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4. Alternative Gas Turbine Fuels Education for Aviation Technologists
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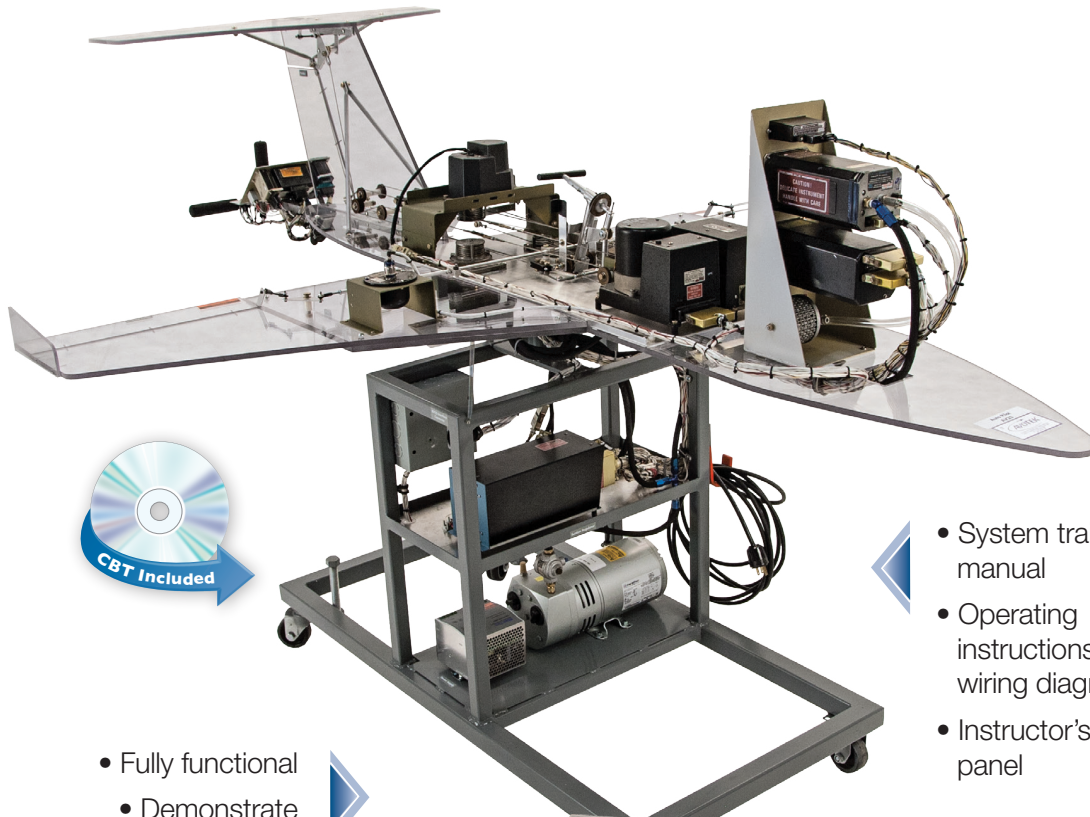
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# Alternative Gas Turbine Fuels Education for Aviation Technologists

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## **Abstract**

Students and Faculty from the Aviation Technology Department at Purdue University are working towards improving the educational methods utilized for training future Aviation professionals. As the number of alternative gas turbine fuels used as “drop in” replacements for conventional fuels increases, the need for a better understanding of aviation fuels in general emerges. Aviation Technology faculty have developed a new “Aviation Fuels” course, welcoming upperclassmen as well as graduate students, with input from industry partners such as Swift Fuels LLC, Mercurius Biofuels LLC., and Aero Engine Controls (AEC). One portion of this course aims to decode the steps involved in approving conventional and alternative aviation fuels. The educational methodology utilized helps students gain a deep comprehension of the procedures, test methods and criteria in a “learning by doing” environment. The course scope covers the three primary American Society for Testing and Materials (ASTM) International standards regarding aviation turbine fuels: D40541 Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives, D16552,3 Standard Specification for Aviation Turbine Fuels, and D75664 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons. Learning outcomes emphasize students comprehending how these three standards relate to and interact with each other.

## **1. Introduction**

The College of Technology at Purdue University, soon to become the Purdue Polytechnic Institute, is working towards transforming higher education in ways that address the current challenges brought about by a changing world. The Purdue Polytechnic Initiative (PPI) follows three main channels to accomplish an innovative learning environment for all technology students<sup>5</sup>. The “incubator” serves as an entity free from conventional academic and administrative constraints. Within the incubator, the first cohort of students began their journey toward a transdisciplinary education in the fall semester of 2014. The second branch of PPI is the “task force”, promoting the diffusion of innovative techniques

and ideas (validated by the incubator) within each department. The third channel strives towards encouraging and guiding curricular initiatives originating from traditional departments.

PPI principles are based on the reality that the world is changing in fundamental ways. The conventional academic methods of transferring knowledge to students in a highly controlled environment are no longer sufficient to prepare them for a successful future. In addition, students currently served have entirely different motivations, aspirations and ways of learning<sup>6</sup>. Learning by doing, industry driven curriculum, global perspective, experiential labs and multi-discipline integration are the core necessary components for inspiring an “intrinsically motivated” lifelong learner.

The Aviation Technology (AT) Department within the College of Technology at Purdue University is the perfect home for implementing the above mentioned PPI principles. AT faculty are constantly collaborating with the industry to solve “just in time” problems. The aviation industry’s vast and global nature demands future technologists who are able to handle a wide array of scientific, technical, economic, and political challenges. Thus, teaching techniques utilized by the educators should be well beyond the conventional “sage on stage”, transforming professors into rather a “guide on the side”<sup>7</sup>.

The current study describes the pedagogy employed by the faculty in the “Aviation Fuels” course. The multicomponent nature of the fuel approval process in aviation industry demands experts with a deep understanding of fuel properties and logistics. Introduction of biofuels for aircraft further emphasizes this need. Aviation biofuels relate to an even larger group of disciplines (such as biological sciences and agriculture) than conventional ones; demanding an expanded breadth of education necessary for future professionals in this field. Similarly, the dynamic nature of the aviation fuels world necessitates frequent feedback from industry on the expected skills set for future technologists.

