DOT/FAA/TC-18/28

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Angle of Attack Equipment in General Aviation Operations

November 2018

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/TC-18/28		

4. Title and Subtitle	5. Report Date
ANGLE OF ATTACK EQUIPMENT IN GENERAL AVIATION OPERATIONS	November 2018
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Brian Dillman, Shawn Pruchnicki, Dennis Wilt, Marshall Pomeroy, Mary Johnson, Justin Abrams, Richard Fanjoy, Lukas Rudari, Mark Ball and Seth Young.	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Purdue University 155 S. Grant Street West Lafayette, IN 47907-2114 Ohio State University 1960 Kenny Road Columbus, OH 43210-1016 Florida Institute of Technology 150 W. University Blvd. Melbourne, FL 32901-6975	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Aviation Administration Office of Accident Investigation and Prevention 800 Independence Ave., SW Washington, DC 20591	Final Report
	14. Sponsoring Agency Code AVP-200

15. Supplementary Notes

The FAA William J. Hughes Technical Center Aviation Research Division COR was Michael Vu.

16. Abstract

Throughout history, although piloting an aircraft has remained essentially the same, the information that the pilot must interpret and the interface through which control must be accomplished have changed dramatically. Examples including autopilots, flight directors, glass cockpits, and Flight Management Systems, to name a few, have necessitated that pilots interface with their aircraft in a way that was not foreseen when flight was first accomplished. Despite all these technology advancements, many of which are designed to help with aircraft control, a loss of control due to stall/spin encounters continues to be a primary cause of fatal accidents in both general and commercial aviation. The use of an angle of attack (AOA) indicator was assessed during this project to determine if the stability of the approach was impacted by varying levels of exposure to an AOA display, and education on the concepts of AOA and the mechanisms by which the display for this study illustrate the AOA during various phases of flight. Four groups participated in the study from three different universities, with three different aircraft flown. One group received education on the use of the AOA display and was granted access to the display during the data-collection phase. One group was only provided education on the use of the AOA but was prohibited from using the display during data collection. One group did not receive education on the use of the AOA display but was allowed access to the display during data collection. Another group neither received education nor was allowed access to the display during data collection.

17. Key Words	18. Distribution Statement
Angle of attack, General aviation, Approach stability	This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	125	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENTS

This work was conducted through the FAA's Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS) partnership with three universities: Purdue, Florida Institute of Technology (FIT), and Ohio State University. There were many individuals, both inside and outside the PEGASAS partnership, who we would like to thank, namely: Oscar Dillman and Bing Yu from Purdue, and Bruno Villela from CAP Aviation Consulting Group LLC for their help with statistical analysis; Brian Stirm (Purdue), Felix Fernandez (FIT), and Roger Tucker (Ohio State University) for their flawless help with equipment installations and maintenance. A special thanks to Rod Kern (FIT) for his patience and assistance with the Orlando FSDO and to Don Judy (FIT) for his patience, cooperation, and scheduling of participants and flight instructors. We would also like to thank the flight instructors from all three schools, without whom this project would simply not be possible.

Finally, thanks to Dave Ratte, Manager of Test Engineering at Avidyne Corporation, for his assistance with data cables and data downloads.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AIM	Aeronautical Information Manual
AOA	Angle of attack
AOPA	Aircraft Owners and Pilots Association
CAA	Critical angle of attack
CFI	Certified Flight Instructor
EvalGRP	Evaluation Group (1-4)
FDR	Flight data recorder
FIT	Florida Institute of Technology
FOQA	Flight Operational Quality Assurance
FPA	Flight path angle
FSF	Flight Safety Foundation
GA	General aviation
GA-JSC	General Aviation Joint Steering Committee
IRB	Institutional Review Board
LED	Light-emitting diode
LOC-WG	Loss of Control Working Group
NOTAM	Notice to airmen
PAPI	Precision approach path indicator
PEGASAS	Partnership to Enhance General Aviation Safety, Accessibility and Sustainability
SAT	Safety Analysis Team
SME	Subject-matter expert
SumFPA	Sum of the flight path angle variation
TDZE	Touchdown zone elevation
VASI	Visual approach slope indicator

Vspeed Definitions

V_{S0}: Stall speed in landing configuration

This is the stalling speed of an aircraft when flaps and gear are extended and the aircraft is configured for landing.

V_{S1} (V_{STALL}): Stall speed in normal configuration

This is the stalling speed of an aircraft when it is configured for cruise flight—flaps and gear are retracted.

V_A: Maneuvering speed

An aircraft flying at or below maneuvering speed will stall before it exceeds its maximum load factor and its structure is damaged. Maneuvering speed is the maximum speed at which abrupt control inputs may be applied without the risk of structural damage.

EXECUTIVE SUMMARY

The ultimate aim of this research project is to determine if the use of an angle of attack (AOA) display can provide a pilot with additional information necessary to increase the stability of an approach. This research project centered around four core aspects as outlined below:

1. Analysis of Best Practices and Development of Educational Materials

This research analyzed current best practices provided by AOA display manufacturers, groups, and individuals that advocate the use of AOA displays. A comprehensive analysis of the devices available for installation, the ease of operation, the information provided, and the mechanism with which this information can be used to understand the flight dynamics of the given aircraft in operation would be a logical next step.

2. Attitude-Awareness Enhancement

With the introduction of AOA displays, it has become possible to incorporate the relationship between the current AOA and the desired phase of flight. As such, the potential for a more precise approach path during the approach and landing phase has been suggested.

3. Stabilized Approach Analysis

Whereas the primary objective of an AOA display is to provide an understanding of the current AOA and its proximity to the critical AOA to prevent unintentional aerodynamic stalls, other benefits and additional insights can potentially be provided to the pilot. The primary objective of this study will be to conduct a comparative analysis of a pilot's ability to conduct a stabilized approach both with and without AOA displays.

4. Cost/Benefit/Risks

The benefits associated with AOA displays (e.g., the necessary cost for acquisition, installation, and training) and the mitigation of associated risks will all need to be clearly identified, addressed, and communicated in a clear and consistent manner to the general aviation (GA) flying community.

Participants were recruited from both the local GA population and the flight schools of the three participating universities. A predominant number of participants were from the flight schools and therefore have experience within a highly structured curriculum and a consistent and stable degree of proficiency. The requirements for the pilots were that they must have their private pilot certificate, 50–200 total flight hours, and did not possess commercial or instructor certificates.

Once selected, participants were randomly placed in one of four groups as follows:

- Group 1 received training and had access to the AOA display.
- Group 2 received training but did not have access to the AOA display.
- Group 3 did not receive training but had access to the AOA display.
- Group 4 did not receive training and did not have access to the AOA display.

Stabilized Approach

Within the GA environment, the targeted outcome of a given approach is determined by the individual pilot and can vary depending on the landing airport, aircraft used, environment, and other factors. For this reason, the approach stability within this project was measured by the variability of the flight path angle at each second for the last 30 seconds of each approach and was added together to arrive at a sum of the flight path angle variation (SumFPA) that was then compared among the various groups.

For instances in which the approach for landing was conducted under traditionally normal circumstances for the participants, the use of the AOA system did not significantly impact the stability of the approach for any of the experimental or control groups.

Differences in the SumFPA were discovered for instances in which the AOA system could replace information that is normally present but was absent for a given approach. These include a lack of a visual guidance system at the landing airport and unfamiliarity with the aircraft being used. It was discovered that there were differences among the groups, and the more AOA information the pilot had received (in both education and AOA access), the more stable the approach.

During instances in which a simulated engine-out approach was conducted, it was anticipated that the AOA system could be used as a tool for approach stability for the participants. However, it was determined that participants for two universities did not have differences in the stability of the approach in a simulated engine-failure situation; one university showed that participants not trained on the use of the AOA system but allowed to utilize the AOA display performed less-stable approaches than the other groups. This result was not anticipated, but the highly structured programs within the collegiate environment and the level of proficiency present in practicing emergency and abnormal situations might be a contributing factor because the participants were experienced in the scenarios that were presented and might have relied on their previous experience to conduct as stable an approach as possible.

In summary, there were three notable instances for which there was a difference in approach stability among the groups:

- Results from one university showed that participants who were allowed access to the AOA display flew more stable approaches when power was allowed to be controlled by the pilot (as opposed to the “simulated engine failure” power-off landing).
    - Two universities did not show any statistical difference in approach stability, whether power was on or off, when comparing approaches with access to an AOA display versus ones that did not have access to an AOA device. However, participants at one university revealed a statistically significant result when power-on approaches with AOA access were compared to those without access to the AOA display.
- Results from one university showed that participants who had both received education and were allowed access to the AOA display flew more stable approaches when a visual-approach system was not available for use.

- When looking at the differences in group performance, Group 1 performed better than the rest of the groups. Group 4 performed better than Groups 2 and 3. A conclusion can be drawn that with both AOA education and access to AOA displays, approaches are more stable. For instances in which either just AOA access or just AOA education are provided and a pilot is attempting an approach without visual guidance, the approaches are more stable when the pilot has not been influenced by an AOA device. This indicates that proper education and proper usage are important to the stability of an approach when conducted to runways without visual guidance information.

- Results from one university showed that participants who did not receive education but were allowed access to the AOA display flew approaches that were less stable than the other participants during approaches in which engine power was placed at idle in the traffic pattern abeam to the touchdown point.

    - Group 3 at one university had the most variation in the SumFPA during power-off approaches. Group 3 did not receive any training on the AOA display indications and had the potential for the display to be a distracter in the completion of the power-off landing, which could explain why their performance was the most unstable.

