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# Incorporating 3D Printing as an Introduction to Digital Manufacturing in an Aeronautical Engineering Technology Curriculum

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## ABSTRACT
Fluency in application of digital manufacturing practices like 'additive' 3D printing is key for engineering and technology graduates entering the next generation aerospace workforce. Research faculty and students at Purdue University's Hangar of the Future Research Laboratory teamed with the Dept. of Aviation Technology's Aeronautical Engineering Technology Powerplant Lab to design, 3D print, install and operationally test a 3D printed prototype part on a turbine engine. The component was a bellmouth inlet manufactured using rigid plastic prototyping material. This design project was developed to evaluate ease of integration of advanced manufacturing practices into existing aeronautical engineering technology laboratory learning projects. In addition, the component was successfully tested on the department's outdoor engine test cell and is one of a series of advanced aerospace manufacturing design projects being integrated into Aviation Technology research and curriculum laboratories at Purdue.

## INTRODUCTION
Advances in computing power, automation and the network enabled workspace have allowed aerospace manufacturers to rapidly evolve and integrate digital manufacturing practices like 3D printing directly into production operations at the point of manufacture or maintenance. These advances are rapidly changing how we view lifecycle management of today's 'smart' sensor driven air vehicles and their powerplants. 3D printing in particular has been coined by some as the 'standard bearer of the next industrial revolution' (Koten, 2013) as the art and science of today's 3D printing capabilities continues to allow for faster and more cost effective printing applications (Brewster, 2014).

As advanced manufacturing practices are being rapidly integrated along all parts of aerospace manufacturing processes, the demand for graduates with these skill sets has increased as well. In fact, a recent study in September 2014 indicated that in addition to core technical background, global demand for 3D printing and other additive manufacturing skills in the last year was the highest across high technology manufacturing industries including aeronautical (Columbus, 2014) where job ads requiring workforce knowledge and skills in 3D printing alone increased over 103% since 2013. It is therefore essential that graduates in aerospace manufacturing and air vehicle maintenance programs have more than just cursory knowledge of this important technology.

## BACKGROUND
The aerospace landscape engineering and technology graduates enter today is characterized by rapid virtual collaboration capabilities, multi-sourced data acquisition, sensing and computer assisted visualization technologies, rapid prototyping and computer assisted problem solving. All of these which were once accessible only in the remote domain of an Information Technology or Engineering department, are now part of front line operations daily tool kit required at the point of manufacture or maintenance. They are now useful portals or reference points for self directed teams working at all stages of the aircraft or engine's lifecycle, aptly referred to as the 'Digital Thread' (NIST, 2014). These critical networked information portals form the basis by which the U.S. government has defined advanced manufacturing (U.S. NNMI, 2014) used by many high technology industries including aerospace, as U.S. manufacturing is becoming revitalized at a rapid rate.

To produce successful gradates with the requisite knowledge, skills and abilities for working with this ‘digital thread’, the modern aviation engineering technology curriculum must do more than just discuss this rapidly evolving digital workspace. Curriculum applications must immerse the learner in direct, experiential learning applications within a realistic setting.

Integration of advanced manufacturing principles, (like adding 3D print design solutions to existing methodologies for air vehicle and engine component fabrication and repair descried here) has been reported to facilitate transfer of basic passive textbook knowledge into deeper active learning and knowledge transfer. This approach, enhanced by access to more powerful design software and more affordable and user friendly 3D printing technology, is believed to result in deeper engagement, optimizing knowledge transfer similar to previous studies when using computer enhanced, self-directed learning platforms (Johnson, Adams, & Haywood, 2011; Ropp, et.al, 2012).

Research shows increased achievement levels and understanding when classroom material is augmented with the tools of advanced manufacturing like networked computing (computer based tools and projects), as demonstrated by tests of technical content mastery by Greaves et.al., (2010) in a study on the impact of technology transformed schools. Adding the additional project attribute of the learner’s direct involvement in the component design (including direct involvement in planning, generating and producing a solution part with the options for creative re-design), not just mastering the installation process, adds synthesis, evaluation and assessment opportunities to the learning process, which are the preferred domains of higher level learning taxonomies (Bloom, 1956; Krathwohl, 2002).

## *PROJECT DESIGN AND TEST METHODOLOGY*

This design-build-test project involved CAD modeling a component for a jet engine powerplant simulating a common removal, repair or replacement process. An Allison 250 gas turbine engine was selected as a test platform from the department’s powerplant laboratory. This particular powerplant was selected for its compact size, accessibility and robust operating performance reliability making it easy to work with and very mobile.

A component routinely inspected, removed and reinstalled during test cell runs is a bellmouth inlet surrounding the intake (Figure 1) which was selected as the design test piece.


***Figure 1. Engine inlet bellmouth - Original component***

The turbine engine test cell bellmouth is used to simulate an actual aircraft intake system and offered enough complex geometry for a low to moderate level of design challenge for this project. It must be able to streamline the airflow into the intake of the engine, allowing the engine to receive a smooth distortion-free supply of air as on an actual aircraft. The bellmouth is also utilized as an attach point for static temperature, pressure and other test probes.

### *3D engine component modeling and configuration process*

The part was dimensioned and modeled using CATIA, a commercial three dimensional computer aided design (CAD) software application (Figures 2 and 3) in approximately 4 hours by the research student with basic CATIA skills from AET curriculum courses. This software was selected because of its original design for use in aircraft manufacturing and its continued common use in the aerospace industry. Other CAD software has been used successfully in 3D printing as well, provided file formats are compatible with the 3D print system being utilized. The most common file format for many consumer level 3D printers is Standard Tessellation Language (STL). STL was the file language used for this print as it proved to be the easiest format to work with and recognized by the model printer used for this experiment, a Makerbot 5th generation 3D print system.