The Aviation Technology Department is working very closely with industrial partners to address issues concerning the educational needs of students. It was brought to our attention that future aviation professionals will greatly benefit from an insightful education on the aviation fuels approval process. To answer this current need, “fuel approval” process was cautiously integrated into the “Aviation Fuels” course developed. Close collaboration with Swift Fuels Inc., Mercurius Biofuels Inc., and Aero Engine Controls (an Original Engine Manufacturer–OEM) allowed keeping the course content practical and relevant. Below, information on aviation fuels is provided as this knowledge would help further clarify the teaching methods employed.

Aviation fuels are different than the ground transportation fuels which are only charged with the crucial task of supplying power. In some cases as with jet fuel, the fuel is also utilized for lubrication of fuel pumps and fuel controls along with serving as a coolant medium for the engine. Consequently, the fuel needs to come into contact with multiple aircraft components, demanding strict regulations of operation and safety. In addition, a candidate alternative aviation fuel must pass all the technical, engineering, economic, environmental and political screening tests for a world-wide approval. ASTM International, known until 2001 as the American Society for Testing and Materials, is the organization responsible for the development and execution of all aviation fuel standards since World War II. Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants is the branch within ASTM that continuously coordinates with multiple organizations (military

and civilian) to accomplish this exhaustive task in the most efficient manner.

Aviation Technology has traditionally been educating our students to be the next experts and leaders in aircraft and power plants in addition to aviation managers and professional pilots. Fuels, on the other hand, have not been a significant focus. This situation needed to be addressed as the ever expanding research on sustainable aviation fuels makes “fuels” very relevant and important for future work force. Foreign oil independence, domestic security, sustainable feedstock and lowered high altitude emissions are crucial driving forces for alternative aviation fuels. As of March 2015, three alternative aviation fuels already have been approved by ASTM for use as a blending component with the conventional jet fuel. Government, academia and industry will continue to collaborate heavily in the foreseeable future to increase this number. Hence, a deeper knowledge and hands on experience on aviation fuels are not only beneficial but essential.

An additional motivation for a revised aviation technology curriculum is the industry. The current expectations are shifting away from the merely theoretical expertise as we globally move away from the Knowledge Economy towards more of a Thinking Economy<sup>5</sup>. In other words, revised teaching methods are a necessity for the current students who are expected to succeed in a massive influx of smart devices, social media and easily accessed information<sup>9</sup>. Current Professionals do not achieve success simply by reciting information but by applying the information in the most creative manner. AT faculty took these parameters into consideration and designed the instruction of “aviation fuels” in three main parts as discussed below. These course sections are developed concurrently throughout the semester.

1. Analysis and comparison of fundamentals
2. Industry on site visits and special guest speakers
3. Learning by doing modules at laboratory

## **2. Fundamentals of Aviation Turbine Fuel Standards**

A comprehensive study<sup>10</sup> of ASTM D1655, ASTM D7566 and ASTM 4054 is provided to the students for in depth analyses of these standards as well as their interactions with one another. For the scope of this project, only main points about these standards will be discussed as our purpose is merely to show the complex nature of the “fuel approval process” as it relates to the teaching methods utilized. One common feature of these three gas turbine fuel standards is that they do not only define the properties of the fuel but also contain information pertinent to the source material and the process by which the fuels are manufactured. Hence an accurate interpretation of these standards demands foundational knowledge on how these rules were established in the first place.

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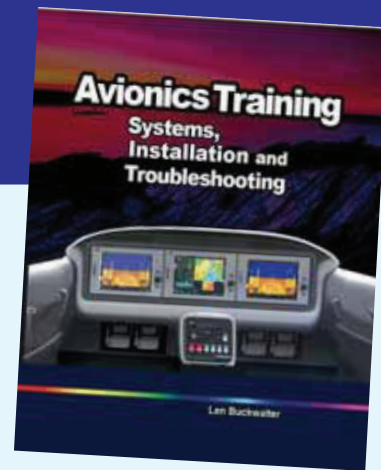
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## 2.1 ASTM D1655

Gas turbine fuels have become a crucial subject matter after the World War II upon the introduction of more powerful engines for aircraft that allow transportation at higher altitudes, with faster speeds and longer range. The first version of the ASTM D1655 specification, released in 1959, defines three grades of civil aviation turbine fuel: Jet A, Jet A-1 and Jet B11. The properties of these fuels have not varied much since then. Jet A and A-1 are kerosene-type fuels with different freezing points. Jet B is a naphta-kerosene cut that is used only in extremely cold weather operations and should be handled extremely cautiously due to the lighter composition, thus lower flash point. The U.S. military equivalence of Jet B is JP-4. Jet B was re-standardized in 1970s as D66153.

D1655 contains multiple parameters which the fuel under evaluation has to be tested for. Students should be aware that each ASTM gas turbine standard has a "Table 1" that lists the key properties. These properties of combustion, volatility, fluidity, safety, durability, and stability require strict regulations for a safe and secure engine operation. Students are educated in this course to develop the foundational knowledge required for further evaluation of these values.

Table 2 of ASTM D1655 includes three sets of additives that aim to deliver the necessary fuel performance: 1. Antioxidants (to prevent fuel system oxidation deposits in aircraft and improve fuel storage stability); 2. Metal deactivators - MDAs (offset active

metal reactivity in fuel systems); 3. Fuel system icing inhibitors – FSII (prevent ice crystal formation as water condenses at low temperatures of high altitudes or polar environments). Further additives that facilitate fuel handling and maintenance can be classified in four groups: 1. Electrical conductivity improver; 2. Leak detection additives; 3. Biocidal additives to prevent microbial contamination; and 4. Corrosion inhibitors/lubricity improvers.

Table 3 of ASTM D1655 regulates incidental materials which may find their way into the jet fuel supplies involuntarily. One example to such materials is the fatty acid methyl esters (FAME), a compound contained in biodiesel. An incident occurred in 2010 which had engine stalling shortly after takeoff, causing an emergency landing. Accident investigators concluded that the fuel meters having clogged with allegedly biodiesel related matter was the probable cause. This event raised red flags on the cross interaction between the biodiesel and gas turbine fuels which may occur via mutual shipping and storage locations at the airports. In an attempt to assure jet fuel stays free off any biodiesel residue, a maximum level of 5ppm FAME in gas turbine fuel was added to ASTM D1655 in 2011. Most recently, this value was shown to be excessively low by multiple studies<sup>12</sup>, urging the Joint Inspection Group (JIG) to revise this limit because the inspection and removal of such low quantities of FAME in jet fuel at the airports demands very high costs and efforts that may after all be not necessary.