Because of the nature of conducting research studies in real-world environments where not all of the variables are directly controllable by the researchers, it is possible that there are hidden factors present that cannot be sorted out within the scope of this study. This situation is potentially present because the results were not consistent across all the universities. Factors such as weather and other environmental conditions, pilot capabilities, pilot proficiency (overall and aircraft-specific), pilot currency, mental workload, and airport familiarity will need to be evaluated further to understand the entirety of the potential benefits of an AOA device as a mitigation strategy for loss of control accidents. To determine the impact of these factors, additional data would need to be collected to determine the exact circumstances in which AOA education and displays could have the maximum impact.

There are subject matter experts in the aviation industry who promote the use of AOA as a mitigation strategy for the reduction of loss of control accidents during the landing phase of flight. The qualitative feedback that was received from the participants and the statistical results that were obtained indicate there is merit in the promotion of the use of AOA displays. At this time, there is insufficient information to draw conclusions as to exactly who would benefit most from the usage of AOA devices and the exact circumstances under which this mitigation strategy would be the most effective. Additional research is required to identify those characteristics, and one of the study universities is including AOA exposure for their flight students in their training curriculum for single-engine commercial candidates.

1. INTRODUCTION

The General Aviation Joint Steering Committee (GA-JSC) is a joint FAA and aviation industry group established with the goal of improving safety in general aviation (GA). The GA-JSC's technical arm, the Safety Analysis Team (SAT), identifies safety issues and develops mitigation solutions and strategies for the GA-JSC to implement in GA. In April 2011, the GA-JSC chartered the SAT to conduct a review of fatal GA accidents from 2001 through 2010. The SAT reviewed 2472 fatal GA accidents based on Commercial Aviation Safety Team/International Civil Aviation Organization Common Taxonomy Team categories and identified Loss of Control—In-flight accidents as the most prevalent accident type with 1259 fatal. Industry and government have agreed to propose a data-driven approach to identifying high-priority safety initiatives for GA and jointly agreed to work toward the mitigation of accident causes. The Loss of Control Working Group (LOC-WG) was formed by the FAA and GA industry to review GA accidents related to LOC and to recommend safety enhancements. Some of the safety enhancements recommended by the LOC-WG pertain to the usage of angle of attack (AOA) systems in GA aircraft.

The AOA is the angle formed by the chord[1] of the airfoil and the flight path of an aircraft. As the AOA increases, so does lift up to a point referred to as the critical angle of attack (CAA). Beyond this angle, there is a subsequent loss of lift and the airfoil is now considered to be stalled. As a mitigation strategy, it has been proposed that the use of an AOA indicator in an aircraft will keep the pilot informed of the AOA related to the aircraft performance and margin from the CAA. This would allow the pilot to reduce the risk of an inadvertent stall resulting in a loss of control. It is important to note that although this technology is readily available, AOA systems are not required equipment and are not widely used in the GA community. There has been evaluative work concerning the awareness of AOA and potential stall conditions by groups such as the American Bonanza Society, Aircraft Owners and Pilots Association (AOPA), The Boeing Company, and others when utilizing AOA displays for AOA awareness. Pilots that have adopted AOA displays verbalize the benefit to be gained in understanding the complete picture that is presented when AOA displays are utilized as a crosschecking tool with airspeed indicators and attitude indicators. Aviation practitioners have reported the ease with which pilots can intuitively understand the AOA of the aircraft during a given phase of flight and understand the proximity to the stalling angle during critical situations, such as takeoff and landing. AOA displays also assist in the approach phase by compensating for factors that sole references to airspeed cannot.

Whereas the objective of an AOA display is to provide input to the pilots as a crosscheck mechanism for standard instrumentation like any other flight deck instrument, its proximity to the primary instrument scan and primary field of view, and therefore the ease of interpretation, could play a factor in the utilization of this information. Although there are numerous choices from manufacturers as to the basic design and functionality of AOA indicators, the displays in figure 1 (from Alpha Systems AOA) are representative of the majority seen in the market place. This type of instrumentation is available as an add-on technology with relatively little maintenance intervention. In a letter published by the Small Aircraft Directorate (Appendix A), AOA systems such as the one displayed in figure 1 are considered a minor alteration to the aircraft for installation. Because of the cost of adding equipment using a FAA Form 337 or a Supplemental Type

[1] The chord of an airfoil is an imaginary line drawn between the leading edge of an airfoil to the trailing edge of that same airfoil.

Certificate, this would be an important consideration for aircraft owners considering the purchase of non-required additional flight instrumentation, affecting not only the decision to purchase but also from which manufacturer.

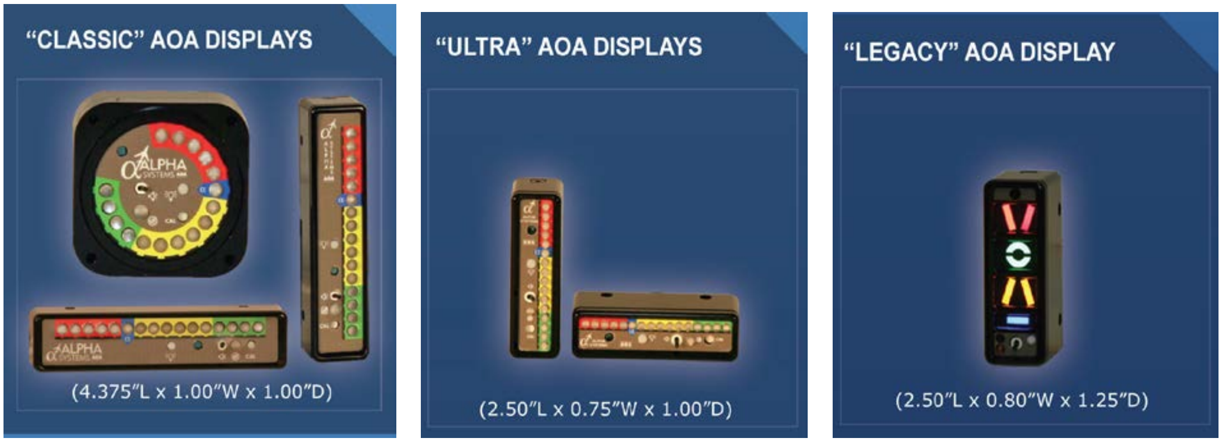


Figure 1. Alpha Systems AOA displays

However, the method of interpretation and analysis, especially as a crosscheck mechanism for instrumentation displays, may vary substantially, depending on the aircraft avionics suite and the AOA display that is installed.

In collaboration with pilot advocacy and industry groups, such as AOPA, the Experimental Aircraft Association, and the General Aviation Manufacturers Association, this research will study the possible benefits and incentives for the installation and usage of AOA systems in the GA environment, specifically focused on their applicability towards a stabilized approach.

2. METHODOLGY AND EXPERIMENTAL DESIGN

Participants were recruited from both the local GA population and the flight schools of the three participating universities. Many participants were from the flight schools and had experience within a highly structured curriculum and a consistent and stable degree of proficiency. Additionally, participants were recruited from the GA population at each university; most of those recruited were flight students taking part in the professional aviation programs at Purdue University, Ohio State University, and The Florida Institute of Technology (FIT). The requirements for the pilots were that they must have their private pilot certificates, have 50–200 total flight hours, and have no commercial certificates or instructor certificates. The reason for the 200-hour maximum was the theory that a student enrolled in the professional pilot program in the university would no longer be representative of the GA population after that amount of training in the program.

Once selected, participants were randomly placed in one of four groups, one of which was a control group. The three experimental groups were designed to analyze any potential comparative differences. The control group served the purpose of a baseline comparison and, as such, did not receive any guidance or have access to AOA displays during visual approaches.

The first of the three experimental groups received guidance on the usage of AOA displays and were encouraged to use the AOA displays while executing the visual approaches.

The second group received specific guidance on the usage of AOA displays but was prohibited from using the displays during the approach conditions. This group will help to establish whether it is the combination of educational materials and the technology that establishes any distinguishable differences between the groups versus the AOA technology alone. The third group did not receive any specific guidance on the usage of AOA displays but was not prohibited from using the displays during the approach conditions.

The design matrix for the stabilized approach comparative analysis was a 2x2 design, as shown in table 1. This design allowed the researchers to determine the degree to which each of the treatments played a role in the accuracy of the approach segment for each condition. In summary, four test conditions were created to which participants were randomly assigned for participation.

- Group 1 received training and had access to the AOA display.
- Group 2 received training but did not have access to the AOA display.
- Group 3 did not receive training but had access to the AOA display.
- Group 4 did not receive training and did not have access to the AOA display.

Table 1. Experimental design matrix

<table>
<tr><td colspan="2"></td><td colspan="2">Education</td></tr>
<tr><td colspan="2"></td><td>None</td><td>AOA Ground Instruction</td></tr>
<tr><td rowspan="2">AOA Displays</td><td>No Access</td><td>30 Participants</td><td>30 Participants</td></tr>
<tr><td>AOA Display Access</td><td>30 Participants</td><td>30 Participants</td></tr>
</table>

When considering the need to generalize the findings of the comparative analysis, the researchers conducted the analysis using a single AOA display in a variety of aircraft types and avionics platforms. The aircraft used were a Cirrus SR-20 with a Garmin G1000® Perspective avionics platform, a Piper Warrior with an Avidyne avionics platform, and a Piper Arrow with an Avidyne avionics platform and retractable landing gear, which added a degree of complexity to the landing approach.

2.1 EXPERIMENTAL OBJECTIVES

The ultimate aim of this research is to provide pilots and instructors with information that could give additional assistance to interpret the flight path and aircraft attitude relationship. This focus will be accomplished by the advancement of the following outcomes:

1. Analysis of Best Practices and Development of Educational Materials

With the wide variety of AOA indicators available, there is a vast amount of subjective opinions that could wrongly influence operators who seek to enhance the pilot's understanding of current flight attitude. This research analyzed current best practices that are provided by AOA display manufacturers, and groups and individuals who advocate the use of AOA displays. A comprehensive analysis of the AOA devices available for installation, including the ease of operation, the information provided, and the mechanism with which this information can be used to understand the flight dynamics of the given aircraft in operation, will be conducted.

