, 2023).

Regardless, despite the evident value of a digital mentor, it is not intended to entirely replace human instruction and supervision. Its intention instead is to serve as a complementary tool, and a means to provide additional support through augmenting the traditional mentoring process. The resulting blended approach combines the consistency and availability of AI powered mentors with the nuanced guidance and experience of a likewise suitable human mentor (Amano et al., 2023). The proposed system that this approach represents can deliver a mentoring solution that is scalable, consistent, and personalized, with the goal of significantly enhancing the effectiveness of AMT language training in view of the complex communication demands that these roles will require in the future.

Developing a Rigorous and Immersive English Language Training Environment

It is a complex exercise to develop a digital environment such as the one proposed. At the level of complexity demanded by AMT training, the best training resources will be developed by multiple contributors with a deep understanding of their respective fields of expertise.

This is no different to how rigorous EOP can only be done well with collaboration between language experts and SMEs. To develop a replica AMT work environment with the proposed level of functionality and utility to a particular industry, there will be a collaboration of three experts, an industry SME (for example a current and qualified AMT), a language expert, particular skilled in EOP, and a digital media expert to build the user experience and the meaningful user interaction.

The authors represent such a trio, and the collaboration is proving productive. But further collaborations with industry organizations are sought. Investment will be welcome to accelerate the development, and to conduct more research to verify the efficiency of using such a system.

The Potential Outreach

Prototyping, consultation, and further analysis have convinced the authors that this new system for English language training has many likely benefits in providing a new way for trainees to better learn workplace language conventions progressively. While the author's focus is firmly on the worldwide AMT community, and strategies to increase the outreach for employment, and to make training more efficient, it is apparent that the system may be modified to be use in any front-line aviation job role and any industry.

Therefore, the proposed system represents a way for the AMT community to influence the quality of language training in other aviation sectors, for example, in flight training. This system can also be applied in other industries where the struggle to recruit new employees also extends their outreach to people from non-English-speaking backgrounds.

Conclusion and Takeaways for Practitioners

This paper argues for more care and thought to be taken in the worldwide aviation community for English language training in AMT. Most speculation and examination of the aviation industry concludes that English language training is set to gain more importance in the near future, as the industry widens its outreach for new staff. The outreach is set to tap demographics that are currently under-represented in the aviation industry, namely women, people from lower socio-economic groups, and people from non-English speaking backgrounds.

Anecdotally, language training is not done well in many parts of the aviation industry. Firstly, there is a challenge with AMT in that there are not yet accepted standards for English language proficiency or for English language testing. But even in the area of flight training, there are issues with inconsistent testing of ICAO English language proficiency standards. Plus, a common problem is that front-line instructional staff are often tasked with language training responsibilities, without adequate preparation or qualification. A comment from a flight training organization concurs that, "Flight instructors are not language teachers."

AMT organizations have done great work in the past developing resources, such as illustrated dictionaries or glossaries that achieve so much in the overall teaching of aviation-related English language. These resources will be invaluable also in the future, when matched up with a new way of replicating job tasks. It is envisaged that the digital world and these physical resources could possibly become integrated, so that there are hyperlinks into and out of the virtual workplace, exploiting the good things in both styles of resource.

Digital media such as virtual environments can improve facilitation and student satisfaction as they exploit those natural tendencies for the new generations to explore and find out for themselves.

Vocabulary lists are a great start, but the focus must be on the realistic job tasks. The techniques of EOP dictate that job tasks hold the 'nuggets' of aviation terminology and grammar that are required for a new trainee to be successful in their new language.

In reflection of the EOP principles, the time is ripe for us to:

- Define the need,
- Collaborate, and
- Customize, for the benefit of our industry.