**Table 1.** Aviation Turbine Fuel Properties (adapted from ASTM D1655-13a Table 1)

Property	max/min	Jet A or Jet A-1
<b>COMPOSITION</b>		
Acidity, total mg KOH/g	max	0.10
Aromatics	max	25 (D1319), 26.5 (D6379)
Sulfur, mercaptan, mass %	max	0.003
Sulfur, total mass %	max	0.30
<b>VOLATILITY</b>		
Distillation temperature, °C		
10% recovered, temperature	max	205
50% recovered, temperature		Report
90% recovered, temperature		Report
Final boiling point, temperature	max	300
Distillation residue, %	max	1.5
Distillation loss, %	max	1.5
Flash point, °C	min	38
Density at 15°C, kg/m <sup>3</sup>		775 to 840
<b>FLUIDITY</b>		
Freezing point, °C	max	-40 Jet A, -47 Jet A-1
Viscosity at -20°C, mm <sup>2</sup> /s	max	8.0
<b>COMBUSTION</b>		
Net heat of combustion, MJ/kg	min	42.8
One of the following:		
(1) Smoke point, mm	min	25
(2) Smoke point, mm, and	min	18
Naphthalenes, vol %		3.0
<b>CORROSION</b>		
Copper strip, 2 h at 100°C	max	No. 1
<b>THERMAL STABILITY</b>		
(2.5 h at control temperature of 260°C min)		
Filter pressure drop, mm Hg	max	25
Tube deposits less than		3
<b>COMTAMINANTS</b>		
Existent gum, mg/100 mL	max	7
Microseparometer, Rating	min	85
Without electrical conductivity additive With electrical conductivity additive	min	70
<b>ADDITIVES</b>		
Electrical conductivity, pS/m		See D1655 text

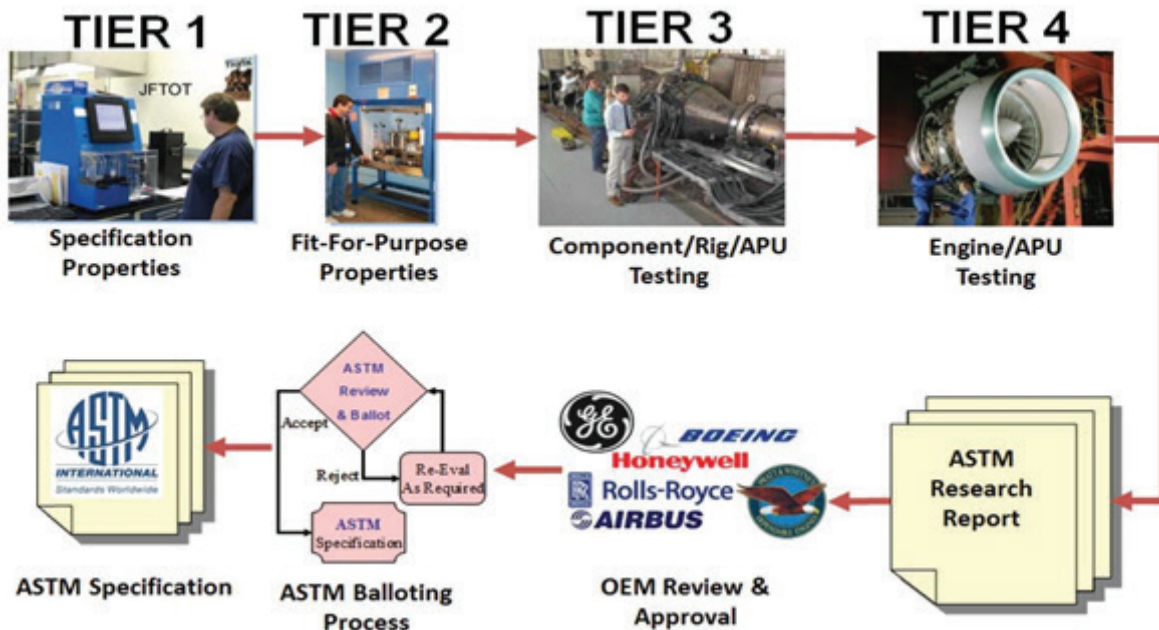
**2.2 ASTM D4054**

Alternative sources for aviation gas turbine fuels have been heavily investigated in the past 30 years owing to advantages over the fossil derived fuels such as reduced emissions, domestic energy security and sustainable feedstock options. The increasing number of technologies and pathways of alternative fuels production has introduced the crucial need to streamline the “fuel approval process”. ASTM committee answered this need by implementing the specification D4054, Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives. Similar to other ASTM standards, D4054 summarizes the investigated Fit-for-Purpose fuel properties. One important distinction ASTM D4054 brings is that for any fuel property, corresponding test information, applicable test method, and additional comments expanding on the information must also be described. D4054 has been introduced as guidance for the newly emerging renewable fuels in aviation industry. Therefore, it is predictable that D4054 Table 1 involves new test requirements and test limits not found in D1655. The fuel qualification process needs to follow the steps that are summarized in Figure 1 (adapted from the International Air Transport Association Report on Alternative Fuels<sup>14</sup>).

For the purposes of this paper, details of the fuel approval process will not be exhaustively investigated. However, one important fact about D4054 protocol worth mentioning is that while Tier 1 and 2 testing require only a few tens of gallons of the candidate fuel, Tier 3 and Tier 4 tests need multiple thousands and hundreds of thousands of gallons respectively. In addition,

due to its highly thorough nature, the ASTM D4054 procedure may take up to 5 years and approximately \$5 million to be completed. Consequently, “fuel qualification” regrettably serves as a deterrent for many startup companies that could otherwise be successfully developing promising renewable alternatives. Targeting to combat these challenges, academia, industry and government are currently seeking pathways to implement fuel approval strategies and tactics that could enable a much wider deployment of alternative aviation fuels<sup>15</sup>.

The issues surrounding alternative aviation gas turbine fuels are very relevant to Aviation Technologists. However, a conventional methodology of teaching the ASTM standards would not be sufficient as these documents contain numerous dense information; hence, certainly require comparative analyses. Students in “Aviation Fuels” class are given the unique opportunity to get this valuable information from professionals who work with these specifications and protocols on a regular basis. Guest lecture modules and industry visits mentor our students on the D4054 procedure very efficiently. Some of the industry partners who participate actively in mentoring Aviation Technology students are from Pratt &Whitney, General Electric, Rolls Royce, and Honeywell, UOP. Industry involvement in design and delivery of the “Aviation Fuels” course provides vivid examples that inspire future aviation professionals. In addition to the fuel manufacturers and Original Engine Manufacturers (OEMs), the lectures provide “just in time” information transfer from the regulatory agencies such as ASTM, Environmental Protection Agency (EPA) and Federal Aviation Administration (FAA).