2. Attitude Awareness Enhancement

During flight training, pilots are generally required to demonstrate knowledge, recognition, and recovery from stalled situations and knowledge of spin entry, spins, and spin-recovery techniques. Following demonstration of this ability, there is no requirement for pilots to incorporate AOA concepts into what would be considered "normal" flying. With the introduction of AOA displays, it has become possible to incorporate the relationship between the current AOA and the desired phase of flight. As such, the potential for a more precise approach path during the approach and landing phase has been suggested.

3. Stabilized Approach Analysis

Whereas the primary objective of an AOA display is to provide an understanding of the current AOA and its proximity to the critical AOA to prevent unintentional aerodynamic stalls, there are potentially other benefits and additional insights that can be provided to the pilot. For example, the AOA can be used to execute more precise flight during phases such as approach and landing. A primary objective of this study will be to conduct a comparative analysis for pilots to conduct a stabilized approach both with and without AOA displays.

4. Cost/Benefit/Risks

The challenges, both financial and otherwise, for aircraft owners and fleet operators alike are of concern in the decision-making process for continued safety improvements. Upgrading avionics platforms, standalone tablet and hand-held devices, and advanced training all compete for the scarce financial and time resources available. The benefits associated with AOA displays; the necessary cost for acquisition, installation, and training; and the mitigation of associated risks will all need to be clearly identified, addressed, and communicated in a clear and consistent manner to the GA flying community.

2.2 HYPOTHESES

Hypothesis 1—Training related to AOA, the use and operation of an AOA system, and the use of the AOA system in flight will allow GA pilots to conduct a more stable approach to landing.

Hypothesis 2—Training related to AOA and the use and operation of an AOA system will allow GA pilots to conduct a more stable approach to landing, even without the use of an AOA system in flight.

Hypothesis 3—The use of an AOA system in flight will allow GA pilots to conduct a more stable approach to landing, even without training on the use of an AOA system.

2.2.1 Research Questions

Research Question 1: Of the groups evaluated, which pilots had a more stable approach?

Research Question 2: What difference does it make on approach stability whether AOA training occurs?

Research Question 3: What difference does it make on approach stability whether AOA is visible?

Research Question 4: What difference does it make on approach stability between the different aircraft?

Research Question 5: What difference does it make on approach stability during "normal" versus "engine-off" approaches?

Research Question 6: What difference does it make if visual guidance (visual approach slope indicator [VASI] or precision approach path indicator [PAPI]) is available for each of the groups?

2.3 EXPERIMENT APPROACH AND PROCEDURES

Because of practical, legal, and procedural concerns, it was important to have the study participants fly with a trained observer who was also credentialed as a Certified Flight Instructor (CFI). To fill this requirement safety pilots from the flight instructor staff at each university were recruited. They were trained in the objectives of the experiment, how to provide the participant consent forms to the participants, provided the ground training to those participants that were selected for the ground training, and completed the training and evaluation flights.

All participants for the study were recruited from the student and local GA populations in the area of each three universities. Participants were then randomly assigned to one of the four different condition groups. The participants and safety pilots were contacted by the researchers so that they could schedule their study participation.

After scheduling was complete, the safety pilots provided the participant consent forms, pre-flight surveys, and training (if appropriate for the participant).

The training for the participants who obtained ground and flight training was based on viewing a video developed and created by the research team and peer reviewed by Rich Stowell, a Master Flight Instructor. Mr. Stowell is well known in the aviation industry for training in unusual attitude and upset recovery. Changes to the training video suggested by Mr. Stowell were incorporated before the final training video was released for use.

The participants randomized into groups requiring training started their experience by watching the educational video before commencing flight training. This training flight included various maneuvers and the normal stall sequence of approach to landing, takeoff, departure, and accelerated stalls to observe the operation of the AOA display. Additionally, the training flight also included landings and takeoffs at three separate airports—two outlying airports, and the primary airport used by each university for training. The participants performed two takeoffs and landings at each airport. It was decided that the outlying airports should be included to provide participants with some unfamiliar air traffic pattern and landmarks.

Regardless of their assigned groups, there was an evaluation flight for all participants that did or did not allow the use of the AOA display, depending on the condition group for which they were assigned. (See table 1 in section 2.) The evaluation flight was designed to include a takeoff from the primary airport, flight to a satellite airport for two landings and takeoffs, then a flight to a second satellite airport for two landings and takeoffs—where the second landing would be a power-off landing—then back to the primary airport for two landings.

After the evaluation flight, the participants completed a post-flight survey, which can be found in Appendix E.

During the experiment, for both the training and evaluation flights and to ensure both consistency and completed items were accomplished within the instructor group, the safety pilots had checklists to guide them on the specifics of the participants' assigned groups. Additionally, the safety pilot had an evaluation form to fill out for both the training and evaluation flights. The guidance material, checklists, and evaluation forms are included in appendices B and F.

2.3.1 Condition A—Group 1

During condition A, the participants were trained on the use of AOA displays and had access to AOA displays during approach and landing demonstrations.

Condition A provided a participant grouping that allowed both experimental conditions to be applied. In this scenario, designated as Group 1, pilots were given ground training on the use of the AOA display by watching a video prepared by the research team. In addition, participants in Group 1 also received in-flight training on the use of the AOA device from the instructor/safety pilot administering the AOA research encounter. Following completion of the training, participants were evaluated during a second flight in which they had access to the AOA device. This evaluation flight consisted of no instruction, but only observation by the flight instructor/safety pilot during the six approaches to landing. The safety pilot noted basic qualitative data about the flight while the flight data recorder (FDR) saved specific flight parameters for further analysis.

2.3.2 Condition B—Group 2

During condition B, the participants were trained on the use of AOA displays but did not have access to AOA displays during approach and landing demonstrations.

Condition B is one of two conditions that only had partial experimental treatment applied. Similar to condition A, this grouping, also known as Group 2, had a training flight and an evaluation flight. As with Group 1, pilot participants watched the AOA training video and completed the training flight that consisted of instructional use on the AOA device in an identical manner as Group 1. However, during the evaluation flight, the AOA device remained off and the participant had no access to AOA information, whereas the flight instructor/safety pilot served as a safety pilot to record observational information about the flight as the FDR saved specific flight parameters for further analysis. The condition-B design evaluated educational transfer of the AOA training. The research team's primary focus for this group was to determine the effect AOA training had on pilots when they were tasked with going back to flying without access to the AOA display.

2.3.3 Condition C—Group 3

During condition C, the participants were not trained on the use of AOA displays but did have access to AOA displays during approach and landing demonstrations.

Condition C, labeled as Group 3, also applied a partial experimental treatment design. Participants in this group did not receive any AOA training but performed a single evaluation flight with access to the AOA display. Like all four conditions, pilots completed the six approaches to landing while undergoing evaluation from the flight instructor/safety pilot as the FDR saved specific flight parameters for further analysis. The safety pilots were not permitted to give any guidance to the participant on the use of the AOA indicator. Researchers designed this group to simulate a pilot who either rents or flies an aircraft with an AOA device or purchases an AOA device for a personal aircraft but does not receive any specific training regarding operation of the device before using it during flight. From an experimental standpoint, this group helps to establish whether AOA training combined with access to the AOA device produces results that differ from use of the AOA by itself.

2.3.4 Condition D—Group 4

During condition D, the participants were not trained on the use of AOA displays and did not have access to AOA displays during approach and landing demonstrations.

Condition D, labeled as Group 4, served as the control group for the experimental design. During this condition, pilots did not have access to the AOA display nor were participants given instruction or education on the use of the AOA device. Researchers conducted a single evaluation flight consisting of the required six approaches to landing while the AOA device remained off, simulating how the aircraft would normally be flown without any AOA device installed. During the evaluation flight, quantitative flight data from the FDR and qualitative comments were recorded by the safety pilot for comparison against the other experimental groups.

2.3.5 Pilot Participant Requirements

For this project, the research team required that participant pilots hold only a private pilot certificate and have 50–200 hours of total flight experience to be eligible for recruitment into the study. An instrument rating was not considered for the purpose of recruiting participants. The reason for the 200-hour maximum was the theory that a student enrolled in the professional pilot program in the university would no longer be representative of the GA population after that amount of training.

The study design had a fairly narrow window of allowable flight time, which was designed to simulate the typical experience of the private pilot. Because many pilots recruited to the study fly on a regular basis, it was noted that those pilots were close to the maximum allowable flight hours and, as such, were scheduled as soon as possible. However, despite these efforts, participant attrition was expected because some pilots might gain more than 200 hours of flight time or a commercial pilot certificate between the moment of recruitment and the actual first flight as part of the experiment. It was also conceivable that for pilots assigned to an approach group with two flights, one or both of the recruitment parameters may be exceeded between the training flight and the evaluation flight. To keep participant attrition as low as possible, those pilots who had less than 200 hours during recruitment were allowed to continue as participants in the project. Pilots who earned commercial certificates before the first flight were not allowed to participate, but if the commercial certificate was earned between the first and second flight, the pilots were allowed to complete participation in the study. Because of the short duration of the data-collection portion of the study, researchers surmised that, although pilots may have exceeded the recruitment criteria before the first flight or between flights, their overall abilities as pilots would not change in a brief period of time and were judged to be acceptable.

Whereas pilots ranging from low-time new student pilots to Air Transport Pilots with several thousand hours of flight time were available to participate, the researchers determined that the study needed to focus on a select group of GA pilots with similar experience and certification to provide both a better representational cohort and a proper statistical analysis. Additionally, allowing a wider range of participant experience would have forced a high number of approaches to be evaluated, thereby exceeding both the budgetary and time limitations.