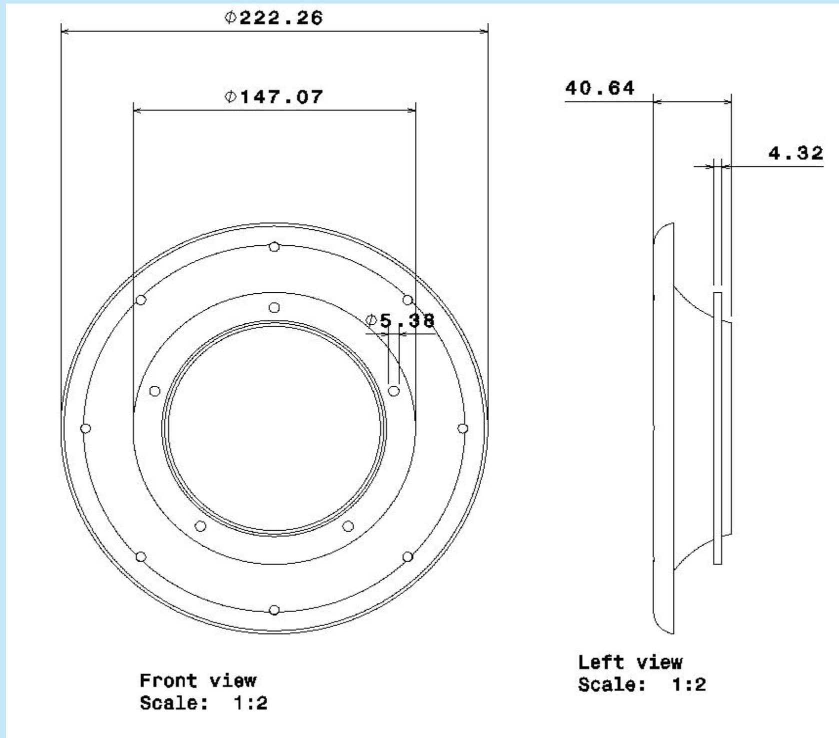



***Figure 2. Inlet Dimensions (in mm).***

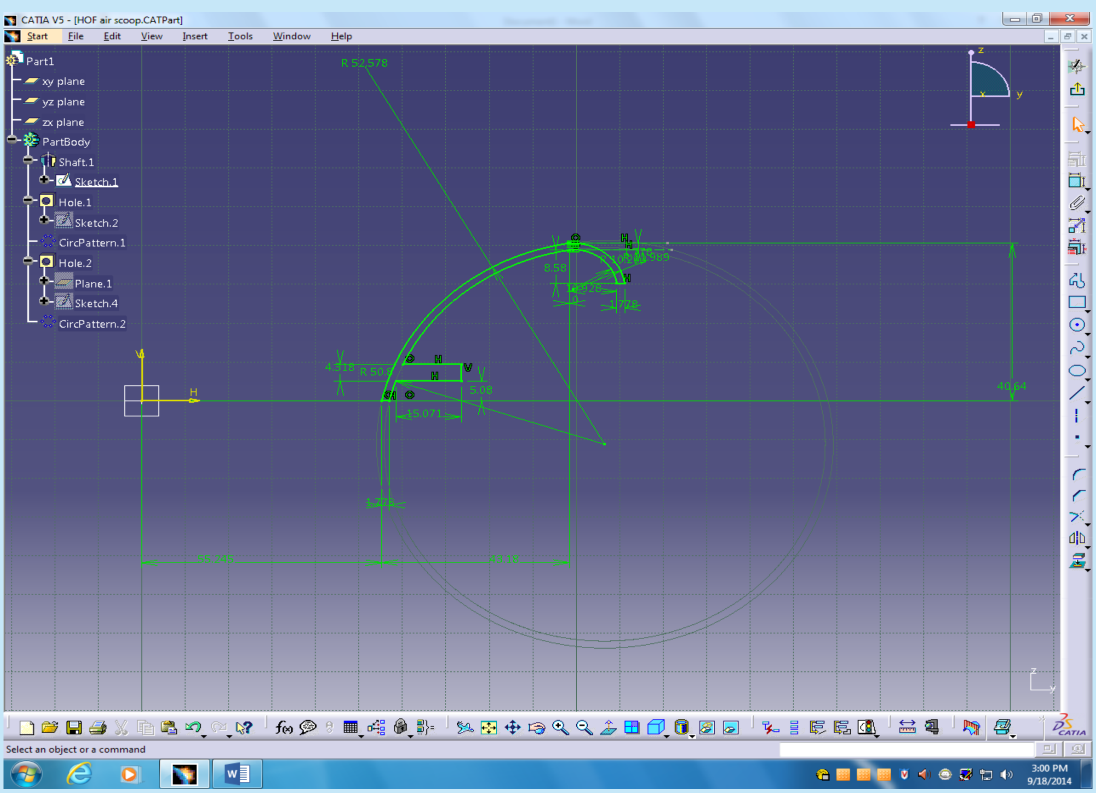



***Figure 3. Sketch of the inlet cross-section with dimensions (in mm).***

Because 3D printers create three dimensional parts in x, y and z axis, the inlet component presented constraint challenges of staying within the print build volume limit of the printer's design plate. Print build plate limits were 9.9" L (251.46 mm) x 7.8" W (198.12 mm) x 5.9 H (149.86 mm). Because the diameter of the part (222.26 mm) was larger than the width of the plate, the final installation part had to be 3D printed in two separate halves (Figure 4) which were then attached together after manufacture to form the finished inlet piece.

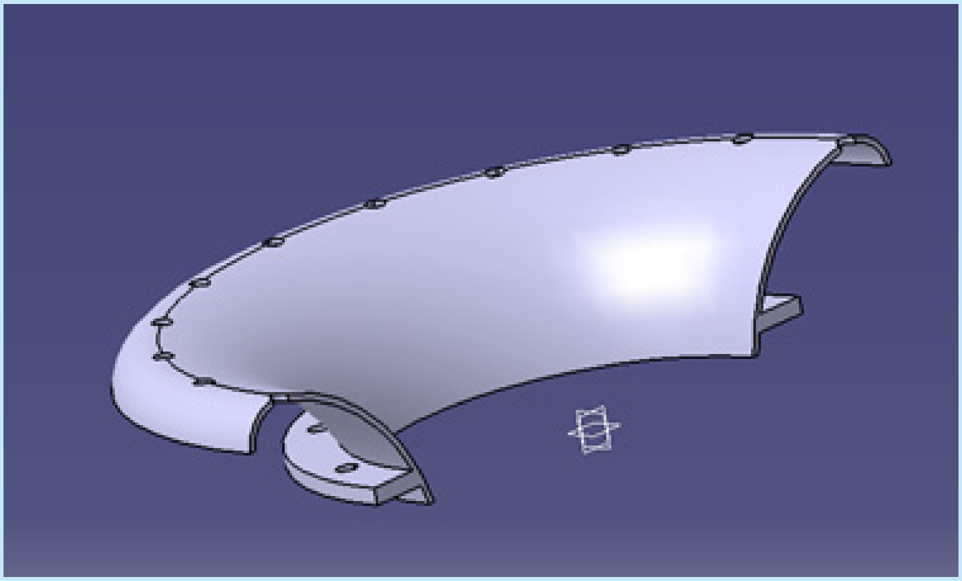


***Figure 4. CATIA modeled bellmouth inlet half.  Courtesy: A. Anne***

The full part model configured into the printer's virtual build plate interface is shown for reference (Figure 5). This view enables pre-print orientation of the part on the build area.