**Figure 1.** ASTM D4054 Qualification Process (extracted from IATA14, Figure 3)



### 2.3 ASTM D7566

ASTM D7566 standard embodies all turbine fuel specifications of synthesized hydrocarbons as opposed to the conventional fossil turbine fuels. ASTM introduced D7566 in 2009. The current revision was recently released in 2014. Table 1, Table 2, and Table 3 of the ASTM D7566 are very similar to the ones found in standard ASTM D1655 with minor differences. The most significant fact about D7566 is that if a fuel gets approved by the specification D7566, by definition then it becomes a D1655 fuel. In other words, as long as a fuel sample gets certified via the specification D7566, any potential buyer(s) such as airlines will not be able to differentiate between fossil derived and synthesized turbine fuel.

While analyzing the standard D7566, students were mentored to carefully evaluate the definitions as they may be challenging to distinguish. According to D7566, three main gas turbine fuel groups are identified as:

1. Conventional Blending Components: the hydrocarbon mixtures that are petroleum derived.
2. Synthesized Hydrocarbons: the hydrocarbon mixtures that are derived from alternative sources such as coal, natural gas, biomass, and hydrogenated fats and oils by processes such as gasification, Fischer-Tropsch synthesis<sup>16</sup>, and hydroprocessing.
3. Synthetic Blending Component: synthetic hydrocarbons that satisfy the specifications defined by the Annex 1, Annex 2, or Annex 3.

It should be noted here that, according to the categories displayed above, the third group of fuels are a subset of the second group. The term "annex" was given special attention as it was observed to be easily confused with "Appendix" by our students. Annex is an obligatory portion of the ASTM D7566 document whereas an "Appendix" would imply a supplementary addition which is not mandatory. While D7566 is applicable to all the blends of synthetic turbine fuels with conventional ones, the following Annexes are utilized for the properties of the corresponding neat blending component. D7566 currently has these three Annexes.

- A1. Fischer-Tropsch Hydroprocessed Synthesized Paraffinic Kerosene
- A2. Synthesized Paraffinic Kerosene from Hydroprocessed Esters and Fatty Acids
- A3. Synthesized Iso-Paraffins from Hydroprocessed Fermented Sugars (Farnasene)

However, this number is expected to increase as more sources and processes get approved as "drop in" turbine fuels.

### 3. Instruction Methodology - Learning by Doing

Learning outcomes of the "Aviation Fuels" course are as listed below. The students upon completion of the course are expected to:

- Classify fuel properties and characteristics to evaluate the impact on aircraft performance.
- Recognize conventional fuel production processes, and be able to identify and explain the steps required to produce various grades and types of aviation fuels.
- Review the specific processes used to develop alternative fuels, and be able to differentiate the technologies as they apply to specific fuel feedstock.
- Analyze the protocols and procedures to test aviation fuels to the extent necessary to assemble bench scale tests assigned and evaluate data collected.
- Demonstrate an understanding of the aviation exhaust emissions including the basic chemistry involved and the general effects the emissions have on the environment.
- Prepare alternative aviation reports predicting fuel readiness level of the emerging technologies based on comparison to the already approved technologies.

Having the abovementioned objectives in mind, the course was designed to minimize the traditional "teacher-centered instruction" and instead, to encourage an active learning through a "student-centered instruction" methodology. Thus, the faculty served as a "facilitating coach" who aims to increase the students' intrinsic motivation through:

1. Guest lectures from industry.
2. Field trips to fuel manufacturing sites.
3. Laboratory projects involving ASTM defined fuel testing equipment and procedures.

College of Technology students are very keen on learning by doing and have traditionally responded very positively to challenges emulating real life problems. Therefore, the faculty put added emphasis on the laboratory modules. The laboratory modules were distributed within groups of three. Each group was assigned one column of the experimental matrix provided below. The lab assignments were executed at three major laboratories within Purdue University: Materials Laboratory (Aviation Technology), Laboratory of Renewable Resources Engineering (LORRE - School of Agricultural and Biological Engineering) and Discovery Park (interdisciplinary research center). As the field of aviation fuels crosses boundaries within multiple disciplines, the above mentioned collaborative lab locations provided a "close to real life" experience for fuel testing.

**Table 2.** Experimental Matrix for Aviation Fuels

	Jet A	"Fischer-Tropsch (FT) SPK"	HEFA SPK	"50vol%FT in Jet A"	"50vol%HEFA In Jet A"
Net Heat of Combustion (MJ/kg)	X	X	X	X	X
Density at 15°C, kg/m3	X	X	X	X	X
Viscosity at - 20°C, mm2/s	X	X	X	X	X
Freezing point, °C	X	X	X	X	X

**Summary**

Aviation Fuels research is science of practical application. As long as aviation industry continues its growth, there will always be a demand for fuels that provide safer operation and longer ranges at cheaper costs. These issues are very relevant and important to all of our lives. Furthermore, especially for the past twenty years, there has been a constantly increasing trend to deploy alternative aviation fuels as “drop-in” replacements for aircraft. This novel field of sustainable fuel development, aggressively pursued by the industry, government and academia introduces multiple career choices for our students. It is highly likely that future aviation technologists may very well find positions within bio refineries that operate under interdisciplinary rules of technology, science, economy and politics. Close collaboration with industry, government and regulatory agencies greatly benefits faculty and students in understanding the future work force skills set in an accurate fashion. AT faculty at Purdue University, along with valuable input and supervision from industry developed an “Aviation Fuels” course to begin addressing this future need for aviation professionals with “farm to fleet” expertise on sustainable fuels. This paper summarizes the importance of fuel specifications and approval while describing the methodology utilized in instructing the students.

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**Gozdem Kilaz** is an Assistant Professor of Aviation Technology Department at Purdue University. Dr. Kilaz holds B.S., M.S., and Ph.D. degrees in Chemical Engineering. Currently, she serves as the Chief Scientist for the Air Transport Institute for Environmental Sustainability (AirTIES). Her research is focused on aviation biofuels and sustainability. Her courtesy appointment with the Laboratory of Renewable Resources Engineering (LORRE) research center provides collaboration between Colleges of Technology and Engineering. Gozdem is also one of 15 faculty fellows appointed by the Dean of Technology for the Purdue Polytechnic Initiative (PPI) targeting transformative innovation in learning. She teaches a course on Aviation Fuels.