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Winter, J., 2023. Adapted from IoT Analytics https://iot-analytics.com/

A WORD FROM THE INDUSTRY:

Addressing the Skills Gap

Snap-on®

By **John Gamble**

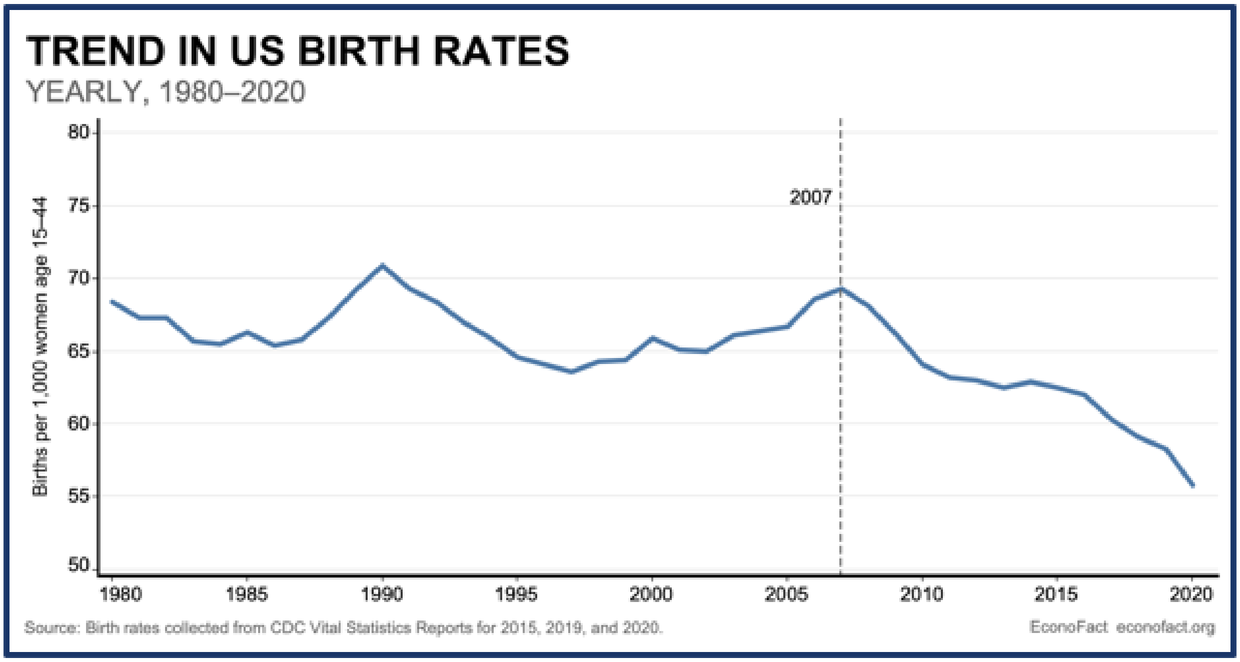
John Gamble is an Education Partnership Manager for Snap-on Industrial covering the United States and has fourteen years of experience with a focus on helping technical institutions collaborate with industry. Originally hired to support aviation maintenance institutions, John now works with high schools and colleges covering all types of technical related disciplines. He is a veteran of the U.S. Coast Guard and a proud alum of Santa Barbara City College, a community college he attended prior to transferring and graduating from the University of California at Berkeley with a degree in Political Science. He resides in Vermont with his wife and son (and sees his adult daughter as often as possible).

ABSTRACT

1. Topic – Skills Gap
2. Importance – the skills gap has the potential to weaken the strength of the American manufacturing and maintenance workforce to a point where it may damage our national security.
3. Goal - How can we aid Part 147 schools with trying to fill the skills gap.
4. Answer -
    a. Start career awareness younger (elementary age)
    b. Hands on relevant fundamental training
    c. Work with underserved candidate pools
    d. Short term upskilling training

ATEC authored a report stating that by 2031, two out of every five current mechanics in the U.S., more than 90,000 mechanics in total, will reach retirement age (ATEC, 2022). When you add declining birthrates, and the fact that, on average, 13% of students from that already shrinking pool drop out of high school (National Center for Education Statistics, 2024), we are looking at not just a national workforce issue, but a national security issue.