2.3.6 Flight Scenario

There are three flights to describe for the experiment—one is a training flight for those participants who obtain ground and flight training; another is for those participants who have access to the AOA display; and another is for those participants who do not have access to the AOA display.

The participants who were provided ground and flight training were given a training flight that provided information about the display and how it responds to varying phases of flight. The safety pilots had the participant take off from the primary airport and perform a slow flight and a stall sequence that includes an approach to landing stall, a takeoff and departure stall, and an accelerated stall. The participant then conducted two landings and takeoffs at the first of two outlier airports. After completion, the participant flew to a second outlier airport and performed two landings and takeoffs. Finally, the participant flew to the primary airport and performed two landings at that location before commencing a full stop, thereby ending the flight portion of the research.

There are two types of evaluation flights, one where the participant had access to the AOA display and one where they did not. Other than the display access, the flight procedures were the same and are described below.

The evaluation flights are very similar to the training flights, but do not include the slow flight and stall sequence because they were only exposed to those maneuvers to better understand AOA functionality. The participant flew to the first outlier airport, performed two landings and takeoffs, then proceeded to the second outlier airport and performed two landings and takeoffs. During the second landing, the safety pilot pulled the power to idle, and the participant performed a landing with engine power at idle. If the landing resulted in a go-around instead of a landing, the participant performed a second landing, after which the participant flew to the primary airport and performed two landings, followed by a full stop. Airport diagrams for airports that were used during the study can be found in Appendix I.

2.3.7 AOA Equipment Configuration and Installation

There are several manufacturers of AOA equipment that could have been used for this experiment. Unfortunately, at the time of equipment purchase, the only manufacturer that had a letter allowing installation without a lengthy Supplemental Type Certificate or other FAA approval paperwork was Alpha Systems. Most manufacturers of off-the-shelf AOA displays now have the letter from the FAA Small Airplane Directorate that allows installation as a minor alteration if the manufacturer's installation instructions are followed. See Appendix A for an example of the approval letter.

Alpha Systems provides an installation and operator's manual for the Alpha Systems AOA system. The version of the Alpha Systems equipment chosen for this experiment was their legacy system and is described below. Although Alpha Systems manufactures and sells various types of display formats, this one was chosen because it almost exclusively represents the type of unit sold to the GA community. (Since the purchase of the equipment used for the experiment, Alpha Systems has redesigned the displays used in their system. The researchers determined that changing the display in the middle of the experiment would insert undue complexity in the research and could affect the results.)

Alpha Systems' AOA Legacy chevron-styled, light-emitting diode (LED) driven AOA system is 2.5 inches long by .860 inch wide by 1.250 inches deep and weighs .300 lb with the electronic cable. Other components considered part of the design include an interface module, tubing, an external probe, and an associated mounting plate. The display can be mounted anywhere in the cockpit and comes with angle brackets when needed for instrument panel mounting. Other optional mounting kits are available for glare shield mounting, vertical dash mounting, or vertical swivel flush mounting for the aircraft that has a sloping glare shield, allowing positioning of the display so that it can be seen in the pilot's peripheral vision. The AOA display is mounted in the top middle of the instrument panel on the Cirrus SR-20 aircraft and on the top of the glare shield to the left on the Piper Arrow and Piper Warrior aircraft.

Figure 2 shows the center two LEDs on the display as green. When the current installation took place, the system was sold using a green LED for the center LEDs and blue for the bottom or cruise indicator. The systems are currently sold reversing the colors on the display. This change was at the request of the FAA to standardize the color schemes for AOA systems.

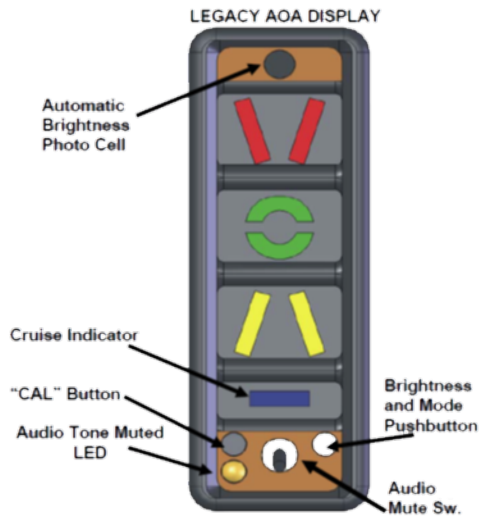


Figure 2. AOA display

Figure 3 shows the installation of the AOA display in the Piper Arrow and Warrior aircraft.

Figure 3. AOA display installed in Piper Arrow and Warrior aircraft

There is an AOA computer or interface module and a probe with the appropriate tubing and wiring for installation in addition to the display. The installation instructions provide a general description for the installation of all components so wiring and tubing will not interfere with any control cables, pushrods, or other wiring and a general positioning of the AOA probe. The probe is normally positioned where it can be mounted solidly to the aircraft in clean air flow (undisturbed air), a minimum of 2 feet outside the prop arc; typically mounted at least 6 inches back from leading edge, and at least 6 inches up from the trailing edge, so at any attitude, slip, or skid, nothing should disrupt the air into the AOA probe. Figure 4 shows an AOA probe installed on the Piper Arrow aircraft. Additional information concerning installation and additional Alpha Systems specifications for the Legacy system can be found in Appendix K.

Figure 4. AOA probe on Piper Arrow aircraft

The installation manual also provides detailed information on power requirements and instructions on installation for power to the system, and instructions on how to install the optional probe heat capability if desired. After installation, the system must be calibrated, and detailed instructions are provided. The specific process for calibration can be found in Appendix C. In summary, the system must go through a three-part calibration in which there is a ground calibration with zero airflow to the probe, a calibration in the air while flying the aircraft at $1.3V_{stall}$, and a calibration at cruise flight. There are also means to set the display brightness and a capability for providing different audio tones and voice warnings to the pilot. The systems in the research aircraft for all three universities are set for maximum brightness and the use of both tone and voice warnings.

With a successful calibration, the system will determine the AOA in any weight or configuration that provides proper information to be provided to the pilot through the AOA display. The calculation of AOA is completed by measuring the differential of air pressure between two ports on the probe. One port is facing forward, similar to the pitot tube for the airspeed system on the aircraft, but this system does not calculate airspeed. The other port is on the bottom of the probe and provides a different air pressure measurement but is not a static port as commonly designed on similar looking airspeed probes. The Alpha Systems electronic AOA system measures pressure at these two points on the AOA probe and transmits those pressures via AOA sense lines to the AOA interface module. The AOA interface module converts those pressures into an electronic signal that is transmitted to the display. The display interprets the signal and turns on the appropriate colored bars to convey the AOA information to the pilot.

A general description of the LED indications and audio warnings is as follows:

- Blue bar: Indicates normal operations calibrated at a weight-adjusted V_A value and lower AOA. Alpha Systems calls that set point CRUISE. The AOA is low, and there is a high margin of lift from stall.

- Yellow segments: Indicate approaching caution; the AOA is starting to transition. If not intentional, take action to reduce the AOA. When the system begins to show the yellow segments and the bottom of the green doughnut, there will be an audio tone and a voice that says "getting slow."

- Complete green doughnut: Is the set point that identifies optimum alpha angle, calibrated at a weight adjusted 1.3 V_{STALL} (see definition). The system can illuminate both arcs, just the top arc, or just the bottom arc to give a display just above or just below the set point.

- Red segments: Indicates the AOA is too high. Take immediate action to reduce the AOA, such as performing a stall-recovery procedure. When the red segments appear, there will be an audio tone and a voice that says "too slow, too slow."

The indication of the green doughnut is the calibrated AOA that provides the pilot with an indication that she/he is flying at 1.3 V_{STALL}. This is the indication that should be showing when on final approach to land the aircraft.

2.3.8 Flight Parameter Data Collection

The system used to capture data during the evaluation flights was provided by an AvConnect Smart Box™. The Smart Box is a standalone data recorder that is mounted into the aircraft on the longitudinal axis and is powered either through the auxiliary electrical panel or through a 12-volt portable power supply.

The FDR unit captures the parameters shown in table 2.

Table 2. Smart Box recorded parameters

LAT—Latitude	HDG—Heading	LON_G—Longitudinal G
LON—Longitude	PITCH—Pitch	MIN_LON_G—Min Longitudinal G
GS—Groundspeed	ROLL—Roll	MAX_LON_G—Max Longitudinal G
TRK—Track	LAT_G—Lateral G	VERT_G—Vertical G
VSI—Calculated VSI	MIN_LAT_G—Min Lateral G	MIN_VERT_G—Min Vertical G
ALT—GPS Altitude	MAX_LAT_G—Max Lateral G	MAX_VERT_G—Max Vertical G

For the purposes of this study, GS, VSI, ALT, PITCH, ROLL, and VERT_G were used to calculate a flight path angle (FPA) for each second of the approach from 615 feet above the touchdown zone elevation (TDZE) of each runway down to 15 feet above the TDZE. The traditional altitude on completing the base leg and initiating the final leg of the traffic pattern (base to final turn) is 400 feet above the ground. By capturing the data starting at 615 feet above the TDZE, it was intended that the base to final turn was also captured.

Further information concerning the calculation of the FPA can be found in Appendix G.

Further information concerning the collection of data used for the statistical analysis can be found in Appendix H.

Further information concerning the use of the Smart Box versus the Garmin or Avidyne data information can be found in Appendix J.

2.3.9 Flight Instructor/Safety Pilot Training

All safety pilots recruited into the project held current CFI certificates and received training on the administration of the AOA experiments. Group or personal meetings with a member of the research team served to introduce the instructors to their roles in the project as safety pilots and to do walkthroughs of the necessary steps to help a participant from each approach group complete the experiment. All project materials—including forms, instructions, checklists, and the video—were provided with any related supplemental information. Instructors also watched the AOA training video and were permitted to use the AOA device when flying equipped aircraft to familiarize themselves with the technology prior to administering the experiment.