**Ronald F. Brender** holds an M.S. in Aviation and Aerospace Management from the Aviation Technology Department at Purdue University. He also holds a B.S.E. in Engineering Sciences, a M.S. in Applied Mathematics and a Ph.D. in Computer and Communication Sciences, all from the University of Michigan. He holds FAA CFI and CFII Certificates for Airplane Single Engine Land. Dr. Brender was an Adjunct Faculty member in the School of Aviation Sciences at Daniel Webster College and is now a Lecturer in Aviation Technology and a consultant to the Air Transportation Institute for Environmental Sustainability (AirTIES) at Purdue University.

**Dr. Ronald Sterkenburg** was born and raised in The Netherlands. He served in the Royal Netherlands Navy from December 1979 till June 1999. From June 1996 till June 1999 he was stationed at Naval Air Station Jacksonville, Florida, where he served in a US NAVY Personnel Exchange Program. Professor Sterkenburg started teaching at Purdue University in 1999 and has taught courses in the Aeronautical Engineering Technology (AET) program. Professor Sterkenburg is an author or co-author of 10 text books and has published over 60 papers in national and international journals and conference proceedings

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# Evaluation of the Effectiveness of Youth Aviation Camp Activities

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## **Abstract**

Each summer, the Aerospace Department at Middle Tennessee State University (MTSU) conducts a Youth Aviation Camp for middle grade and high school age students potentially interested in the field of aviation. This project is a consortium of three Undergraduate Research Experience and Creative Activity (URECA) endeavors funded through grants from the MTSU Office of Sponsored Programs Undergraduate Research Center. In the summer of 2014, three fully matriculated undergraduates in the MTSU Aerospace Maintenance Management program designed protocols and obtained IRB approvals to determine if there was a significant difference for aviation camp participants and their ability to retain new information when instructional methods varied. The two instructional methods; Active Based Learning (ABL) and Static Based Learning (SBL) were utilized to introduce three topics: Fire Protection and Extinguishing Systems, Internal Combustion Engines, and Non-Destructive Inspection procedures. SBL relies more on the teacher to introduce, explain and demonstrate the items and concepts of a topic while ABL relies more on technology and more specifically, animations, to convey a more complete understanding of the lesson. The topic was investigated because of the influence it may have on young adults choosing Middle Tennessee State University as their higher educational facility and Aerospace Maintenance Management as a curriculum and career field choice.

## **Introduction**

As part of comprehensive Undergraduate Research Experience and Creative Activity (URECA) Grants obtained through the Middle Tennessee State University (MTSU) Office of Sponsored Programs, three Aerospace Maintenance Management fourth year scholars were to help facilitate, organize, run and analyze two separate methods of introducing new material to four groups of pre-higher educational students during the annual summer aerospace youth camp.

Using the Introduction to Aviation Camp participants as subjects, the investigators serving in a dual rolls as researchers and session leaders, were able to create lessons and activities in the lab that quantified how many of the camp students enjoyed the

maintenance portion of the camp and how much they learned from the session. The camp consisted of students from eighth grade to twelfth grade all with a general interest in the aviation field. The main concern when beginning this project was that teaching methods fall on a concrete, already accepted technique for introducing new information. The research group would also need to incorporate skills that already demonstrated evidence of success. Additionally, investigators would use accredited methods to introduce the information, and secondly there would be an opportunity to analyze the students to ensure they were retaining a certain quantity of the course knowledge. According to an article on "Scientific Teaching" (Handelsman, et al, 2004) these already proven methods of instruction referred to as scientific based teaching.

Another significant concern was that the researchers in their role as project leaders make the activities fun and interesting for the students. Investigators filled various functions during this study, class lecturer, lab instructor, test evaluator, and the researchers wanted camp participants to become active in what they were learning and to take short breaks from the numerous lectures conducted at the various other stations and topics during the weeklong camp. Following the article based on active learning in the classroom, investigators were able to incorporate these quick active learning sessions within the maintenance and systems lectures. In turn, the investigators were able to keep the students' attention for longer periods since as author Michael Prince writes: "the pause procedure proves a baseline to study whether short, informal student activities can improve the effectiveness of lectures," (Prince, 2004).

### **Background**

What is the most effective way of getting through to someone on a particular subject?

Does the way a subject is presented make any difference? The research group believed it did and after doing a quantity of topic research had enough background to make an argument for it. Consequently, the researchers decided to evaluate the effectiveness of Aviation Camp activities by changing the way each session leader would teach the IRB approved sessions. The research group chose to do this during the aviation interest camp for middle and high school students that MTSU had been conducting for the past several years.

As the researchers discovered in their literature review, a significant number of students from the Science, Technology, Engineering, and Mathematics (STEM) majors struggle with the material given to them because they find it uninteresting or hard to understand. This could be a major concern in Aerospace, particularly in the applied crafts of piloting and maintenance, where students may be satisfied to achieve the minimum standard in the difficult subjects. This lack of effort to master core aeronautical theories and practical applications of their profession may develop into a serious situation for the future of the aerospace industry, where employees learn just enough to get by, instead of striving to be consummate and safe aviation professionals. The president's national council report warned of the possible consequences: "The United States could renew its commitment to education—and especially STEM education—or it could risk creating a permanent economic gap among American workers at a time of dramatic demographic transition and enhanced global economic competition"(President's Council of Advisors on Science and Technology, 2012).

Another method to engage students further is through an instruction model called active learning. As author Michael Prince describes: "The core elements of active learning are student

activity and engagement in the learning process" (Prince, 2004). Prince goes on to explain that by engaging students in the actual process of learning, teachers are helping students pause and take time to use what they are learning, enhance their understanding of difficult topics and become better problem solvers. Prince includes evidence in his article from other researcher that support an active learning environment. Of example, Prince writes: "Bonwell and Edison [1] summarize the literature on active learning and concludes that it leads to better student attitudes and improvements in the students' thinking and writing. Bonwell and Edison also cite evidence from McKeachie that discussion, one form of active learning, surpasses traditional lectures for retention of material, motivating students for further study and developing thinking skills" (Prince, 2004).