There are many constituents who can play a role in solving this problem, beyond what Part 147 schools can accomplish alone. The key challenge is to improve the quantity and the quality of the pool of candidates for training at those institutions. The focus of this article is to shed light on programs accomplishing such goals.



In my opinion, the gap is due to many factors: technicians aging out of the workforce, declining birthrates, lack of awareness for these careers, and a lack of appreciation for the dignity of technical work .

As we can't address demographic factors of aging out or declining birthrates, our best opportunity is to address awareness of these careers and how they are perceived. One solution is to increase the size of the pool of candidates by starting their exposure to these careers when they're younger. By doing so, we grow the percentage of people who learn about, and then consider going into, a technical career. Starting young helps prevent them from being told false narratives by friends, family , or high school counselors. Narratives such as "girls don't like jobs like this" or "these are low wage jobs for someone else."

Many believe starting younger means middle school, but there is no reason to stop there. Children may not decide what they want to be by the end of third grade, but they may decide what they don't want to do. Awareness of these careers through intentional exploration and hands-on activities can make a big difference.

As an Education Partnership Manager for Snap-on Industrial covering the U.S. I have had the pleasure of meeting and supporting top-tier individuals working to solve these critical needs. One such organization is Flight Works Alabama (FWA), a non-profit collaboration between the state of Alabama and Airbus. "A proven partnership between Snap-on, NC3, and Flight Works Alabama has generated a highly skilled workforce exceeding all expectations for our community. Beginning in middle school with our We Build It Better curriculum and moving onward to our FlightPath9 pre-apprenticeship program, students use industry-grade tools, earn NC3 certifications, and are equipped with skills for success for any career. This workforce development model is unique, proven, and ready to be shared throughout the nation." (Hurdle, 2024)

Another great example of starting younger would be KTEC, the Kenosha School of Technology Enhanced Curriculum, where in kindergarten they begin learning about measurement and soft skills like collaboration, "Collaboration means you don't get to pick who you work with" (Andersson, 2018).

In addition to starting exposure younger, another approach is to find under-served communities who may be unemployed or under-employed and unaware of aviation career opportunities. For example, young adults with justice-involved pasts are benefitting from a program in south Florida. BITTS, or the Barrington Irving Technical Training School, is a great example of how not just to grow the pool of candidates, but also to change lives. "We can't forget the pipeline of talent made up of those who are seeking an opportunity and transitioning back into society. Recruiting is not a problem because this population is immense, underserved, and eager. People want intentional experiences and empowerment." (Irving, 2024)

Starting with thoughtful recruitment practices and communication with local aviation companies about their specific workforce needs, the team at BITTS trains young adults over a twelve-to-sixteen-week period on competency-based skills like measurement, torque, electrical termination and sheet metal assembly, among others. Programs that offer short term training, graduating with industry recognized credentials produce a base product for employers who can be trained up once hired. These programs don't get a student to the point where they earn their A&P Certificate, but it can solve some immediate needs facing industry.

I am a strong believer that reaching a younger audience helps build the pipeline of future technicians. The result is that boys and girls who learn that technical careers aren't all dark, dirty, and dangerous may just learn how much fun it is to work with their hands. Additionally, the young adults who participate in short term training programs are more likely to land at a Part 147 school already possessing many of the foundational skills allowing the institution to focus on the needs of industry.

The future welders, machinists, metrologists, avionics , and maintenance techs are currently in elementary school. We need to take advantage of any opportunities we have to share the benefits of working in technical careers with them, their families, and guidance counselors. We need to let them know about the amazing contributions they can one day make to our society as makers and fixers!