Before instructors could participate in the study, they were required to sign a consent agreement similar to the one signed by participants. In addition, instructors were required to sign a confidentiality agreement to ensure the confidentiality of the project participants and the data they would be collecting.

2.3.10 Pre-Experiment Dry Run

During the development of the materials for the experiment, all three universities shared information concerning the consent forms, data-collection forms, participant-recruiting materials, and pre-test and post-test questions to facilitate consistency across the delivery of the experiment.

On completion of the materials development, FIT performed a dry run for the experiment. An experienced flight instructor was used to review and fill out the participant consent form, the pre-flight survey, the training video, the four different participant checklists, the post-flight checklist, the two post-flight surveys, and the training and study flights.

There were few changes needed for the experiment procedures, but there were some minor changes to add airport identifier information and aircraft registration numbers to the checklists.

Avidyne Primary Flight Display and Multi-Function Display data were downloaded and sent to Avidyne for post-download processing. The researcher at FIT determined that a checklist was needed for downloading the Avidyne data. This checklist was developed and has been in use since the dry run.

Smart Box data were downloaded and sent to CAPACG, LLC for verification. There have been several software upgrades to the Smart Box since the beginning of the project that have simplified the download process and improved data download and upload reliability.

2.3.11 Experiment

The participants were assigned to a flight instructor/safety pilot trained on the administration of the AOA experiment, and a mutual time was agreed on to conduct the experiment. Occasionally, the time of the experiment was changed because of a scheduling conflict or an aircraft maintenance issue. However, at all times, both training and experimental flights were conducted under day Visual Flight Rules conditions, and, therefore, the experiment was subject to rescheduling under adverse weather conditions.

If the pilot was assigned to an approach group that was to receive AOA education—Condition A (Group 1), or Condition B (Group 2)—the participant proceeded to watch the AOA training video and complete an AOA training flight. Participants assigned to Condition C (Group 3) or Condition D (Group 4) did not receive any AOA education and proceeded directly to the evaluation portion of the experiment after receiving a briefing from the instructor on the anticipated plan for the flight.

For participants assigned to an approach group with training, a 38-minute video was shown to brief an overview of AOA concepts and AOA technology. It also included several video segments of in-flight demonstrations of the AOA display during stalls and approaches, which was a real-time recording of a principal investigator demonstrating the device's functionality in a university aircraft. Finally, the video briefed the flight portion of the experiment for the participant and outlined what maneuvers and situations the participant would encounter during the experiment. The exact same video was shown to all participating pilots who received training regardless of the university conducting the training, ensuring standardized content of the AOA ground-training portion of the experiment.

After watching the training video, the pilot and instructor proceeded to the aircraft for the in-flight training portion of the experiment. During this flight, the participant had the opportunity to do a sequence of various maneuvers and aerodynamic stalls, and completed six approaches to landing at three different airports (two at each) while using the AOA technology. Specifically, the training consisted of cruise flight, slow flight, power-off stall, power-on stall, and an accelerated stall (either demonstrated by the safety pilot or performed by the participant, depending on school policy). In addition, participants were given the opportunity to do six approaches to landing at three different airports (two at each) for further demonstration of the AOA technology. These were the same airports used for the evaluation portion of the experiment. Data for the purpose of final experiment analysis were not gathered during training flights.

The final portion of the experiment consisted of an evaluation flight for all participants. The evaluation flight consisted of six approaches to landing at three different airports (two at each airport). During the second approach to landing at the second airport, the flight instructor/safety pilot pulled power to idle to have the participant perform a power-off approach. If this approach resulted in a go-around, the participant was then allowed to remain in the pattern to conduct a second landing at this airport. All participants completed an evaluation flight; however, only Condition A (Group 1) and Condition C (Group 3) had access to the AOA display during the evaluation. The other two groups, Condition B (Group 2) and Condition D (Group 4), flew the evaluation flight with the AOA display in the off mode and were not allowed to reference the AOA technology. Instruction or training was never given during an evaluation flight; therefore, the instructor primarily served the purpose of a safety pilot and also recorded pilot behavior for later analysis by the research team. All evaluation flights were monitored by the Smartbox™ FDR that recorded numerous aircraft parameters to be used later for statistical analysis.

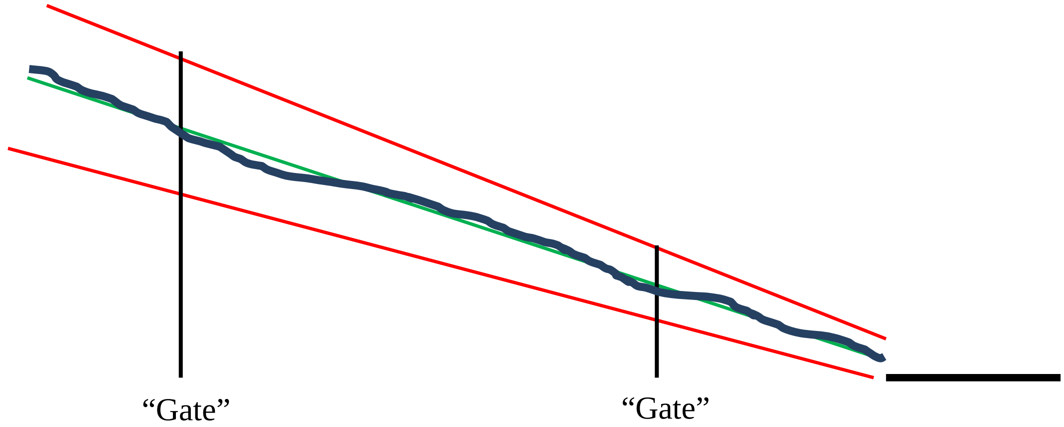
2.3.12 Definition of Stabilized Approach

Worldwide runway overruns continue to be a leading cause of accidents in aircraft of all sizes and types of operation (e.g., air carrier and GA), and post-accident investigations into these events have revealed several commonalities. As such, the aviation industry has focused on these factors in an effort to reduce the incidence or at least the severity of these overrun events. These factors have been analyzed and developed into a list of criteria that pilots can consider or, in some cases, are required to follow (e.g., air carrier flight operations) in determining if their approach is considered stable, and, therefore, they have a very low probability of a runway overrun. Worldwide, both regulators and individual operators alike have promoted or adopted the criteria established by the Flight Safety Foundation (FSF) in whole or in part to reduce these events.

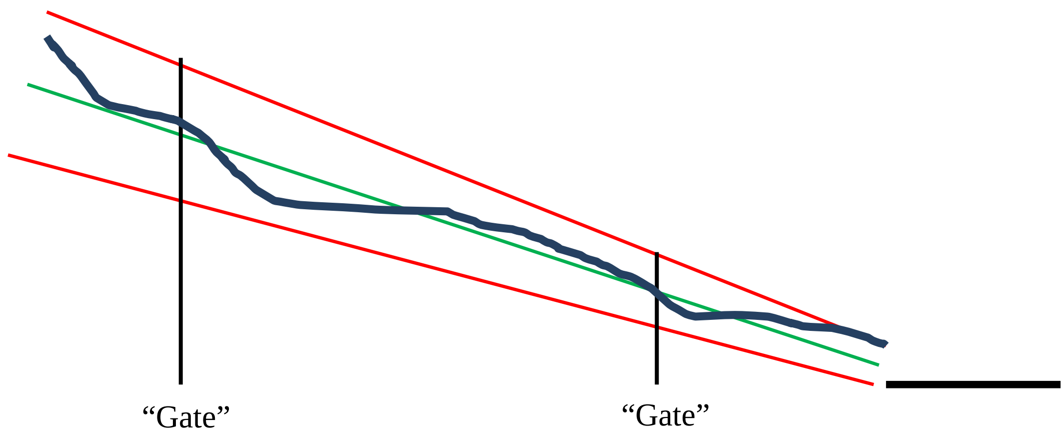
Typically, the accepted criteria for defining stabilized approaches include almost a dozen specific objectives that must be met at either 500 feet visual meteorological conditions or 1000 feet instrument meteorological conditions above runway elevation before an approach can be considered stable and, therefore, continued. However, some of these required goals are dependent on the type of equipment available and the type of operation being flown.

While designing this study and considering the definition of a stabilized approach, the criteria for stabilized approaches were influenced by the less complex aircraft types being used, as compared to transport category aircraft, and the type of data that were captured . In this consideration, both cost and timeline were factored. Because of these inherit limitations, the definition of a stabilized approach is less restrictive as the original FSF criteria. Furthermore, it is important to understand that the primary research goals did not include determining which flights were considered stable and which were not, but instead to examine across the four experimental groups and capture which appeared to be more stable than others. Therefore, when analyzing the quantitative aspect of the data, parameters such as speed, descent rate, roll, pitch, and FPA were all considered. The values collected aided in this determination.