In our contemporary society, individuals are a time deprived people who have become very involved with multitasking. The nation's workforce needs people whom can problem solve and work through problems quickly using the knowledge they already have to the benefit to society. Unfortunately, according to the publication President's Council of Advisors on Science and Technology, the United States has been producing fewer and fewer graduates from STEM (Science, Technology, Engineering and Math) programs over the past decade. When asked, today's modern college student sees these types of courses as dull and categorized exclusively for geniuses. Regrettably, this attitude may discourage otherwise capable students from participating in challenging courses during their higher education endeavors and considering a career in a STEM program after graduation. This lack of consideration or interest has resulted in the United States being no longer seen as a global leader in science, technology, engineering or mathematics. As Holdren noted: "Other nations are now responsible for the majority of US scholars in these advanced fields, but this number too is dwindling due to recent advances in these same nations, thus keeping the careers and scholars in these countries" (Holdren, 2012).

### **Methodology**

The task now at hand is to find ways to relate the material of these courses to concepts and ideas that are easily grasped by not only college students, but also college aspiring students. One major focus has been the study of an active learning approach. A major proponent of active learning, Michael Prince writes: "This approach consists of collaborative learning, cooperative learning, and problem-based learning" (Prince, 2004). In his article, Prince explains that students should be encouraged to "physically engage" in the education progression, in place of the more universally accepted lecture method. As Prince noted: "The techniques are said to be superior to the lecture method, although Active Learning has been found difficult to measure or provide concrete data due to the various approaches and their individual

impact on the students" (Prince, 2004). Thus, the challenge throughout this research project was to find which approach would yield the most retention of information, while keeping the students interested, receptive, and engaged.

For the maintenance part of this camp, investigators had three one-hour sessions to teach three different subjects including a short introduction on the field of aviation maintenance. On an alternating schedule, depending on which group was scheduled to go first on a particular day, each project leader started with the short introduction, illustrating and explaining the role and responsibilities of the Aviation Maintenance Technician, what could be expected going into this field, while impressing the importance of how each concentration in the aviation field is of vital significance whether they be a pilot, engineer, or aviation maintenance technician. Next, the project leaders began teaching their individual subjects, 1 hour each for an introduction of Fire Protection Systems, Reciprocating (or internal combustion) Engines, and Non-Destructive Inspection (NDI) procedures. When each session was completed, investigators requested campers take a short quiz (Appendix A) and an evaluation (Appendix B) for the section. These two data were the primary source of statistics collected for this project.

### ***Session One: Fire Protection Systems***

For Fire Protection Systems, the assigned investigator first taught the attendees the different types of fire protection systems (fire detection and fire extinguishing) and the three items needed to start a fire: oxygen, heat source, and fuel. The investigator also explained how removing any one of these three elements would extinguish the fire. Next, the researcher described the different classes of fire and used this segment of the lesson to conduct the group experiment. Given that, most people have trouble remembering what goes in each category; with the control group the researcher just taught the classes and what was in each one as a part of the lesson. With the experimental group the researcher also did this but then stopped the lesson to have the students look around at several objects laid out on a table; paper, wire, empty gas can, wheel half and label what fire category they thought each item would go in. An initial observation was most of the students in the experimental groups seemed to enjoy this and further developed the match to a challenge between each other to complete the various groupings in the best times. With exercise complete, the researcher explained where the use fire detection systems is important in an aircraft, including the certification requirement that fire detection systems must include an accurate way of testing and provide an audible sound as well as a light in the cockpit or cabin. The researcher then explained the difference between fire detection and fire extinguishing, and two popular types of fire extinguishing systems. Lastly, the campers went to the hanger floor where the researcher demonstrated using an educational board how a High Rate Discharge (HRD) bottle for a

fire extinguishing system works by filling it with talc powder. After explaining system design and operation, the researcher activated the temperature-warning sensor and let the campers extinguish the simulated detected fire with the HRD bottle that expelled the talc powder in a visible cloud. The researcher also showed each group two other different fire detection systems and demonstrated how a squib for the High Rate Discharge (HRD) bottle operated by penetrating the container internal seal. At this point the group went back to the classroom to have a review and questions, take the short quiz and evaluations, and move on to the next subject area.

### ***Data Analysis***

After gathering all the data, grading all the quizzes, and organizing all the evaluations for the Fire Protection session, researchers ran a few tests to see how much of a difference there actually was between the experimental and control groups. In the information gathered from the experimental groups evaluations researchers determined a mean of 4.63 with a standard deviation of .50 on the question of "How much did you enjoy this activity?" in comparison the control group had a mean of 4.39 with a standard deviation of .62. The experimental group had a mean of 4.13 with a standard deviation of .61 on the evaluation question of "How much did you learn from this activity?" in comparison the control group had a mean of 3.94 with a standard deviation of .73. A t-test to determine possible statistical significance was performed on both the "how much did you enjoy this activity?" and "how much did you learn from this activity?" responses. For the "enjoyed" rating scale, a t-statistic of 1.24 was calculated, which was not significant at the .05 level. For the "learned" rating scale, a t-statistic of .783 was calculated, which was also not significant at the .05 level.

### ***Discussion***

The mean of the quiz scores for the experimental group was 70.63 with a standard deviation of 18.79 in comparison with the control group, which the mean was 69.44 with a standard deviation of 15.52. A t-test performed on the quizzes determined if there was a statistically significant difference between the assessment test scores of the two groups. A t-statistic value of 0.1983 was found, which was not significant on the .05 level. Thus, there was no significant difference between the two groups on their test performance. Lastly, Fisher Exact t-tests were performed to determine if any individual questions had a statistically significant difference in performance between the two groups and it was determined there was not. The Fisher Exact test statistic value is 0.100475. Researchers determined the result is not significant at a 0.05 level.

**Session Two: Internal Combustion Engines**

In each presentation for the three different groups, the presentation of material was delivered the same. For this section: Internal Combustion Engines were introduced with general questions by the researcher to the campers centered upon their previous knowledge and experiences with internal combustion engines in daily life, example the family vehicle, lawn mower or boat. Next, the researcher moved to discussing the major parts that make up an internal combustion engine and where they are located in relation to one another, their size, weight, etc. The researcher explained how there are four strokes and five events, what they are called, and in what order, they occur. At this point of the presentation, the ABL groups were shown the animated illustrations while the SBL groups worked with just static pictures. Air induction through cowling design, a spark of ignition delivered by a sparkplug and created by a magneto, and lastly the color, type and grade of aviation fuels were also discussed. Lastly, the researcher explained that without the addition of a propeller attached to the crankshaft flange, power created by the combustion engine cannot be converted to useful thrust.