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Requirements for Training and Qualifying Future Technicians for New Technologies in Aviation

By **Tracy L. Yother, PhD**
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ABSTRACT

Emerging technologies in the aviation industry are changing how aircraft are designed, operated, and maintained. This will require the development of new technician competency standards with the associated curriculum and training equipment to ensure technicians are qualified to service and repair these new aircraft. New technologies involve new propulsion systems that include fully electric, hybrid electric, as well as hydrogen and hydrogen-electric systems. New powered lift systems include multi-rotor configurations that transition from vertical to horizontal flight. These, and other new technologies, are not included in current aircraft maintenance technician certification standards. New standards must be developed, approved, and implemented into the public domain and integrated into new training curricula. Challenges include an ever-evolving technology that is not yet stabilized and access to manufacturer's technical data that is considered intellectual property to maintain competitive advantage. Recommendations to progress with the development of new technician standards include collaborating with aircraft manufacturers, industry standards publishers, the Federal Aviation Administration, relevant industry associations, and educational institutions to identify the new technologies that will be entering into service. Recommendations include the need to collaborate and a process that will result in the development and deployment of new aircraft technician standards that will ensure compliance with regulatory requirements and the successful and safe entry into service of the new aircraft.

The rapid evolution of technology in the aerospace industry changes the development, manufacture, and use of modern aircraft. Examples of technologies affecting aircraft design and air transportation operations include software and artificial intelligence, electric and hybrid-powered flight, and multi-rotor powered lift. Improvements in battery technology continue to reduce the size of our computers and phones, increase power efficiency, reduce weight, and reduce environmental impacts. As a result, the automotive industry has seen exponential adoption and growth in electric vehicles. This technology, and the lessons learned from its development, translate into its adoption and use in emerging aircraft technologies. The changes in lithium-ion batteries provide the flight range and payload capacity to make electrically powered aircraft a viable solution (ICAO, 2022; Vanzieleghem, 2022).

By December 2022, unmanned systems or drones delivered over 10,000 items under 10 pounds in less than 30 minutes (Federal Aviation Administration (FAA), 2023). Multirotor, powered-lift aircraft are under development and type certificate testing which will create a new ecosystem for air transportation. New aircraft technologies are making these types of aircraft and modes of transportation viable, and coming to a neighborhood near you, in the not-too-distant future.

As these new technologies revolutionize the aviation industry, they have associated challenges. One of these is training technicians on these new technologies in aviation. Historically, as flight systems evolved, designers and manufacturers worked with regulators, such as the FAA, to change training requirements and share technical data. Changes incorporated into a school or program's curriculum provide the industry with qualified technicians to support the new aircraft systems.

However, this approach has challenges. These challenges include the speed of the changes to flight systems, which is difficult to incorporate into the regulations and curriculum in advance of the new technology's entry into service. Even education and training program administrators, who wish to incorporate new technologies into their curriculum in advance of regulatory changes, find it difficult to obtain the technical data and equipment needed because companies are often reluctant to share proprietary data. Proprietary data keeps the original equipment manufacturer (OEM) competitive in the market of new aircraft deployment and acquisition. To increase this competitiveness, some manufacturers, such as Joby Aviation, are planning for a vertically integrated approach to maintenance. Joby Aviation received its FAA Repair Station certificate complying with the regulations in Title 14 of the Code of Federal Regulations (CFR) Part 145 (Joby Aviation, 2024a). Therefore, Joby is less dependent on, but does not eliminate the need for, FAA airframe and powerplant certificated aviation maintenance technicians to support their fleet. The challenge goes beyond effectively revising maintenance training programs to ensure aircraft technicians are qualified to service and repair these aircraft. Aircraft maintenance, repair, and overhaul service centers are also searching to find qualified technician sources to properly support modern fleets.

Purpose Statement

The purpose of this study is to explore requirements and solutions for developing technician qualification standards for new technologies to support the airworthiness of advanced air mobility (AAM) aircraft.

The following are the research questions for this study.

RQ1 What are the key, typical airworthiness requirements based on existing and developing standards for new technologies in aviation?

RQ2 Recommend a go-forward plan to develop new technician qualification standards to support new technologies entry into service and how best to integrate these into training curricula.