For the purposes of this experiment, the definition of a stabilized approach is: a consistent glide path with no more than 1000 fpm descent and with a stabilized speed and controlled bank with coordinated turns and a rectangular-shaped pattern. In an effort to capture as accurate of a measure of the stability of the approach as possible, the team decided to use a different measure of stability than has traditionally been used in Flight Operational Quality Assurance (FOQA) programs. In a traditional FOQA program, the system is set up with thresholds of measurements based on one or more measures. It could be a measurement of airspeed, vertical speed, roll rate, pitch rate, g-forces, or a combination of individual measures and the FPA. It is common for a FOQA program to establish "gates" along a flight path where flight parameters and aircraft configuration have to be within predetermined thresholds or a missed approach/go-around is warranted. If the aircraft goes beyond the boundaries of the FPA or exceeds the limits at an individual gate, then an exceedance is recorded. These exceedances are traditionally recorded on the aggregate, and the organization follows up with a mitigation strategy to reduce the number of exceedances and continues to monitor the trends within the system. Looking at figure 5, the framework of this system can be seen in a representation for approaches to an example runway. Looking at the blue line that represents the flight path, it can be seen that figure 5a stays relatively close to the center line, and figure 5b varies along the flight path but never exceeds the outer boundaries. If the aircraft had met the criteria at the given "gates," then the FOQA system might not have recorded either approach as an exceedance, even though the aircraft in figure 5a was more stable. For the purposes of this study, it is important to measure the stability of the approach and not just a measure established within boundaries, as in a traditional FOQA program.



(a)



(b)

Figure 5. FPA analysis

To accomplish this task, the FPA was measured at 1-second intervals along the approach, the absolute value of the difference between a given second and its subsequent second value was calculated, and the sum of the variations in the FPAs for the last 30 seconds was calculated. An approach that maintained a perfectly consistent FPA would have no difference in the FPAs at each second interval, and then the sum of the variations in the FPAs for the last 30 seconds would equal zero. An approach that had a lot of variation would end up with a larger sum of the variation in the FPAs for the last 30 seconds. It is this measure that was then compared among the groups.

The decision to capture the last 30 seconds of the approach was based on the length of time it took for participants to complete the approach at each airport. Thirty seconds was the maximum length of time able to be captured to retain the maximum number of approaches to be considered for analysis. If a timeframe that was longer than 30 seconds was selected, then data would have to be eliminated from the analysis.

3. EXPERIMENT PROCEDURE

All participants in each group completed an informed consent form, pre-experiment survey, evaluation flight, and post-experiment survey. Additionally, half of the participants also received education on the use of AOA technology. To ensure proper flow for the approach groups, each university developed a specific checklist to ensure conformity with the experimental procedure within each approach grouping.

All participants were given informed consent prior to beginning any segment of the experiment and were required to sign a Research Participant Consent Form. After agreeing to the informed consent, all participants were also asked to complete a pre-experiment questionnaire to determine pilot experience and AOA knowledge and principles. Following completion of the first two tasks, participants continued on one of the two paths through the experiment. Half of the pilots received AOA education (video and flight training) and an additional evaluation flight; the other half of the participants only completed an evaluation flight. Prior to any flying, participants were given a chance to review aircraft procedures and limitations, and the instructor and pilot worked together to obtain proper pre-flight briefings for weather and Notices to Airmen (NOTAMs) for the airports and airspace that was expected. Outside the AOA training portion for two of the experimental groups, instructors were allowed to provide only specific aircraft instruction for those not familiar with the specific aircraft being used. For example, University B used a Piper Arrow, and several of the participants had never flown a complex aircraft. Those participants were allowed some flight instruction for proper approach speeds and power settings.

Completion of a post-flight questionnaire was the final portion of the experiment. This survey differed based on the participants' approach group assignments, and, therefore, there are two versions of the post-flight questionnaire: one for pilots with access to AOA technology during evaluation and another for pilots who did not have access to the AOA during the evaluation flight. After completion of the final survey, pilots were able to ask any final questions they had about the research encounter and fill out any required forms to be compensated for their time as a participant in the experiment.

3.1 RESEARCH PARTICIPANT CONSENT FORM

The consent form required for human-in-the-loop experiments is a necessary part of the system to ensure that all participants are aware of their rights while participating in any type of experimental research. The consent used in the study varied slightly as each university involved in this study submitted university-specific consent forms to its respective Institutional Review Board (IRB) for approval.

The consent form explains the purpose of the study; the activity the participant will be conducting during the study; the possible length of the participant's activity; any possible risks or discomforts; possible benefits, payments, and incentives; and potential costs to the participant. The consent form also provides the participants with assurance of confidentiality and of how their confidentiality will be assured. The form also provides participants with contact information allowing them the ability to contact the principal investigator, researchers, and the information of the IRB chairperson if they have any questions regarding the study or their confidentiality and rights. The form must be signed by the participant and one of the study researchers before any experimental activities can take place. There are copies of each university's consent forms in Appendix D.

3.2 PRE-EXPERIMENT QUESTIONNAIRE

The pre-experiment survey had several purposes: to verify pilot demographic and experience information, to determine the participant's pre-experiment knowledge of AOA technology, and to establish the pilot's knowledge of AOA principles. This information served as a benchmark to compare the post-experiment surveys and to assist in determining how AOA training or usage changed a participant's understanding of AOA technology and AOA principles.

Many participants had not been exposed to the AOA technology, but it was important for the research team to conduct a pre-experiment questionnaire to establish if any participants previously encountered AOA technology in literature or any aircraft they had flown. The survey also established the understanding each pilot had of AOA principles and, in particular, the relationship of AOA to aerodynamic stalls and approach to landing. The requirement for participation, as outlined in section 2.3.5, focused only on total flight time and pilot certification level. Prior exposure to AOA technology did not preclude pilots from participating in the experiment. Prior exposure to AOA technology was assessed during the pre-experiment questionnaire.

3.3 PRE-EXPERIMENT BRIEFING

Following completion of the pre-experiment questionnaire, participants were briefed on the expected maneuvers for the upcoming flight. This was done one of two ways. For participants watching the AOA training video, a brief of the flight was included as part of the video. Approach groups not watching the video were briefed regarding what to expect during the evaluation flight. For pilots not familiar with the aircraft, the instructor serving as the safety pilot was permitted to give basic information about aircraft procedures, speeds, and operating limitations.

Providing a streamlined process to each participant was important to ensure that pilots were given the proper experimental treatment for their assigned approach group. As such, the research team at each university created internal checklists to be used to standardize the flow of each participant through the experiment for each approach group. The checklists were used to remind instructors administering the research of each step involved in completing an AOA study flight. Beginning with verifying the approach group, type of flight (education or evaluation), and participant information, the checklist served as a guide throughout the preflight process. Items on the checklist included the following: whether to watch the training video, brief the flight with the participant, complete required preflight tasks, such as a weather briefing, and a check of the NOTAMs at airports to be used for the flight. The checklist also reminded instructors to ensure the battery pack that powered the Smartbox FDR was powered on and to determine whether to turn on the AOA display for the flight.

3.4 POST-EXPERIMENT QUESTIONNAIRES

On completion of the evaluation flight, all participants were asked to complete a post-experiment questionnaire based on their approach group assignment. The post-flight survey for those with AOA access sought to determine if AOA education had any effect on the stability of the approaches during landing. The survey also asked questions regarding the participant's experience with the

AOA technology by requiring pilots to respond with their opinions about how they used the technology, and what benefits or issues a participant encountered while using the AOA device. Group 1 and Group 3 had access to AOA technology during evaluation; however, only pilots in Group 1 received the AOA education. Therefore, this survey was designed as an important step in determining whether the AOA education was beneficial to the participant's understanding and use of the AOA device.

For participants without AOA access during evaluation, a different survey asked pilots about their knowledge of AOA technology. It also sought information about their current methods for ensuring a stabilized approach and provided space for any other feedback about experiences as a participant in the study. This survey for participants without AOA access was given to Groups 2 and 4. Group 2 received AOA education, and Group 4 was the control approach group. Therefore, this questionnaire focused on the effectiveness of the AOA education and recognizing if any education transfer from the AOA training assisted the participant in completing the evaluation approaches.

4. EXPERIMENTAL RESULTS

There were 84 participants that completed evaluation flights in which data were captured and collected for analysis. To center the discussion on the effect of the AOA, the labels "University A, B, and C" are used at various points in the discussion that follows. University A had 33 participants complete the evaluation flights in which data were captured and collected for analysis. University B had 14 participants complete the evaluation flights in which data were captured and collected for analysis. University C had 38 participants complete the evaluation flights in which data were captured and collected for analysis.

The approaches analyzed for all universities combined are shown in table 3.

Table 3. Composition of approaches analyzed for all groups

Group 1	133
Group 2	124
Group 3	124
Group 4	126
Total	507

4.1 PILOT CHARACTERISTICS

Participants were predominantly young adult male private pilots. The responses were 90% from males, 87% from 18–22 year olds, and 93% from private pilots.

Total flight hour experience level varied among the breakdown groups of <50, 50–99, 100–149, 150–199, 200–249, and >250 hours (see figure 6).