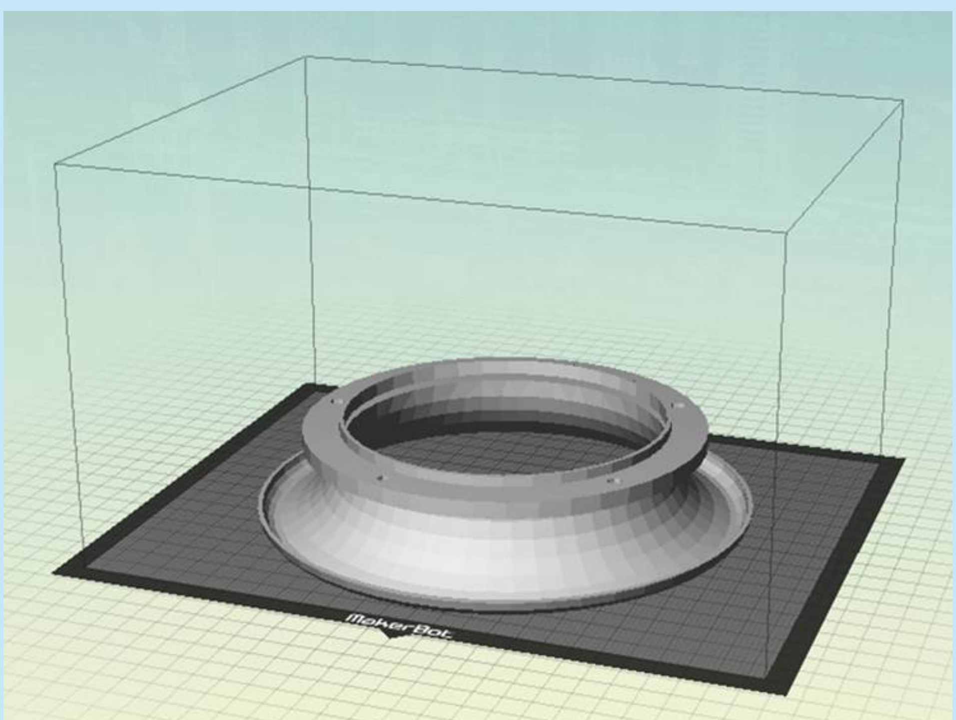



***Figure 5. CATIA modeled bellmouth full inlet on virtual build plate.***

***3D engine component print process***

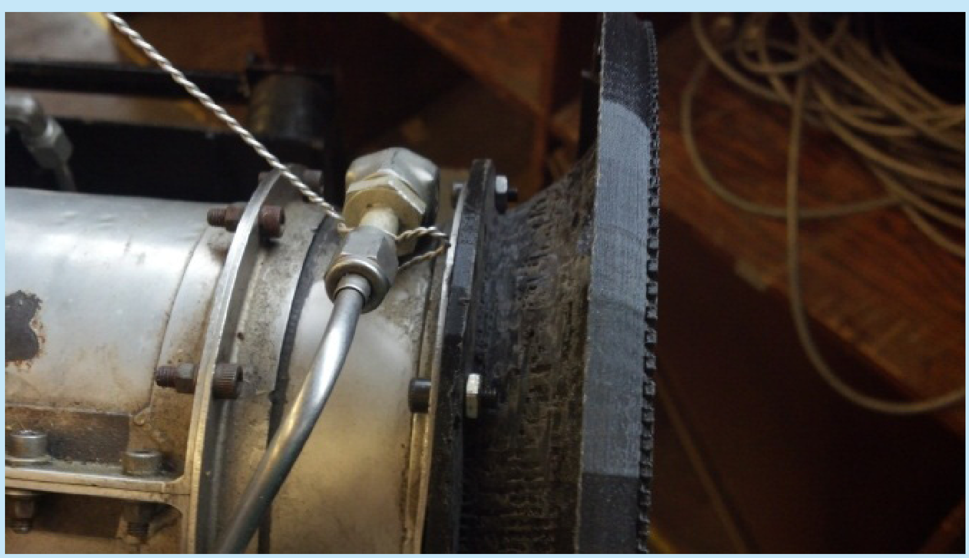
The print was accomplished using the department's current 3D printer, a Generation 5 Makerbot Replicator. When the print file is loaded into the printer CPU, the printer uses a process known as fused deposition modeling. This essentially involves numerous passes of the print head extruder, which additively layers melted prototype material, building the part in successive passes of the print extruder head.

In this test case a polylactic acid (PLA) rigid plastic prototyping test material of 1.75 mm diameter was utilized. This material was deemed rigid enough to approximate the original strength and structural fit requirements of the original inlet for fit and low power engine test runs.

***Printed Engine component installation and test***

The 3D printed inlet (shown in black, Figure 6) had concentric alignment of fastener holes, however some excess material from printing had to be removed from the holes. Excess material was minimal however, and a sander was used to easily remove excess material from planar areas taking about 15 minutes. All fastener holes were able to receive the original engine component fasteners during installation.

***Figure 6. 3D printed bellmouth inlet installation.***



A low power test run protocol was used to evaluate overall part integrity and fastener fit. As this part was not designed or intended for high power structural testing, only low power engine settings were used.

After installation, the engine was secured at an external engine test run up stand (Figure 7).

The test run duration was five minutes evaluating the part's fit, hardware fastener security and overall structural integrity at 50% rpm.

***Figure 7. Turbine engine test run with 3D printed inlet installed.***

***DISCUSSION***

It must be re-emphasized that the printed part was a rigid plastic filament prototype material, not intended for large force or structural load testing. It is recognized that 3D parts as produced in the aerospace industry utilize advanced metal or composite print processes and have manufacturing and airworthiness capabilities and approvals for their design and installed use.

The thrust of this project was 1) to evaluate overall manufacturability and efficiency of a 3D printed design, build and installation task and 2) demonstrate the ability to incorporate 3D printing as part of a deeper, immersive learning process within an existing Aeronautical Engineering Technology Part 147 curriculum. As such, the goals for this phase of the 3D printing research described in this report were to demonstrate the 'art of the possible' by blending existing curriculum with next generation, digital advanced manufacturing principles that closely approximate current industry standard processes. This design project was therefore considered a success.

***CONCLUSION***

3D printing within an active learning context notably engaged multiple learner competencies simultaneously. These included: problem identification, technical and contextual repair design, transfer of ideas and creations from virtual to the material world, installation methods, testing and assessment. These skills included Computer Aided Design (CAD) for 3D modeling, hands-on dimensioning, understanding the mission profile of the powerplant and use case of the part, as well as understanding the potential benefits and applications of the additive manufacturing process of 3D printing itself.

Major engine manufacturers are already employing advanced metal or other aerospace grade materials in 3D printers to produce aircraft engine fuel nozzles and ducting. This immersive learning project applied skill sets resulting in deeper learning with notable tendencies by learners to seek similar novel assembly and maintenance solutions for other air vehicle airframe and engines. Future advanced manufacturing projects will incorporate productivity comparisons (time to print versus traditional subtractive manufacturing or composite layups) and material cost comparisons. The primary benefit noted for applying 3D printing into an AET project was the ability to rapidly reproduce a part to test fit, form and function in a matter of hours that would otherwise take weeks or months to produce. The student designer was also able to produce and experiment with customized design variations in a relatively short amount time while extending learning transfer of core aerospace design and repair skills into the realm of advanced manufacturing.

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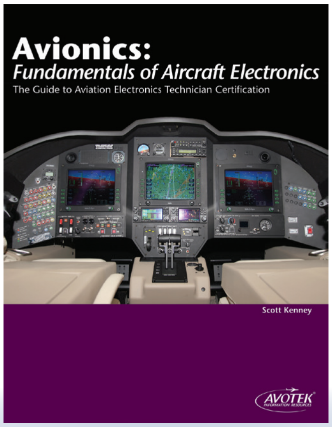


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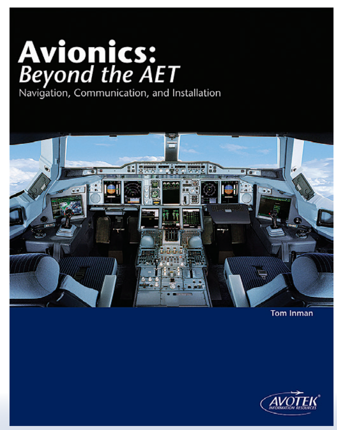


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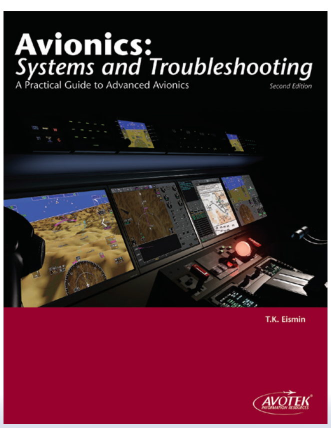


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# FAA to Begin Evaluation of Unleaded Fuels for GA

## EAA an active leader in industry/government Piston Aviation Fuels Initiative

***Reprinted from EAA***

**July 10, 2014** - The search for viable alternatives to leaded avgas is moving to the next stage as the FAA prepares to begin evaluating fuels submitted for testing through the Piston Aviation Fuels Initiative (PAFI), announced today by the FAA. July 1 marked the deadline to submit candidate fuels.

The FAA received nine replacement avgas proposals from fuel producers Afton Chemical Company, Avgas LLC, Shell Oil, Swift Fuels, and a consortium consisting of BP, TOTAL, and Hjelmco.

"Collaboration between aviation industry and petroleum innovators along with aviation and environmental regulators is key to finding and transitioning to the most viable unleaded aviation fuel for the greatest possible range of the general aviation fleet that currently relies on 100 low-lead avgas," said Jack Pelton, EAA's chairman of the board. "We have worked hard to reach this milestone, but it is only a first step. We must continue to work together to evaluate and introduce fuel that meets the highest safety and performance standards, can be supplied on a consistent, widespread basis, and is affordable to those who will ultimately use it."

***The FAA announced July 10 it would begin evaluation of several unleaded fuels submitted for testing through the Piston Aviation Fuels Initiative (PAFI). Photo credit: Julie Wegner***

PAFI is a joint industry-government effort to facilitate the development and deployment of a new unleaded avgas that will meet the needs of the existing piston-engine aircraft fleet. In addition to EAA and the FAA, the PAFI Steering Group includes the Aircraft Owners and Pilots Association, the American Petroleum Institute, the General Aviation Manufacturers Association, the National Air Transportation Association, and the National Business Aviation Association.