Background/Review of Literature

AAM is a term for a new sector of the aerospace industry that integrates automated and electric technologies into both new and existing platforms for moving people and cargo (BAE Systems, n.d.; FAA, n.d.; National Business Aviation Association, n.d.). AAM is not a monolithic technology or design, but it includes multiple technologies and platforms such as electric vertical takeoff and landing aircraft (eVTOL). eVTOL aircraft are used in multiple applications such as air taxis, firefighting, and search and rescue operations (Federal Aviation Administration, n.d.). Electric short takeoff and landing (eSTOL) aircraft can land on a runway the size of a soccer field without a reduction in range and speed (Electra, n.d.). Electric and hybrid-electric conventional takeoff and landing (eCTOL) aircraft optimize short-haul and regional operations while reducing or eliminating emissions and operating costs while leveraging existing infrastructure (Nehls, 2023; Randall, 2023).

Industry standards from organizations such as SAE and ASTM International can help both educators and manufacturers with supporting technical data, but these standards are still in the early stages of development. However, industry standards are a necessary early step in the maturation of new technologies in the industry. In 2023, the National Aeronautics and Space Administration (NASA Office of Inspector General, 2023) cited the lack of design standards for electric propulsion motors as a contributing factor to the lack of success on the X-57 Project. Limited work has started on developing student outcomes and curricula based on released standards (Yother & Johnson, 2023).

The list below is not a comprehensive list of all standards related to advanced or new technologies in aviation, but simply a starting point (see Table 1). Standards are continually being introduced and canceled. Common electrical standards that would apply to all aircraft regardless of the type of propulsion are also not included such as SAE AS50881H Wiring Aerospace Vehicle or CerTEC's aircraft electronics installation.

RQ1 What are the key, typical airworthiness requirements based on existing and developing standards for new technologies in aviation?

Manufacturers are incorporating new propulsion technologies into their platforms. Some aircraft, such as the Pipistrel Taurus Electro, are fully electric (Pipistrel, n.d.). The Horizon Cavorite X7 uses hybrid gas-electric technology (Horizon Aircraft, n.d.). Joby Aviation is expanding into hydrogen-electric powered aircraft (Joby Aviation, 2024b). Other OEMs, such as ZeroAvia

Table 1: Sample of industry standards related to new technologies in aviation

Standard number	Standard title
ASTM F3338	Standard Specification for Design of Electric Propulsion Units for General Aviation Aircraft
ASTM F2840	Standard Practice for Design and Manufacturer of Electric Propulsion Units for Light Sport Aircraft
ASTM F3239	Standard Specification for Aircraft Electric Propulsion Systems
ASTM F3316	Standard Specification for Electrical Systems for Aircraft with Electric or Hybrid-Electric Propulsion
FAA AC 20-184	Guidance on Testing and Installation of Rechargeable Lithium Battery and Battery Systems on Aircraft
ASTM F2840	Standard Practice for Design and Manufacture of Electric Propulsion Units for Light Sport Aircraft
SAE ARP8676	Nomenclature and Definitions for Electrified Propulsion Aircraft (Recommended Practice)
SAE AIR8678	Architecture Examples for Electrified Propulsion Aircraft (Information Report)
AIAA G-136-2022	Guide to Lithium Battery Safety for Space Applications
ANSI/AIAA G-095A-2017	Guide to Safety of Hydrogen and Hydrogen Systems
AIAA R-103-2004	Recommended practice: Terminology for Unmanned Aerial Vehicles and Remotely Operated Aircraft
ASTM F3547	Standard Specification for Fuel Cell Power Systems for Use in Small Unmanned Aircraft Systems (sUAS)
FAA PS-AIR-21.17.01	Safety continuum for Powered-lift (Policy Statement)
FAA-2024-1586 (AC 21.17-4)	Type Certification of Powered-lift (Draft Advisory Circular)
FAA-2023-1275	Integration of Powered-Lift: Pilot Certification and Operations (Notice of Proposed Rulemaking)
EASA SC-22.2014-01	Installation of Electric Propulsion Units in Powered Sailplanes
CerTEC	Unmanned Aircraft System Maintenance (UAS)
CerTEC	Aircraft Electronics Technician