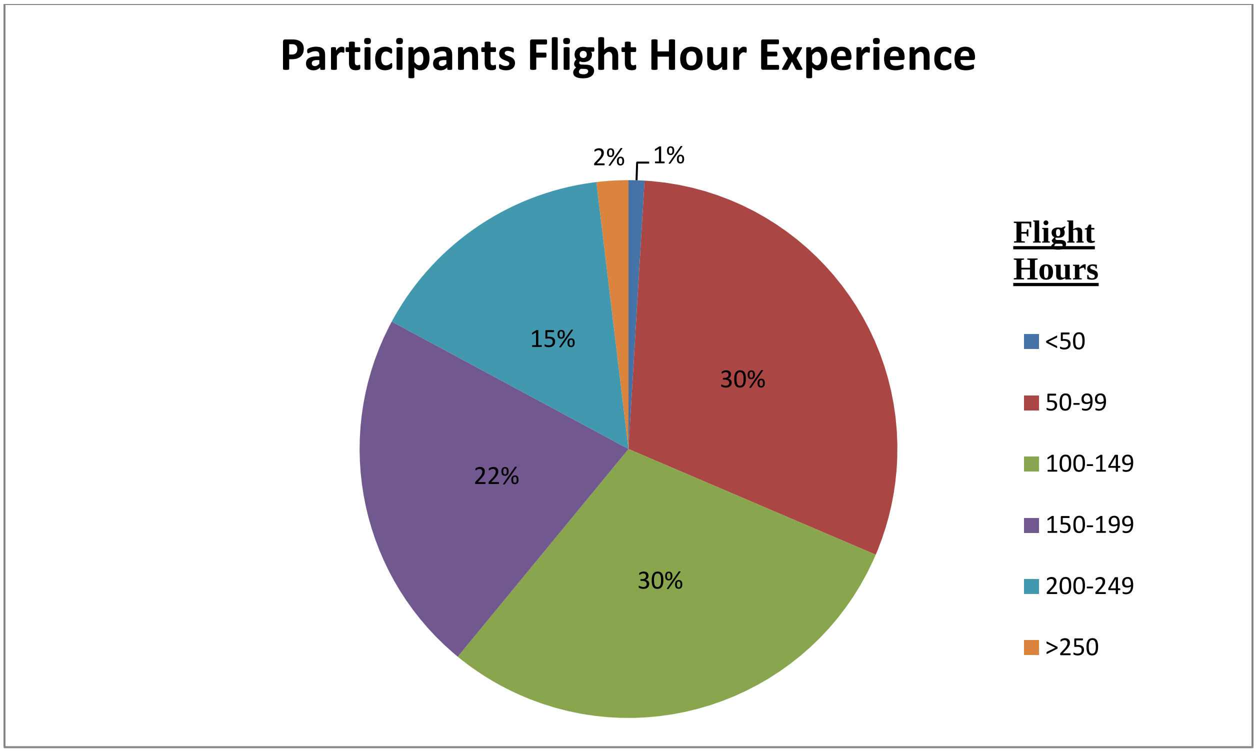


Figure 6. Participant flight-hour experience

4.2 OBSERVERS' ASSESSMENT OF PILOT

The safety pilots are collecting information for the purposes of the study regarding the following areas:

- the manner in which the participant used the device
- the performance of the student on the simulated engine failure (power-off) landing
- the frequency of usage of the device

The collected data were used in the statistical analysis of the approach stability found in section 4.7.

4.3 PILOT'S SELF-ASSESSMENT

4.3.1 Pre-Test

When participants described what causes a wing to stall, nearly all responses were similar to the example "exceeding the critical angle of attack." They all included such keywords as critical angle of attack, wing, enough, and lift.

When the pilots were asked to describe an accelerated stall, however, the answers varied considerably. Some respondents were able to provide a detailed description of an accelerated stall whereas other replies were more vague, such as describing the stall as "caused by increased load factor" or "rapid back pressure causing the aircraft to lose vertical lift."

There was a consensus when describing AOA, such as, “the angle between the chord line and relative wind.” Most participants responded using keywords like angle, wing, relative wind, and chord line.

Only one participant had used an AOA device before. Most participants did not know how an AOA device works. Some of the responses included “I'm assuming it measures/approximates the AOA and informs you whether you are flying at a high AOA,” and “possibly indicates when a wing is approaching its critical AOA on a display so that a stall can be avoided. With regards to how it works, maybe it takes into account G forces and airspeed.”

4.3.2 Post-Test

Question: “Do you find that the angle of attack device helped with your approach to landing?”

This question was asked of those participants that had access to the AOA display during the approaches and the result is shown in figure 7. The majority of the positive responses were from those participants who had access to the AOA display and received training on its usage. For those participants who answered “Yes,” the display was most helpful on the final phase of the approach.

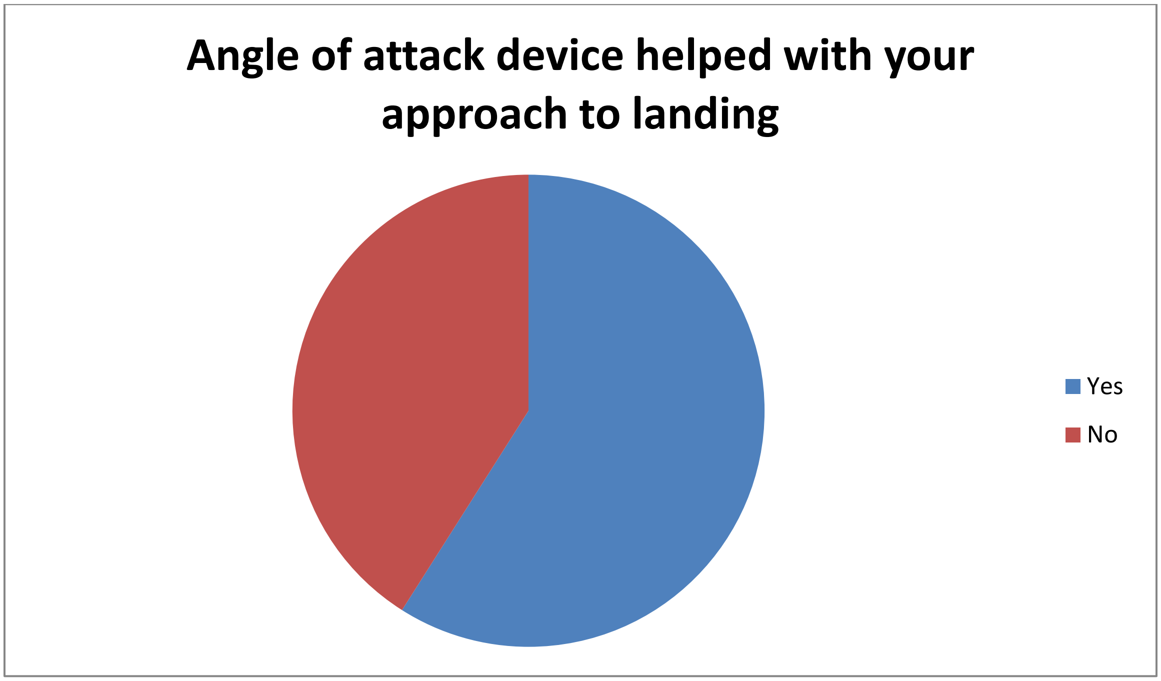


Figure 7. Post-test question

There were many different kinds of responses to the question about how the device assisted the participant’s approach. Many included keywords like airspeed, better, red, green, centered, and angle. For example, “I used the green section as a sort of guide on setting up for the approach to get a good airspeed and rate of decent; also I tried to avoid red whenever possible,” and “Pretty much as an extra reference of landing angle.”

When asked "Do you believe that angle of attack devices would be useful in the cockpit of all aircraft?" all participants but six said "yes." The ones who said "no" either were not familiar with the device or thought it would be ineffective and too distracting. The participants who said yes were very pleased with its usage. For example, "Yes because especially in beginner pilots, awareness about the critical angle of attack can help teach students where a stall is most likely to occur and help avoid dangerous situations," and "Yes because of its ease to operate and learn. A leading factor in a lot of crashes is exceeding the critical angle of attack so it only makes sense to have a device that shows what your angle of attack is."

Answers to the question, "What could be better about the device?" varied significantly. The common responses were:

- If I knew what the lights meant.
- A mute function.
- Less auditory warnings.
- Brightness of device.
- "Too slow" voice is irritating.
- Having it integrated into glass cockpit.
- Having to reset circuit breaker because it was a bit buggy.
- Randomly turned off all the time.
- "The voice that kept reminding me that I was losing airspeed became slightly annoying when setting up for an approach or in situations where I intended to lose airspeed."
- Potentially distracting to a new pilot.

Answers to the question, "Do you find the angle of attack device to be distracting?" also varied significantly. Common responses were:

- The voice saying slow when in fairly normal flight around the pattern.
- During cruise it would occasionally flash.
- When it kept telling me too slow on final.
- When the device was telling me to do something that I did not think was right, it distracted me while I was trying to focus on my landing.
- At night, lights could prove a little distracting.

The answers to the question, "Could the device be better positioned in the cockpit?" revealed that only four participants indicated that it could be part of the avionics display or PFD.

4.4 EFFECTS OF AOA DISPLAY ON PILOT PROCEDURES

The addition of an AOA indicator in the GA cockpit altered the procedures used by the participants to successfully land the aircraft. Depending on the recency of experience and level of education provided on the subjects of stalls and the Alpha Systems product, participants varied in their use of information from the display.

4.4.1 Pilot Use of AOA Display

Participants involved in the study with University B flew in the Piper Arrow, a complex aircraft with which many participants were unfamiliar. Being the first flight behind the controls of this type of aircraft for most of them, the indicator played an advisory role for some and no role at all for others. Participants who flew less than the average participant seemed more concerned with keeping up with the pace of the complex aircraft than focusing on flying a very stable approach, leading to minimal use of the indicator. The use of the indicator decreased even further when the participant received neither education nor maneuvers training. Conversely, participants who flew more often or received education used the indicator more, but not to a level at which they relied on it for a majority of pitch and airspeed change cues. Those who had seen the indicator display its lights in the educational video and in flight during maneuvers became more familiar with the pattern of lights and audio cues, but again did not rely on the indicator for a majority of their information.

4.4.2 Pilot Flight-Control Actions, Based on AOA

For University A participants, six individuals encountered a situation in which the AOA device prevented a stall situation.

For University B participants, even for those who learned before stepping in the airplane that the green doughnut should be displayed on a stabilized approach, the use of the indicator for clues on adjusting pitch and power was not as great as the use of the information gathered from the instruments and outside references. At most, participants would use the indicator to back up or confirm the information presented to them on the PFD.

For University C participants, four individuals encountered a situation in which the AOA device prevented a stall situation.