Once the class presentation were concluded, the group went to the maintenance hangar where they gathered around a four cylinder Lycoming IO-360 reciprocating engine where the researcher identified and discussed the various components introduced in

the earlier classroom portion of the session. In groups of two or three, the researcher escorted each group out to the engine run cell where each camp had an opportunity to start and perform several engine performance checks. Each student was allowed the opportunity to regulate fuel and air mixtures and conduct a magneto check and propeller feathering.

**Data Analysis**

Following the visual introduction of engine components and engine run ups, each group went back into the classroom for evaluations and short quizzes to measure the rate of retention from one group method to the other. Fisher Exact t-tests were performed to determine if any individual questions on the quiz had a statistically significant difference in performance between the two groups, and it was determined that there was not. The hypothesis was that the animated illustrations in the ABL group would have made it so the students retained more information for a longer time, however during the actual camp proceedings it was noticed that the SBL group did receive a more thorough explanation of the inner working of the engine. Perhaps just the assumption that the 'better drawing' would prove to teach better set the researcher up to skip or omit certain redundant steps deemed highly necessary in the SBL groups.

The Static Based Learning group reported a mean of 4.529 with a

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standard deviation of 0.624 on the “how much did you enjoy this activity?” question and 4.471 with a standard deviation of .717 on the “how much did you learn from this activity?” question. For the Animated Based Learning group there was a reported mean of 4.235 with a standard deviation of 0.831 on the “how much did you enjoy this activity?” question and in addition, a mean of 4.059 with a standard deviation of .831 on the “how much did you learn from this activity?” question.

A t-test to determine possible statistical significance was performed on both the “how much did you enjoy the activity?” and “how much did you learn from the activity?” responses. For the “enjoyed” rating scale, a t-statistic of .255 was calculated, which was not significant at the .05 level. For the “learned” rating scale, a t-statistic of .686 was calculated, which was also not significant as the .05 level.

Six of the assessment questions were not statistically significantly different in the student’s ability to correctly answer the item, however one question (Question 6: What component of an aircraft engine produces thrust?) was statistically different. A Fisher Exact test for statistical significance was performed and the SBL group performed better on this item at the 0.000927 level of significance.

### **Discussion**

For the quizzes, the Static Based Learning group scored a mean of 91.59 with a standard deviation of 8.842 while the Animated Based Learning group only scored a mean of 77.76 with a standard deviation of 16.43. A two-sample t-test assuming unequal variances was calculated, with a t-statistic value of 3.125 being determined. Since this is greater than the T critical two-tail value of 2.056, there is a statistically significant difference between the PBL group and the GIF group at the .05 level of significance. Analyzing the data, we see that the group of students whom were given the less advanced/less detailed power point presentation ended up scoring higher on their tests on average. In the beginning, researchers believed that the students who were supplied the more advanced, animated pictures of an internal combustion engine would fare better on a test than in a group who were only explained the function. It can be concluded that the actual teaching of the function of an internal combustion engine was slightly less impressive in the group with the animated pictures. This is because of the idea that the more detailed animations would suffice in the explanation and therefore the lecture was lacking in detail.

### **Session Three: Nondestructive testing**

For this portion of the camp, the researcher focused on nondestructive testing as the topic of the lesson. The purpose was to introduce two different methods that have been proven to work and see how different the outcomes would be. The first two groups were taught in a more traditional lecture setting with just words on power point and use of verbal repetition. The third and

fourth groups were presented the same information and time in both the lab and classroom, with the major difference being visual aids and pictures in the power point.

For the Nondestructive Testing session, the researcher explained to the campers the importance of nondestructive testing in the maintenance field. The research used the same procedure and processes in all four sessions. Guided by researcher, the experimental group read the steps of dye penetrant inspection and saw visual pictures and real-life photographs of the tests performed. The control group received the same information without the photographs or teaching aids in the classroom; the steps were presented. After finishing the power point presentation, the campers then went to the lab, where they were able to perform the liquid penetrate tests on test parts and see the results. During the penetrant’s necessary dwell time, the researcher introduced the campers to other methods of Nondestructive Testing, for example, using a fiber optic bore scope in the inlet of turbine engines to have the campers identify broken or damaged compressor blades. Another activity had the campers identify stress cracks in a crankshaft that underwent magnetization with the use of a black light. Once the dwell time was complete, campers were able to develop the dye penetrant and see the cracks and other faults in the parts. Once all the campers were finished, they went back to the classroom to complete testing and assessments (Appendix A and B) of this camp session and review the material covered. The scores used in this research project, further determine which teaching method the campers benefited from more, as well as which group felt they learned the most information.

### **Data Analysis**

Using the results from the lesson reviews, the visual groups scored a mean of 85.79 with a standard deviation of 1.387 and the lecture groups scored a mean of 76.67 with a standard deviation of 1.589. T-Tests were conducted to conclude that there was no statistical significance between the two assessment scores. The calculated t statistic was 1.757, while the t critical value for a two-tailed test was 2.048.

Overall, there were two questions on the review that had significantly different results between the two groups, question numbers six and nine (Appendix A). Question 6 had a recorded low score of 2/15 correct for the lecture groups and relatively high score of 10/19 correct for the visual groups. Similarly, question nine scored a low 5/15 correct for the lecture groups and high 15/19 correct for the visual groups. Fisher Exact tests were used to determine if there was a significant difference between the groups on any particular item. The Fisher statistic value of .000965 for question six and Fisher statistic value of 0.009998 both had a value of  $p < .05$ , indicating significance. In both cases, the visual groups scored higher than the lecture groups. Question 6 asked, “What is the last step in the dye penetrant process?” and question

nine asked “What is the trade name of the dye penetrant used in the lab?” Each group was exposed to the answers, but the visual groups were able to see the two different dye penetrant kits and there were visual aids to the process that may have helped retain the information.

According to the lesson assessment scores, when asked, “How much did you enjoy this activity?” the visual groups scored an average of 4.44 out of 5. When asked, “How much did you learn from this activity?” the visual groups scored an average of 4.05 out of 5. The lecture groups were asked to answer the same questions scoring a 4.43 (little to no difference when compared to the visual groups) and 4.64 showing that even though the overall test scores were lower, the lecture groups’ results on the assessment show that they felt they learned more.