With the window for submissions closed, the FAA will now begin assessing the viability of the candidate fuels using the data packages provided during the submission process. The FAA will evaluate the proposals in terms of impact on the existing fleet, production and distribution infrastructure, environmental considerations, toxicological effects, and cost of aircraft operations.

The most promising fuels will be selected to participate in laboratory testing at the FAA's William J. Hughes Technical Center beginning in September. Fuel developers will be asked to supply 100 gallons of fuel for phase one testing. Fuels that are successful in the first phase will move on to aircraft and engine testing. The second test phase will require 10,000 gallons of fuel and will generate standardized qualification and certification data, as well as property and performance data.

Congress appears poised to set aside approximately $6 million to continue the testing program in 2015. The FAA has set a 2018 deadline to develop at least one new unleaded fuel for general aviation piston aircraft.

There are approximately 167,000 aircraft in the United States and a total of 230,000 worldwide that primarily rely on low-lead avgas for safe operation. It is the only remaining transportation fuel in the United States that contains added tetraethyl lead (TEL) needed to create the very high octane levels required by high-performance aircraft engines. Operations with inadequate octane can result in engine failures.

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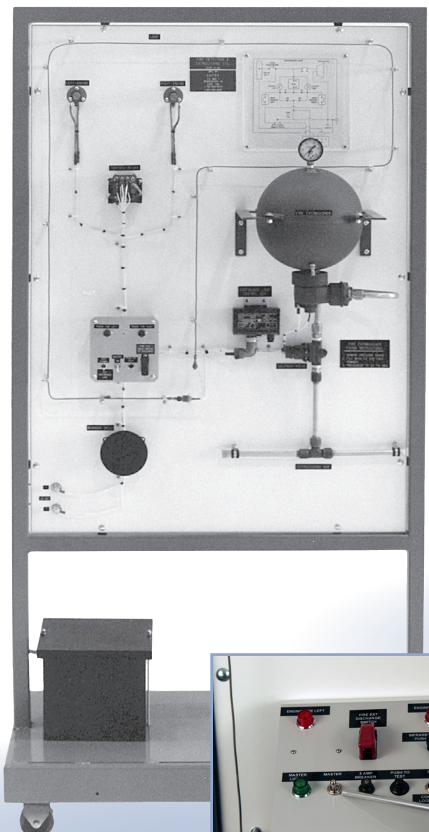


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# Aviation Sustainability through Electric Propulsion: The Research and Design Project

**Benjamin Albertson, Samuel Martin, Jeffrey Richardson, J. Eric Dietz, and Sergey Dubikovsky**
**Purdue University**

***ABSTRACT***
Two-semester long senior capstone design course was implemented in the Aeronautical Engineering Technology program in 2007 to fulfill requirements of ABET certification. One of the major goals of the course was to provide opportunities for students to apply everything they learn through curriculum while working on a project of their choice. The purpose of this paper is to chronicle the efforts of Purdue's Electric Airplane Research (PEAR) team and inform the reader of the current state of the project. Also discussed is the current technology relating to electric propulsion systems, and various aircraft that utilize this technology.

## *INTRODUCTION*

The ABET certification requires both engineering and engineering technology programs to implement project based senior design capstone courses; these standards require students to demonstrate "the ability to apply the knowledge, techniques, skills, and modern tools of the discipline to narrowly defined engineering technology activities" (ABET, 2012, p. 2). At Purdue University's Department of Engineering Technology - Aeronautical Engineering Technology (AET) program, the students themselves formed teams, were able to select their own project, and worked independently to achieve final results. The ultimate goal of AET senior design course is to prepare the students for positions in the modern work world which include liaison, manufacturing, test, and other types of engineers. Many of the program graduates are hired by major aerospace and aviation companies, such as Boeing, Lockheed Martin, and many others. It is also anticipated that graduates will move to midlevel management positions within the first 5 years after graduation (Dubikovsky, Stanley, & Wild, 2008). To achieve these goals, the problem-based learning (PBL) approach was implemented for the senior design capstone course, as it is at many engineering and engineering technology programs at universities around the US (Ellis, Carswell, Bernat, Deveaux, Frison, Meisalo, Meyer, Nulden, Rugelj, & Tarhio, 1998; Brodeur, Young, & Blair, 2002; McIntyre, 2003; Coyle, Jamieson, & Oakes, 2005; Immekus, Maller, Tracy, & Oakes, 2005).

In the fall of 2011, AET seniors began researching technology related to the development of an electric powered aircraft. The idea of an electric light sport aircraft was conceived through the interaction of three faculty members, who wanted to reduce cost of the department's flight program. It was predicted that this electric aircraft would reduce the operating cost from $220/hour to around $80/hour. The initial proposal included an aircraft weighing 1320 pounds, having a max airspeed of 120 knots with a stall speed of 45 knots, and capable of seating one pilot and one passenger, and have a single engine with a fixed or ground-adjustable propeller. The group of researchers at Purdue University considered using the university's Cessna 152 airframe due to flight characteristics closely matching those of the proposed electric aircraft. However, as the project progressed over the course of two years, it realized that current electric motor and battery technologies would be the deciding factor affecting the airplane's flight performance and payload. In order to better identify and study the electrical characteristics of the system required, the team decided to focus their initial efforts on the creation of a test stand prior to committing to retrofit an existing airframe.

## *ANALYSIS OF PAST AND CURRENT TECHNOLOGIES*

The history of electrically-propelled, fixed wing, manned aircraft can be dated to October 21st, 1973, when a modified motor-glider designed by Fred Militky flew for the first time in Austria (Hepperle, 2012). Then, in April of 1979, the first manned, solar-powered flight took place when Larry Mauro's Solar Riser flew for half a mile and reached an altitude of 40 feet (Experimental Aircraft Association [EAA], 2014a). Mauro's airplane was a biplane design, with solar panels providing 350 watts to a Hughes 500 helicopter battery, which, in turn, powered a three horsepower electric motor. After a charging time of one and a half hours, the Solar Riser could fly under power for three to five minutes, which was sufficient for the type of flying intended for the aircraft. After taking off, the pilot would cut the motor and fly the airplane as a glider while the batteries recharged. This way, the pilot was allowed the option of a powered landing (EAA, 2014a). The Mauro Solar Riser had an empty weight of 125 pounds, a maximum level speed of 20 mph, and a takeoff distance of 75-200 feet (EAA, 2014b).

Designer Paul MacCready's Solar Challenger made headlines in July 1981, when it crossed the English Channel during a flight from Cormeilles-en-Vexin, France, to Manston Royal Air Force Base in England ("Sun-Powered," 1981). The 165 mile flight was made at a cruising altitude of 11,000 feet. The Solar Challenger is a unique aircraft in that it has no batteries; instead, it relies on 16,000 solar cells to directly power a 2.7 horsepower motor. The airplane weighs around 210 pounds and cruises at 30 mph ("Sun-Powered," 1981). Electric aircraft made headlines again in the summer of 1990, when designer and pilot Eric Raymond made the first North American trans-continental flight in his Sunseeker I airplane (Solar Flight, 2013a). The record-making airplane was redesigned in 2006 to include a modified wing, more powerful motor, and updated battery and electrical system. The new Sunseeker II became the first solar-powered airplane to cross the Alps in 2009 (Solar Flight, 2013b).

In recent years, the Swiss company Solar Impulse has gained recognition with its prototype HB-SIA solar-powered airplane. In 2010, the HB-SIA set three records during a single flight when it stayed aloft for 26 hours 10 minutes, reached an altitude of 30,300 feet, and became the first solar-powered airplane to fly at night (Solar Impulse, 2013a). The HB-SIA utilizes 11, 628 solar cells on its wings to charge its lithium-polymer batteries (Solar Impulse, 2013b). Each of the four, ten horsepower electric motors are coupled to gearboxes which drive twin-bladed propellers at 400 RPM. Crucial to the performance of this airplane is a lightweight, carbon fiber airframe. The HB-SIA weighs 3,527 pounds, has a takeoff speed of 27 mph, and a cruise speed of 43 mph. The company is currently building a new airplane, the Solar Impulse 2, based on its experiences with the HB-SIA prototype. It is hoped that the Solar Impulse 2 will become the first solar-powered airplane to circumnavigate the Earth in 2015 (Solar Impulse, 2013b).