and Stralis, are developing hydrogen-electric aircraft (Stralis, n.d.; ZeroAvia, n.d.). ZeroAvia is developing the ZA600 600kW powertrain for 10- to 20-seat regional turboprops for entry into service by 2025, the ZA2000 modular hydrogen-electric propulsion system for 40- to 80-seat regional turboprops for entry into service by 2027, and the ZA2000 RJ powertrain, a 90-seat regional jet (fan engine) for entry into service by 2029 (ZeroAvia, n.d.). The technologies to fly and power these aircraft are beyond the existing scope of federal regulations but are close enough to require airworthiness certification. Currently, the FAA is using industry consensus standards to support the certification effort. Joby Aviation has completed stage three of the FAA type certification process (Joby Aviation, 2023). Archer Aviation also received its final certification criteria for its Archer vehicle from the FAA (Weitering, 2023). The FAA does not have criteria for certifying eVTOL aircraft, but is establishing special criteria on a case-by-case basis. For instance, Joby Aviation received its final airworthiness criteria in March 2024 (FAA, 2024a). Later, in June 2024, the FAA and the European Union Aviation Safety Agency (EASA) developed common criteria for certifying eVTOL aircraft (FAA, 2024b), and Advisory Circular, AC 21.17-4, Type Certification – Powered-lift (FAA, 2024c) was opened for comment. In parallel with aircraft manufacturers, electric engine, motor, and battery manufacturers must also receive airworthiness certification. BETA Technologies and magniX USA received special conditions from the FAA to certify their electric engines.

The effort to develop electric propulsion standards is relatively new. While the FAA started with CFR Part 33 Airworthiness Standards: Aircraft Engines, to establish the level of safety, it also used technical criteria from the industry standard ASTM F3338-18 Standard Specification for Design of Electric Propulsion Units for General Aviation Aircraft to develop the special conditions required to certify the aircraft under CFR Part 21 Certification Procedures for Products and Articles.

The FAA frequently uses industry standards to demonstrate compliance with certification. In 2018, the FAA announced the acceptance of 30 published ASTM international standards as the means of compliance (MOC) for obtaining certification for Part 23 small aircraft (AVweb, 2019). Multiple organizations are already working toward or have recently developed standards or certifications. Civil Aviation Authorities could adopt these standards; examples include ASTM/CerTEC's unmanned aircraft system maintenance technician (F3600-22) and aircraft electronics technician (F3245-19) certifications. ASTM's F46 Aerospace Personnel committee members are working toward instructions for continued airworthiness of AAM systems and a standard for AAM Maintenance Technician Qualifications. SAE-ITC has gathered a workgroup focused on a standard for technicians working with electric aircraft, ensuring that those working in this field have the knowledge and skills to safely maintain the propulsion, distribution, and storage systems for high-voltage electric aircraft.

Changes are happening far beyond these new aircraft's propulsion and fuel systems. Scaled autonomy looks to be a future pathway. Eventually piloted aircraft may even be phased out completely in favor of autonomous technologies and remote-control stations linked to aircraft by robust command and control links. One example is the E-Hang 216-S, a pilotless, passenger-carrying aircraft that costs less than some versions of Cirrus' SR-22. In addition, Wisk Aero is advertising its new aircraft, Generation 6, as "self-flying" (Wisk, 2022).

RQ2 Recommend a go-forward plan to develop new technician qualification standards to support new technologies entry into service and how best to integrate these into training curricula.