### **Conclusion**

This camp and research project was a great experience, but after analyzing the data, there does not seem to be a statistically significant difference in the way the various sessions were taught. The researchers concluded that working with small groups’ negativity impacted study results that were for the most part inconsequential. It may be possible that if the researchers were able to draw data from a larger group, there will be a realization of

results that theorized the basis for the study. Aside of indifferent results, throughout the week of camp, researchers ended up facing not only weather that hindered the use of outside lab equipment and running the test cell engines, but also technical difficulties in the classroom. For one of the groups, the Power points were unable to open; this may have created an outlier in the data as well. This group would have been in the lecture category due to no pictures, but without the words on the screen, the information was solely delivered by oral lecture. This may have hindered the retention of the information, causing more time spent explaining in the lab exactly what the campers were doing. Another factor noticed throughout the week was age. The four groups ranged from eighth grade students to twelfth grade students, with each group comprised of similar-graded students. The older groups seemed to ask more questions and show a keener interest in the information presented during the classroom portions, while the younger groups were more social and only became interested in the material once labs started. During the lecture portions, the researchers took into account and made certain that the two visual groups were not also the two eldest groups. By splitting up the visual with one older and one younger group, the researchers believe it helped obtain a “cleaner” set of data, or the least amount of outliers possible.

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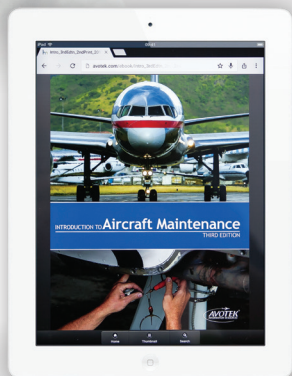
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## Appendix A

### Fire Protection Analysis

Fire Protection Testing

Group # \_\_\_\_\_

1. Which Fire protection system puts out the fire?
2. Which type of fire detection system actually goes off when the flame touches it?
3. What are the 3 conditions needed for fire to exist?
4. What Class of fire involves hydraulic fluids?
5. How will you know if the fire detection system has detected a fire?

Fire Protection  
Assessment

Fire Protection Assessment

Group \_\_\_\_\_

1. How much did you enjoy this section?

5	4	3	2	1
I loved it	It was fun	It was okay	Not my favorite	Didn't like it at all

2. How much did you learn from this activity?

5	4	3	2	1
An extreme amount	A lot	Some	A little	Not much

3. What was your favorite part of the activity?

4. Is there anything you would change amount the activity?

Reciprocating Engines Analyses

Piston Engine Testing  
Group \_\_\_\_\_

1. Engines that burn the fuel mixture within the engine are known as:
  
2. List three other devices that use internal combustion engines:
  
3. List the four (4) sequences plus the additional fifth event of an internal combustion engine:
  
4. What type of fuel do aircraft internal combustion engines use?
  
5. What part similar to both automotive and aircraft engines cause the fuel/air mixture to ignite?
  
6. What is attached to an aircraft internal combustion engine to provide thrust?
  
7. What is the name of the two (2) certificates an airplane mechanic earns from the Federal Aviation Administration?

Reciprocating Engines Assessment

Reciprocating Engine Assessment

Group: \_\_\_\_\_

1. How much did you enjoy this activity?

5	4	3	2	1
Loved it	It was fun	It was okay	Not my favorite	Didn't like it at all

2. How much did you learn from this activity?

5	4	3	2	1
Loved it	It was fun	It was okay	Not my favorite	Didn't like it at all

3. What was your favorite part of the activity?

4. Is there anything you would change about the activity?

Non Destructive Inspection Analysis

Non Destructive Testing

Group \_\_\_\_\_

In the space below, describe the 6 steps involved in a dye penetrate inspection:

STEP

#1: \_\_\_\_\_

STEP

#2: \_\_\_\_\_

STEP

#3: \_\_\_\_\_

STEP

#4: \_\_\_\_\_

STEP

#5: \_\_\_\_\_

STEP

#6: \_\_\_\_\_

7) Shot peening or bead blasting is a fast and efficient way to clean a part prior to a dye penetrant inspection. TRUE or FALSE

8) What physical phenomenon causes the penetrant material to be drawn into a fault?

9) What is the trade name of the dye penetrant inspection process that allows fault detection to take place in white light?

10) What is the trade name of the dye penetrant inspection process that required fault detection to take place using ultraviolet light?



Non-Destructive  
Inspection  
Assessment

Non-Destructive Inspection Assessment

Group \_\_\_\_\_

1. How much did you enjoy this activity?

5	4	3	2	1
I loved it	It was fun	It was okay	Not my favorite	Didn't like it at all

2. How much did you learn from this activity?

5	4	3	2	1
An extreme amount	A lot	Some	A little	Not much

3. What was your favorite part of the activity?

4. Is there anything you would change amount the activity?

**About the authors:**

**Kayla Arthurs** is a May 2015 Aerospace Maintenance Management graduate from Middle Tennessee State University. She served as Vice President of the MTSU Aerospace Maintenance Club and Secretary of the MTSU Chapter of the professional aviation fraternity Alpha Eta Rho. For the past two years, she was student worker in the MTSU Flight School Maintenance Section. Kayla has completed the Maintenance Management Capstone class along with the Oral and Practical portion of the FAA Aircraft and Powerplant Certificates. After graduation, Kayla has accepted a job as an Avionics Technician for Carpenter Avionics in Smyrna, TN.

**Kristelle Blake** is a senior on track to graduate in December, 2015 from the MTSU Aerospace Maintenance Management program. She has served as the secretary and is the current President of the Aerospace Maintenance Club. Kristelle is a student worker in the executive aircraft section, where she assists with maintaining the university's B200 King Air and de Havilland Beaver aircraft. Kristelle will complete the Maintenance Management Capstone class in the fall. She is looking forward to career in the United States Coast Guard as an aviator after graduation.

**Cody Elliott** is an August 2015 graduating senior in the Middle Tennessee State University Aerospace Maintenance Program. He is active in the MTSU Aerospace Maintenance Club and has served as Secretary for the past two years. Cody is employed as a Line Service Technician/Mechanics Assistant at a nationally recognized FBO. Cody has completed the Maintenance Management Capstone class along with the Oral and Practical portion of the FAA Airframe and Powerplant Certificates. Upon graduation, Cody will obtain his Airframe and Power plant certifications along with his Bachelor's degree. He plans to pursue a career in business aviation.

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