However, the use of electric propulsion systems is not limited to prototype aircraft. The ElectraFlyer ULS is one of several electrically-propelled, production aircraft (Lawrence, 2013). This aircraft is a motor glider and has a carbon fiber/foam airframe with twin tail boom, lithium-polymer batteries, and 20 horsepower electric motor in a pusher configuration. The motor has a unique design in that it is an outrunner type, meaning that the shaft is coupled to a rotating shell of magnets inside the motor (Lawrence, 2013). Because this type of motor produces high torque at a low RPM, a gearbox isn't needed to drive the propeller (Electric Aircraft Corporation, n.d.; Lawrence, 2013). The aircraft's optional, folding propeller is another design innovation worthy of mention. When driven by the motor, centrifugal force opens the propeller blades. However, when the pilot cuts the motor, the blades fold back, thereby reducing drag and allowing the aircraft the best performance as a glider. With a price tag of $59,000, the ElectraFlyer ULS is a reasonable option for those wishing to buy an aircraft of this type (Lawrence, 2013). The ElectraFlyer ULS is manufactured by the Electric Aircraft Corporation and has an empty weight of 245 pounds, a cruise speed of 40 mph, and flight duration of two hours with fully charged batteries (Electric Aircraft Corporation, n.d.).

PC-Aero of Germany is another leader in the field of electric propulsion. The company's Elektra One airplane is notable in that it resembles a conventional airplane more than it does a motorized glider. The Elektra One boasts a 160 km/hr (99 mph) cruise speed and an endurance of more than 3 hours, resulting in a range of over 400 km (249 mi). Empty weight, including batteries, is 200 kg (441 pounds) and the electric motor provides 13.5 kW (18 hp) of continuous power (PC-Aero, 2014a). The surprising performance of this airplane is perhaps best summarized by a statement on the company's website:

> "We do not have to wait for new technologies, we need only to integrate current components (light-weight structures with high-quality aerodynamics, light and modern electric motors and batteries) in an optimized system. Our Elektra One is such a modern single-seat Ultralight Electric Aircraft in composite construction" (PC-Aero, 2014c, "Electric- & Solar-Aircraft," para. 1).

The airplane, together with a solar hanger to charge the batteries, can be purchased for roughly $137,000 (PC-Aero, 2014a). Another one PC-Aero's designs, the Electra One Solar, draws half of its power from solar cells on its wings, has a cruise speed of 140 km/hr (87 mph), and an endurance of more than 8 hours (PC-Aero, 2014b).

The Elektra One isn't the only electric airplane to achieve relatively high speeds while maintaining endurance. In 2011, Slovenian manufacturer Pipistrel flew its Taurus G4 prototype in the Green Flight Challenge organized by CAFÉ (Comparative Aircraft Flight Efficiency) and NASA (National Aeronautics and Space Administration) ("Pipistrel Taurus," 2013). The aircraft won the efficiency competition after completing a 200 mile course in less than 2 hours, all the while achieving an equivalent of 403.5 passenger-miles per US gallon of fuel. Two days later, the aircraft reached 113.6 mph in the speed competition ("Pipistrel Taurus," 2013). These performance characteristics are particularly impressive considering the aircraft's four-place seating; in fact, the airplane carried two people and 400 pounds of ballast during the Green Flight Challenge. The Taurus G4 is essentially two Pipistrel Taurus G2 sailplanes joined together, with an electric motor sitting between the two separate cockpits. The water-cooled motor draws from lithium-polymer storage cells and provides 85 kW (114hp) of continuous power. The airplane is of primarily composite construction and has an empty weight of 1,316 pounds ("Pipistrel Taurus," 2013).

### *DEVELOPMENT OF PURDUE ELECTRIC AIRCRAFT*

The original plan for Purdue's Cessna 152 was to remove the traditional Lycoming O-235 engine and replace it with a three-phase permanent magnet motor. The motor chosen by the previous group of student researchers was a UQM Power Phase 145 motor/generator. This motor was chosen due to its power output, tight voltage regulation, excellent thermal management, and extended range. The motor is capable of producing 194 peak horse power and 114 horsepower at a continuous power setting of 5000 RPM while maintaining 93% efficiency. After the removal of the O-235 engine and mount from the Cessna 152 airframe, a custom-made electric motor mount was installed along with the UQM PowerPhase motor. A gear box was added to optimize the power at the most efficient RPM by providing a 2.03:1 reduction. This gear box would then drive the propeller. The propeller chosen for the electric aircraft was the Ivoprop Magnum propeller. The Magnum is a 3-bladed, composite, ground-adjustable propeller with a diameter of 66 inches.

The next biggest challenge for the group of researchers was to decide what type of power source would be used to drive the motor. A lithium-ion power source was chosen due to the high power densities associated with these types of batteries. Because of the high power required by the PowerPhase 145 motor, a high overall pack voltage was chosen to help reduce the amount of current required to meet these demands. The overall power comes from three 96V lithium-ion battery packs wired in series. The batteries for this project were leveraged from an existing research effort within Purdue's College of Technology and are the same ones used in some commercially available electrical vehicles. The overall battery pack provides a total of 288V at 70 amp-hours to the rest of the system. To maintain and ensure that the lithium-ion batteries are operating safely, each battery module is monitored by an appropriate battery management system (BMS) that constantly reads the current, voltage, and temperature of each battery pack. Each individually dedicated battery management system will disconnect its battery pack from the system if the battery current, voltage, or temperature reaches an unsafe condition. A set of power contactors is utilized by the BMS to physically isolate both the high side and low side of the battery module from the rest of the system in the unlikely event a fault is detected. Having both high side and low side contactors provides a dual redundant system to ensure that the battery pack can be removed from the system if necessary. Two additional sets of contactors are utilized to connect the individual 96 volt modules in series and then to the rest of the system. These contactors provide the user the ability to have complete control over how and when the battery modules are connected to the rest of the system. Individual, as well as overall, battery voltage gauges and current meters were added to provide a complete vision of the operating parameters of the system and a method to detect potential problems before they arise.

In addition to the main power source, a secondary, 12V power system was included on the test stand. The 12V system consists of two separate 12V deep cycle marine batteries. One battery provides power to the control circuitry, while the other provides power to the cooling system.

### *DEVELOPMENT OF THE TEST STAND*

It was known very early on in the project that a test stand would need to be constructed in order to test the electric motor and battery systems prior to their instillation on the aircraft. The test stand was constructed out of steel square stock and plates. The stand is mounted on four smart casters capable of easy positioning during testing operations. The angled section of the stand as seen in Figure 1 was used to house all of the electrical components and monitoring systems. It was originally designed for the battery packs to be mounted to the test stand and used as a counter weight on the rear of the stand. However, as an additional safety caution, a separate battery cart was constructed to allow the batteries to be separated and isolated from the test stand to reduce the risk of losing the test stand should all of the safety systems fail and a catastrophic thermal event occurs.