Portions of the knowledge, skills, and abilities needed and discussed above can be readily injected into the FAA's Title 14 CFR Part 147 Airman Certification Standard (ACS) through a scheduled revision of the existing standards without too much effect on the existing required curriculum content, the length of training, and the training aid equipment needed by the Aircraft Maintenance Technician Schools (AMTS). However, needed changes to curriculum and content standards go beyond published ACS requirements. These requirement changes will affect the time required to teach new content and require additional equipment and training aids that will be difficult for the AMTS to identify and acquire. The addition of new and emerging technologies into AMTS curriculum could cause changes in the time requirements for training students and increase the financial burden of acquiring new equipment. These problems are further compounded by the lack of availability of these new technologies to AMTS as OEMs are focused on meeting the demands of aircraft certification and preparation for entry into service. Many AMTS do not see these technologies operating in their regions of influence, which is a further deterrent to timely integration. Operators do not yet see a need to train their workforce and qualify them to work on aircraft with new technologies that do not yet operate in their region of influence.

ACS is a minimum requirement and allows AMTS to add to the curriculum topics and technologies based on their areas of focus and regional needs. The flexibility to add topics and technologies allows AMTS with regional operations with modern aircraft to adapt their curriculum to the needs of their regional workforce. The inclusion of curriculum changes means AMTS can insert learning objectives into their curriculum to address concepts such as electric propulsion and powered-lift or to emphasize topics such as composite structures repair or avionics. The drawback to each AMTS doing this individually will quickly become evident as technician skill sets vary widely based on the AMTS they attended. When presented with a potential employee's mechanic's certificate, employers will not have a solid understanding of that employee's foundational knowledge of new and emerging technologies. Also, without the FAA accepting, defining, and publishing new technology standards within the ACS, this will lead to the continued atrophy of the ACS standard to include only outdated equipment, technologies, and overall technician qualification competencies involving the aforementioned knowledge, skills, and abilities. FAA written knowledge exams and oral and practical examinations will continue to reflect an outdated knowledge and skill set. Employers will be recruiting technicians with limited applicable skills. Employers may need to provide additional training in basic knowledge and skills in existing operational systems not included in ACS.

The FAA could address this lack of standardization by adopting new mechanic ratings specific to the most widely used technologies. As shown in Table 1, a number of standards are in development or already published. Many of these standards can be used as a certification basis for these new ratings. New ratings would allow potential employers to better screen mechanics and ensure they have the needed standard baseline of knowledge. Powered lift, electric/hybrid-electric/hydrogen-electric propulsion, ground-based command and control (C^2), autonomous flight systems, or advanced composite repair, are several possible mechanic ratings that could be earned either as a standalone rating or an endorsement on an existing mechanic certificate such as the airframe and powerplant mechanic certificate that is currently being used. Mechanic's certificates could follow the pilot certificate pathway where the pilot certificate includes multiple pilot ratings to be earned and printed on the certificate.

Future Work

Many colleges and universities have educational program accreditation requirements beyond those of a local or regional accrediting body. It is common for an institution of higher learning to use an outside organization's certification standards to elevate the prestige or competencies of their students to better prepare them for the aerospace workforce. Examples include industry accrediting bodies such as Accreditation Board for Engineering and Technology (ABET) or Aviation Accreditation Board International (AABI). Currently, minimal work tying workforce and technician certification needs to these accrediting bodies is being done. One example, Yother and Ha (2024), examined the incorporation of lithium-ion batteries into aviation maintenance curriculum. However, in the future, there will be an even greater need to provide resources to schools to add new technologies to their curriculum.

Discussion/Conclusion

The aviation industry historically and frequently adjusts to the development of new technologies (Bergey, 1979; Cockburn, 1968; Haberland, 1980). The path forward is generally the same. The aviation industry innovates and identifies the need for new training requirements, and schools support that need. Electric, hybrid-electric, hydrogen-electric propulsion, and eVTOL/eCTOL technologies are rapidly approaching the moment when trained personnel are needed to support these platforms. Organizations that sponsor and develop industry consensus standards are vital to identifying requirements, student outcomes, and curricula for industry training needs. Simultaneously, regulatory authorities must adopt new practices in certifying maintenance personnel to ensure that certificated mechanics have the foundational knowledge necessary to maintain these aircraft and their associated systems to safely ensure compliance and successful operational integration into the national airspace.

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