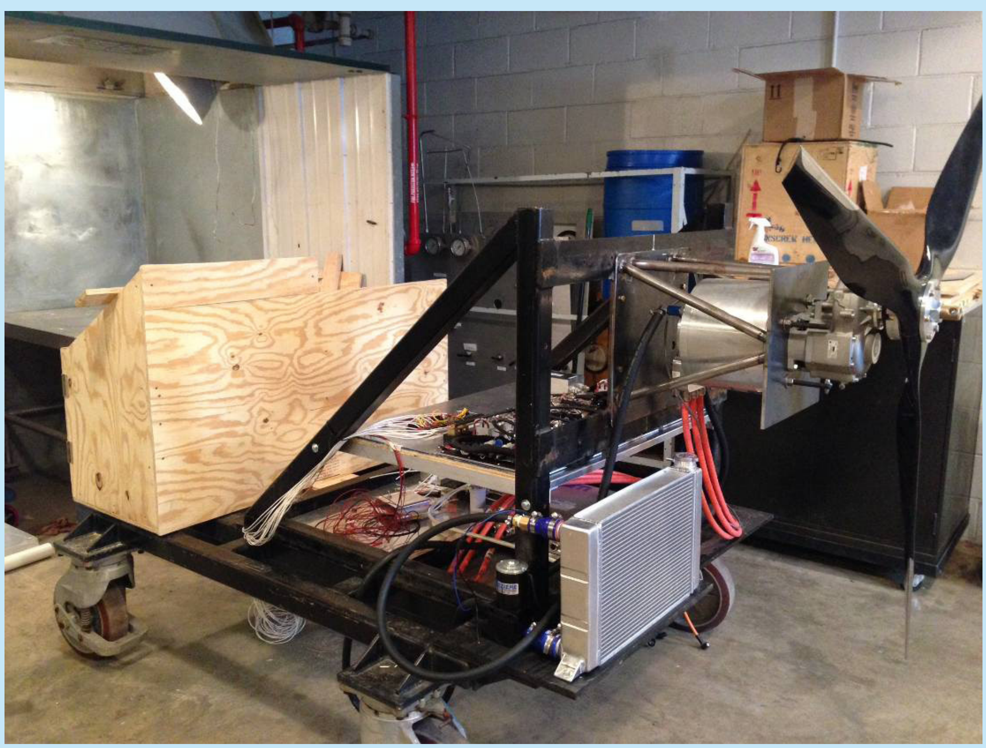

***Figure 1. Test stand***

A command station at the rear of the test stand provides the space necessary for the addition of steel counterweight while also housing the test stand control panel and 12V battery system. After all components required for a function test stand had been correctly wired and mounted in place, ¼" polycarbonate sheets were used to protect people and components from any contact while also providing view of the electrical systems.

## *CONTROL AND OPERATION OF THE TEST STAND*

The control panel was designed to be as user-friendly as possible. For example, all of the switches are laid out so that the operator will activate each switch in a left-to-right, top-to-bottom fashion while working through a checklist. In addition, each gauge is located near the switch that is associated with it. Diagram 1 provides a simplified schematic of the power and control systems and is relevant to the information presented in the next few paragraphs.

The start procedure is begun by enabling the overall 12 volt master switch; in doing so, power is made available to the rest of the control panel. 12V is then applied to the three individual battery management systems by activating a single switch. This allows the battery management systems to sense the state of the batteries. The operator then activates three individual key or "run" switches, thus completing the start-up procedure for each battery management system. If the state of the batteries is acceptable, the high side and low side contactors will close as these key switches are being activated. However, if a battery management system determines that a battery is out of tolerance at any point during the start-up procedure or during the operation of the test stand, it will open the contacts for that particular battery, thus opening the batteries' series circuit and removing power from the inverter. The next step in the start procedure requires the activation of the four switches that place the battery modules in series and then to the rest of the system. The activation of the second pair of switches will result in the total system voltmeter reading 288V.

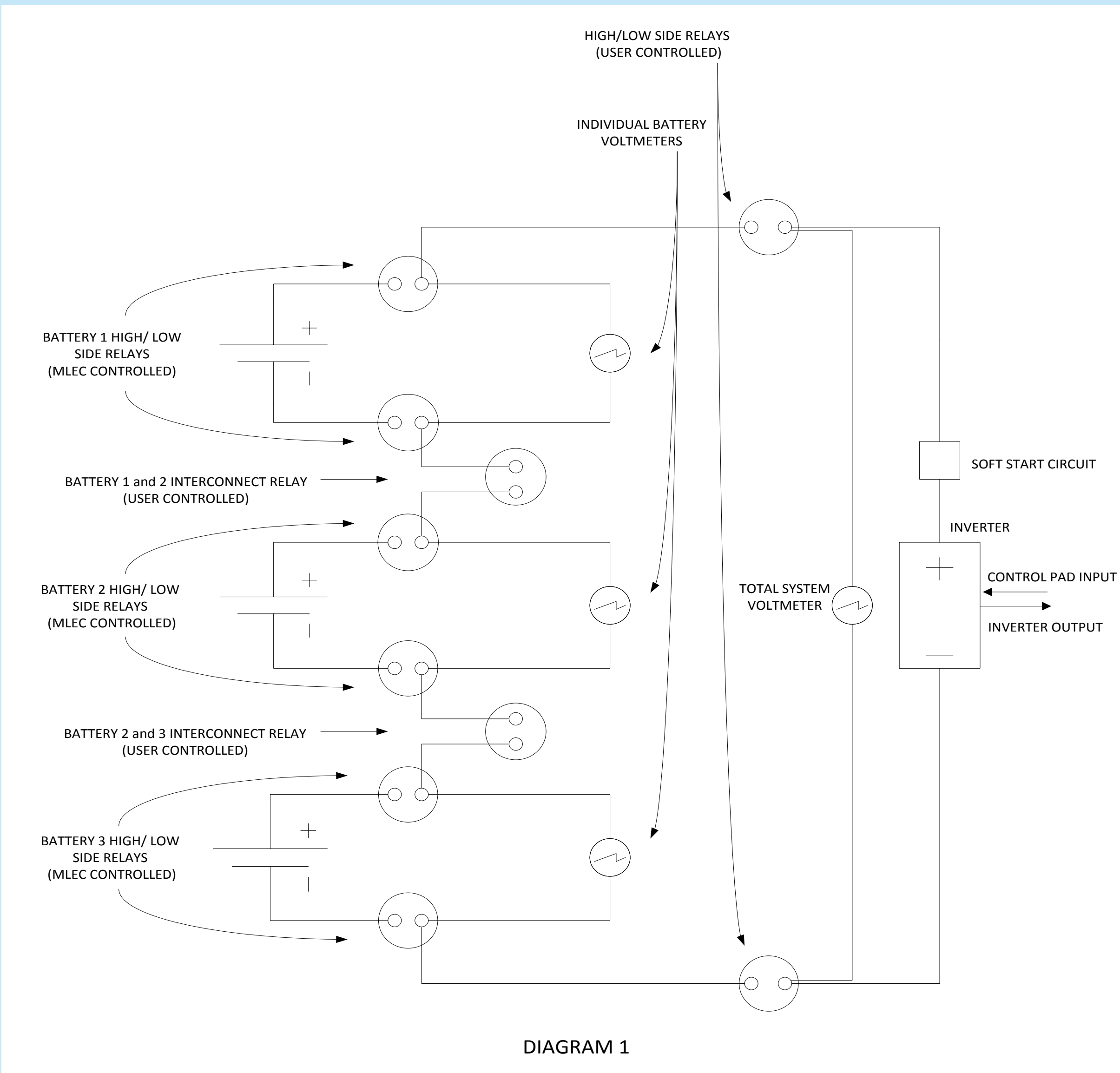


*Diagram 1. Simplified schematic of the power and control systems*

Once the lithium battery startup sequence is completed, the next step is the activation of the two switches corresponding to the water pump and radiator fan. At this point, a cooling medium is provided to the motor and inverter. To energize the inverter, the operator must activate two switches associated with the soft start circuitry. The first switch places a resistive series circuit between the power source and the inverter and charges the inverter's internal circuitry. After a five second delay, the second switch is activated, causing the main contactor to close, thus directly connecting 288V to the inverter.

At this point, the test stand is ready for actual use. The test stand provides a hand control pad with two potentiometers, a direction switch, and an enable switch. The operator first moves the direction switch to the forward position and then the enable switch is activated. Moving the potentiometer labeled accelerator in the upward direction, causes the motor to begin turning. If at any point regenerative braking is requested, the potentiometer labeled brake may be moved and power will be fed into the batteries while the motor is slowed.

With the system fully operational, the operator will be able to monitor the individual and overall current flow of the system, as well as the overall and individual battery pack voltages on the gauge cluster incorporated in the test stand. Additional data can be read and logged through the onboard CAN data bus that is included as part of battery management systems. These values will provide the necessary information needed to design and build the system that will ultimately be incorporated in an airplane.

## CONCLUSIONS/RECOMMENDATIONS

Purdue University's electric propulsion test stand is capable of recording critical test data for the aviation industry, thus allowing research into the possibility of heavier and faster electric airplanes. Other possibilities include the testing of different sets and combinations of batteries. This data could facilitate critical power to weight calculations applicable to general aviation aircraft. Another possibility is the runtime and lifetime capabilities for the battery packs, which could provide the aviation industry with anticipated flight time and range without flight testing. General aviation has been looking for a replacement for petroleum based fuels by either an alternative fuel or electric power. Many of the current light sport electric aircraft have low power and are not capable of carrying passengers. Students at Aeronautical Technology program are looking into the creation of an electric aircraft that will be capable of matching conventional engines in horsepower while carrying passengers. With the research conducted and data collected through this test stand, it is hoped that future Purdue students will collaborate and work towards integrating the test stand components into an airframe such as the Cessna 152. The graduates who participated in the project for last three years all reported back and indicated that this particular project higher level opportunities at their current employer. The authors plan to look in greater detail into the educational aspects and outcomes of the project in the near future.

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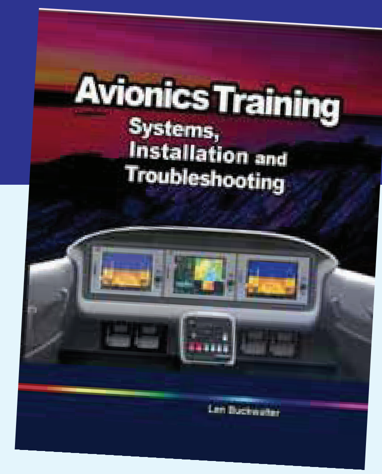


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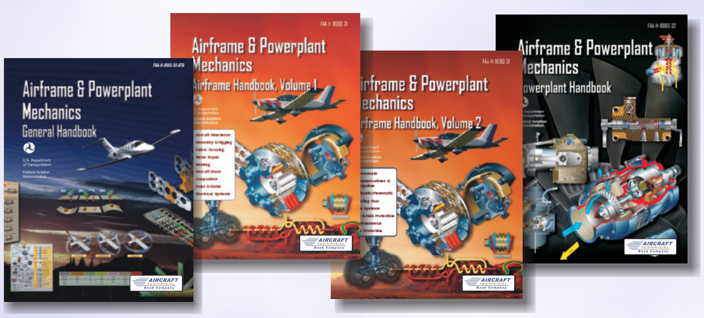


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# New ATEC Business Office

Greetings Fellow ATEC Members:

I am happy to report that business office duties and responsibilities have officially transitioned to Obadal, Filler, MacLeod and Klein (OFMK).

A boutique law firm based in Alexandria, Virginia, OFMK has years of experience running trade associations, including the Aeronautical Repair Station Association (ARSA), and provides regulatory counsel for countless aviation industry clients.

Meet the team that will provide primary day-to-day support:

- Crystal Maguire, ATEC business manager (bio available at http://potomac-law.com/attorneys/crystal-t-maguire/) and staff liaison for the FAA relations and regulatory guidance, member relations and instructional materials committees.
- Daniel Fisher, ATEC government affairs manager (bio available at http://potomac-law.com/attorneys/daniel-b-fisher/) and staff liaison for the legislative affairs committee.
- Brett Levanto, ATEC communications manager and staff liaison for the communications and outreach committee.
- Katie Klotz, ATEC administrative coordinator and staff liaison for the conference programming and planning committee. Katie will also be the point person for all administrative and logistical needs.

A full staff contact list and updated business office information is available at http://www.atec-amt.org/business-office.html.

What does this mean for you, our members? You can continue working on behalf of aviation technical training – through our committees, meetings and communications – with the support of OFMK's dedicated team. The transition will ensure that ATEC continues to grow and mature as a professional trade association proactively working on behalf of its members.

A press statement announcing this new relationship is available at http://www.aviationpros.com/press_release/11622022/atec-contracts-ofmk-to-take-aviation-technical-education-group-to-the-next-level. Take a minute to read it; you'll see very clearly how excited we are about ATEC and OFMK's future together.

Respectfully,

Ryan Goertzen
President

# President's Report - 2014

Greetings Fellow ATEC Members:

It is hard to imagine two months have passed since our annual conference. On behalf of your leadership team and your board members, I would like to take this opportunity to provide an update on the progress that is being made on several fronts.

First, I would like to welcome the following board members who have elected to serve on the board and are replacing the positions vacated by Gary Hoyle (Treasurer), Amy Kienast (Vice President) and myself. Please take time to welcome the following board members.

- Charles Horning, Embry-Riddle Aeronautical University (2 year term)
- Jay Gregson, Hallmark College, (1 year term)
- Kevin High, Western Michigan University (1 year term)
- Kevin Gulliver, NIDA Corporation (Industry Member)
- Art Spengler, Premier Aircraft Sales (Industry Member)

On the website we have posted the latest contact information for all officers and board members. Please feel free to reach out to us if you have questions or concerns you need addressed.

Secondly, we have posted the updated committee pages that outlines the various committees and are in effect working hard on your behalf. I am putting a great deal of focus this year into these committees and to the members that have signed up to participate. It is my belief we can work better as a group to solve our issues and continue with the momentum gained over the last several years to grow our organization and enhance our reputation in the maintenance training education sector. If you are not represented on these committees and want to be, please reach out to the committee chairs.

Thirdly, the board members voted unanimously to develop a standing committee on legislative affairs which I have tasked Raymond Thompson and David Jones to co-chair. Over the last several years we have grown and developed partnerships with various alphabet groups as well as the STEM Coalition. It is my vision we will expand our legislative activities to the Department of Labor, Department of Education, Department of Veteran Affairs, and America Works Campaign. Both Ray and David are developing a go-forward strategy in this area that will be reported to the board over the next several months.

Fourthly, I have placed on the website (below) our strategic goals for 2014-2016. Gary, Amy and I worked to develop these goals which were presented to the board for approval. We believe having strong goals that are measurable and achievable guide our organization forward while at the same time provide clear purpose and direction to the organization, its committees and our members. Please review this document to understand our strategy forward.

Finally, the board has come to a unanimous decision to move the business office transition forward as we say good-bye to Dick Dumaresq and his years of service to our organization. The law firm of Odadal, Filler, MacLeod and Klein located in Alexandria, VA will take over all business operations. A meeting is set for July 15, 2014 to discuss transition of all business office functions. I believe along with our board members this decision will continue the acceleration of our organization as we continue to meet the growing demands of our membership. There will be additional information provided at the end of July on this exciting news.

Respectfully,

Ryan Goertzen
President

# AVIATION TECHNICIAN EDUCATION COUNCIL

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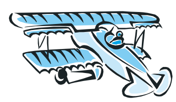

## Aviation Technician Education Council
## Strategic Goals
## 2014-2016

1. Develop Request for Proposal and award new contract for both the Executive Director and Business Office changeover.
2. Restructure current committee structures that will utilize board member strengths and support our strategic initiatives and position.
3. Remain engaged in the Federal Aviation Administration (FAA) rulemaking process and support initiatives that support the successful completion of the new rule.
4. Provide guidance to the Department of Labor on the classification for Aviation Maintenance Technician (AMT).
5. Grow relationship with the STEM Coalition to recognize AMT training as a STEM program and occupation.
6. Work with Governor Mary Fallin of Oklahoma on America Works: Education and training for Tomorrows Jobs.
7. Develop an Industry Working Group with a focus on education needs of the aerospace industry to meet current and future workforce needs.
8. Develop a portal page that provides number of graduates listed by school and location for industry members seeking to find students to employ.
9. Grow revenues by 25% per year to help continue to support membership activities and organizational goals.

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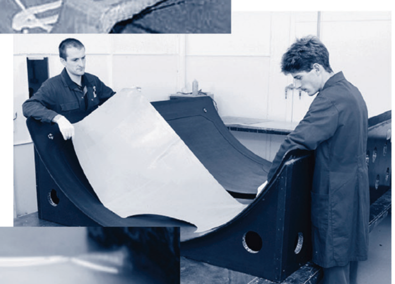

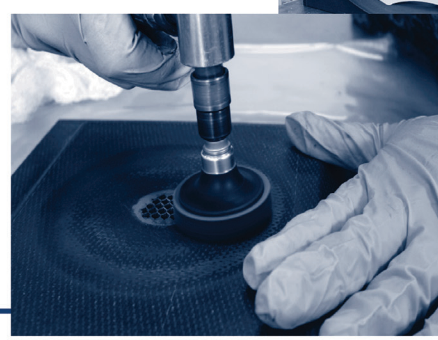

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AVIATION TECHNICIAN EDUCATION COUNCIL

IVAN D. LIVI AVIATION MAINTENANCE EDUCATOR OF THE YEAR AWARD

Purpose: This award recognizes the outstanding achievement of an aviation maintenance technology instructor. This achievement can be in the form of a single event or long term outstanding performance but must have had a direct impact on the Aviation Maintenance student. This award will be presented at the annual ATEC Conference. The winner will be contacted in late February.

CRITERIA FOR ELIGIBILITY

TO BE ELIGIBLE for the ATEC outstanding educator award, the nominee must:

1. Be employed by an institution and/or organization that is a member of the Aviation Technician Education Council.

2. Be an active instructor of Airframe and/or Powerplant Technicians. The applicant's workload must be of such a nature that they spend 80% of their workload time in contact with students teaching actual aviation maintenance technology classes.

3. Present a completed application with appropriate signatures by **January 31** to the ATEC Business Office email: atec@atec-amt.org.

4. Nominations may be made for one particular outstanding achievement by a person. They may also be made for a person who has consistently contributed above average performance.

5. Nominees are not eligible if they are a current member of the Executive Board or, as regular members, they are serving on the Public Relations Committee.

CRITERIA USED FOR EVALUATION

1. Initiative/creativity: What did this person do, what new ideas or applications were used and what was the outcome?
Total value in per cent.........................................................................................45%

2. Attitude/performance: What was the direct impact to the student(s)? How was the attitude and/or performance of the student effected by the event, ideas, or performance?
Total value in per cent.........................................................................................25%

3. Education/training: What education and training does the nominee possess? How did this influence the event, idea, or performance?
Total value in per cent.........................................................................................15%

4. Recommendation(s) and/or nomination statements from the benefit and effect of the event, idea or performance.
Total value in per cent.........................................................................................15%

**IVAN D. LIVI AVIATION MAINTENANCE EDUCATOR OF THE YEAR AWARD**

**NOMINATION FORM**

DATE: ______________________________

NOMINEE: ______________________________________________________________________

POSITION/TITLE: _________________________________________________________________

LENGTH OF SERVICE IN THIS POSITION: _________________________________________

NOMINEE ADDRESS: ___________________________________________________________

PHONE NO.: Business _________________________ Home ___________________________

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NOMINATOR: ___________________________________ Phone No. ___________________

NOMINATOR POSITION/TITLE: _________________________________________________

NOMINATOR ADDRESS: _______________________________________________________

**NOTE:** Nomination statements must be limited to this form and not exceed these pages. Recommendations (separate attachments) are limited to three, no more than one page each. They must be signed and the organization name stated.

NOMINATION STATEMENT

_______________________________________________________________________________

_______________________________________________________________________________

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1. INITIATIVE/CREATIVITY: ____________________

2. ATTITUDE/PERFORMANCE: ____________________

3. EDUCATION/TRAINING: ________________________________________________

4. RECOMMENDATIONS AND/OR EFFECT OF PERFORMANCE:

All information given on this application is correct. I hereby authorize release of all information contained on this application to any authorized awards committee member or board member.

Nominee Signature ______________________________ Date ____________

Nominator's Signature ______________________________ Date ____________

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**JAMES RARDON AVIATION MAINTENANCE TECHNICIAN STUDENT OF THE YEAR AWARD**

**Purpose:** These awards recognize the outstanding achievement of Aviation Maintenance Technician students. These achievements must be demonstrated through academics as well as through involvement that makes a direct impact on the student's associates, school and/or community.

**Eligibility:** To be nominated, an individual must be a full-time AMT student at an institution that is a member of the Aviation Technician Education Council.

**Nomination Process:** Nominators must complete a Nomination Form with appropriate signatures by **January 31** and forward it to the ATEC Business Office email: atec@atec-amt.org.

**Review Process:** Following receipt of the nominations, they will be reviewed by the ATEC Awards Committee and Northrop Rice Foundation Board of Directors to determine ten (10) finalists. The ATEC Awards Committee will then select the James Rardon AMT Student of the Year award winner from the finalists. The winner will be contacted in late February.

**Selection Criteria:**

1. **Leadership/Motivation:** What has the student done to encourage and lead his/her students to newer and higher levels of learning, or to promote aviation maintenance as a career?
   Total value in per cent. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 35%

2. **Academics:** How has the student approached his/her own learning, and what grade level has the student achieved?
   Total value in per cent. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 30%

3. **School/Community:** What has the student done to assist the school faculty develop new/better training methods, maintain necessary records and maintenance requirements, and/or promote the institution in the community?
   Total value in per cent. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 25%

4. **Recommendation(s):** Additional (up to 3) recommendations or nomination statements will be considered to become as familiar as possible with the attributes, abilities and achievements of the nominated student.
   Total value in per cent. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 10%

**Awards:** The James Rardon AMT Student of the Year award winner will receive transportation costs (airfare, hotel, meals, etc.) to attend the ATEC Annual Conference. The recipient will be honored during the Awards Luncheon and will receive the "James Rardon Aviation Maintenance Technician Student of the Year" plaque. The other nine (9) finalists will receive by mail a "James Rardon Outstanding AMT Student" certificate. These ATEC awards are sponsored and funded by the **Northrop Rice Foundation**. Registration at the ATEC Annual Conference for the James Rardon award winner is provided by ATEC.

**JAMES RARDON AVIATION MAINTENANCE TECHNICIAN STUDENT OF THE YEAR AWARD**

**NOMINATION FORM**

DATE: ______________________

NOMINEE: ______________________________________________

LENGTH OF TIME AT THE SCHOOL: ______________________________

NOMINEE ADDRESS: ______________________________________

PHONE NO.: School______________________ Home ______________________

INSTITUTION AND/OR COMPANY: ______________________________

INSTITUTION AND/OR COMPANY ADDRESS: ______________________

______________________________________Phone No. ____________________

NOMINATOR: __________________________ Phone No. ____________________

NOMINATOR POSITION/TITLE: ________________________________

NOMINATOR ADDRESS: ____________________________________

**NOTE:** Nomination statements must be limited to this form and not exceed these pages. Recommendations (separate attachments) are limited to three, no more than one page each. They must be signed and the organization name stated.

NOMINATION STATEMENT

1. LEADERSHIP/MOTIVATION: ______________________________

2. ACADEMICS: ______________________________

3. SCHOOL/COMMUNITY: ____________________________________________

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4. RECOMMENDATIONS/ADDITIONAL ACHIEVEMENTS

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All information given on this application is correct. I hereby authorize release of all information contained on this application to any authorized awards committee member or board member.

Nominee Signature ________________________________________ Date ____________

Nominator's Signature _____________________________________ Date ____________

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