4.5 RESULTS FROM ANALYSIS OF BEST PRACTICES AND DEVELOPMENT OF EDUCATIONAL MATERIALS

An initial task mandated by this project was to conduct a review of material available to determine the quantity and quality of existing best practices and education material related to AOA, with the goal of developing a comprehensive recommendation on the development of future literature and training materials. The review sought out many sources of information about AOA technology, including industry periodicals, journal proceedings, and Internet or blog posts. The research team also reached out to aviation interest or advocacy groups and the manufacturers of AOA devices. Ultimately, the reviewers concluded that basic literature is available, but the depth of information currently available to users of AOA technology is limited.

Many of the sources reviewed consisted of anecdotal evidence of the benefits of AOA devices and called for further investigation into the benefits of promoting the use of AOA technology, similar to this project’s design. Unfortunately, excluding the AOA manufacturer’s specific device user manuals, the research team was unable to find any overall guidance on the use of AOA devices. The predominant feature of the literature was a basic overview by a subject-matter expert (SME), usually found in a trade publication that was not subject to peer review. Although a majority of the literature was SME opinion, the research team did find common themes throughout many of the publications.

An overwhelming amount of the literature promoted the use of AOA in GA operations and found a necessary interest in investigation of the technology. Many of the authors had personally used the AOA display in their personal flying and recounted the experience for the reader as a version of some best practices. The best practices included exact display indications for particular flight segments (especially approach to landing) and a how-to on performing consistent stabilized approaches, both of which are goals of this study. However, all of these best practices were of a personal opinion by the SME and not subject to a broad review by users of AOA technology.

4.6 ATTITUDE AWARENESS ENHANCEMENT

The goal of the AOA display was to aid the participant's understanding of the aircraft's AOA at any given time in the flight. Given the numerous lighting configurations of the Legacy display, a pilot can ascertain whether the aircraft has an AOA representative of a departure, cruise, or approach phase of flight (i.e., how close the wings are to a stall condition). As part of the system's design and the alerting functionality, the Legacy system provides the aural alert of "Getting Slow" at a predetermined proximity to the calibration point established during initial display setup.

A majority of participants indicated that the AOA indicator provided them with a better understanding of the aircraft's AOA, and they would use the display to their advantage as a secondary instrument during the approach phase of flight. In response to questions on the post-flight survey, participants indicated several ways that the equipment could be improved to better achieve the overall goal and provide pilots with even better attitude awareness. Responses also suggested that those participants with access to AOA education before the data-collection flight felt as though the device was much more useful because they were able to use it throughout the entire data-collection flight, as opposed to those who had no training and needed to determine on their own what information the lighting configurations meant.

The completion of this study not only provides great insight into the usefulness of AOA indicators in GA cockpits and the value of education on said systems but also intelligent feedback on the equipment by real-world users. The suggestions provided by the participants should be taken into account when designing future AOA equipment or enhancing current models.

4.7 STABILIZED APPROACH ANALYSIS

There are many ways that the data can be analyzed for the purposes of this study. Each method carries with it a degree of statistical strength based on the available data. Efforts have been focused on having an equal representation of data for each university within the study and for each group within the university. This effort is dedicated to maintaining a dataset that will allow for the analysis of the degree of effect for each condition within the experiment. Measuring the effect size of an AOA on the stability of an approach using statistical methods is enhanced when there is equal representation from each group being analyzed. This type of analysis is not desirable with the current dataset because there is an unequal representation in each of the groups. To analyze the data, a mixed procedure ANOVA was conducted with SAS statistical software using a Kenward-Roger method for fixed effects and degrees of freedom calculations.

To analyze the data and determine what affects the stability of an approach and how each of the participant groups performed when compared against each other, a best-fit model was developed to determine an estimate for the stability of the FPA. Within the dataset are 24 factors and 1 resultant that were used to develop this model. Sum of the Flight Path Angle Variation (SumFPA) is the resultant of the model and the other items are factors combined to estimate the resultant. The point at which each factor is added is based on operational experiences of the researchers as to which factors are likely to affect the SumFPA from greatest to least. The Evaluation Group (EvalGRP) will be added at the beginning, then the factor likely to have the greatest effect on the SumFPA will be added next. Each factor was added from greatest to least in sequential order. The table in Appendix L captures these factors and the resultant.

Before analysis was started, it was necessary to check the data assumptions for normalized data. The plots of the residuals of the SumFPA (see figure 8) show that the assumptions have been checked.

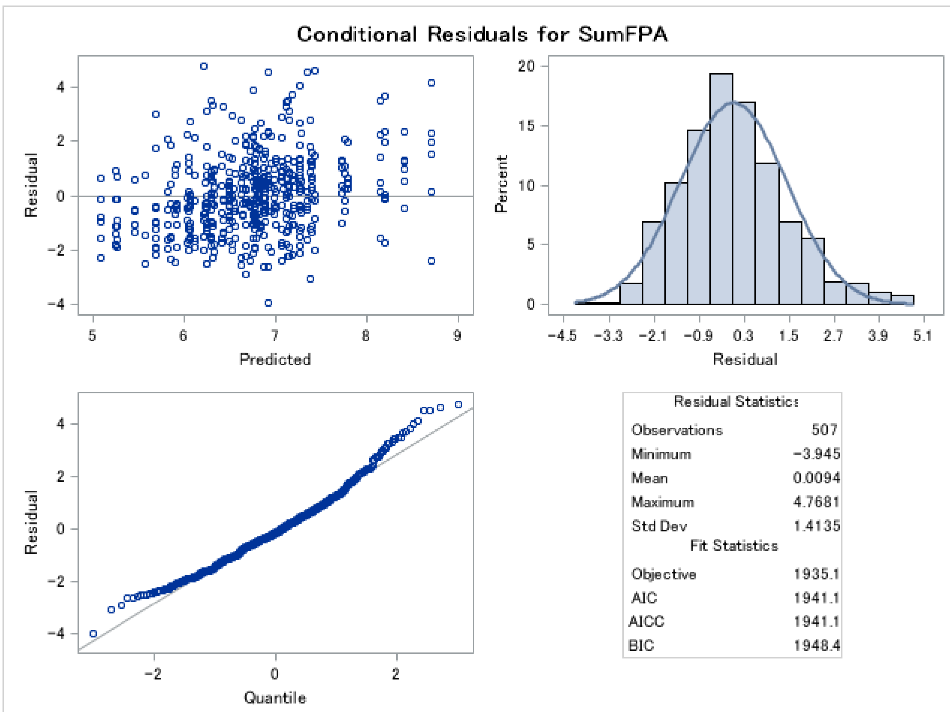


Figure 8. Plot of the residuals for all universities

Before the analysis of the entire dataset began, a check for an effect for the university factor needed to be conducted to determine if the data could be analyzed as an entire set or if the analysis would need to be conducted individually for each university. Table 4 shows the result of this analysis.

Table 4. Tests of fixed effects

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	80.5	0.39	0.7637
University	2	81.1	13.38	<.0001

With a *p*-value of <.0001, this shows that there is an effect on the SumFPA depending on at which university the participant completed the study. This will require that the analysis be conducted individually among the universities so that an effect of one of the factors does not get bunched together in the university factor. To center the discussion on the effect of the AOA, the labels "University A, B, and C" will be used throughout the remainder of the analysis.

The approaches analyzed for individual universities are shown in table 5:

Table 5. Breakdown of approaches analyzed for three universities

University A		University B		University C	
Group 1	62	Group 1	12	Group 1	59
Group 2	40	Group 2	24	Group 2	60
Group 3	54	Group 3	15	Group 3	55
Group 4	51	Group 4	29	Group 4	46
Total	207	Total	80	Total	220

Because the data are being separated out, the assumptions need to be verified again for normalized data.

Figures 9–11 show the assumptions check for all datasets for each of the three universities.

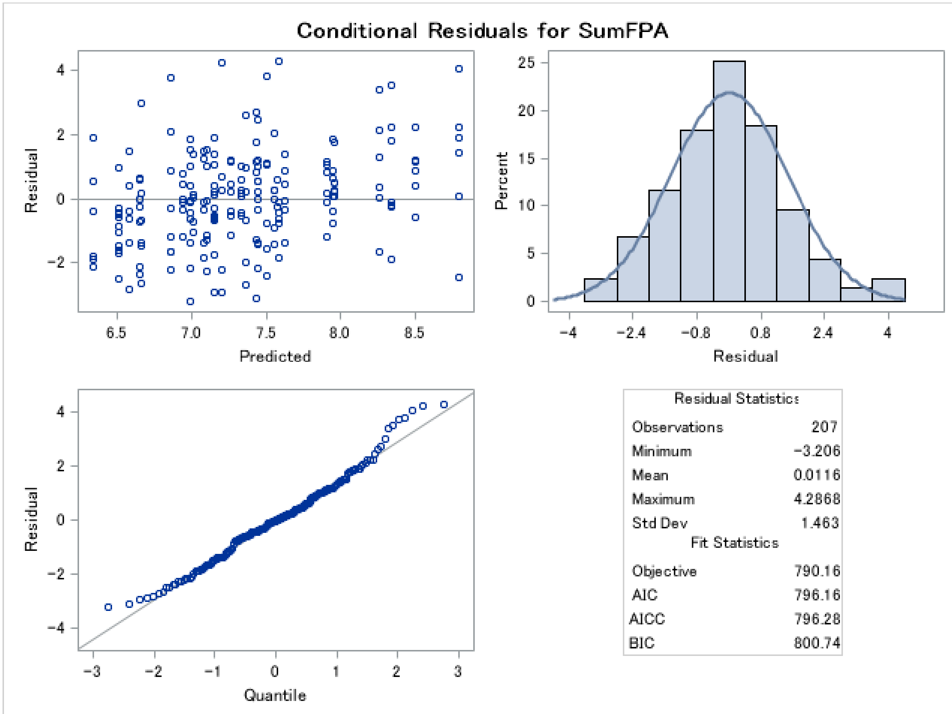


Figure 9. University A plot of the residuals

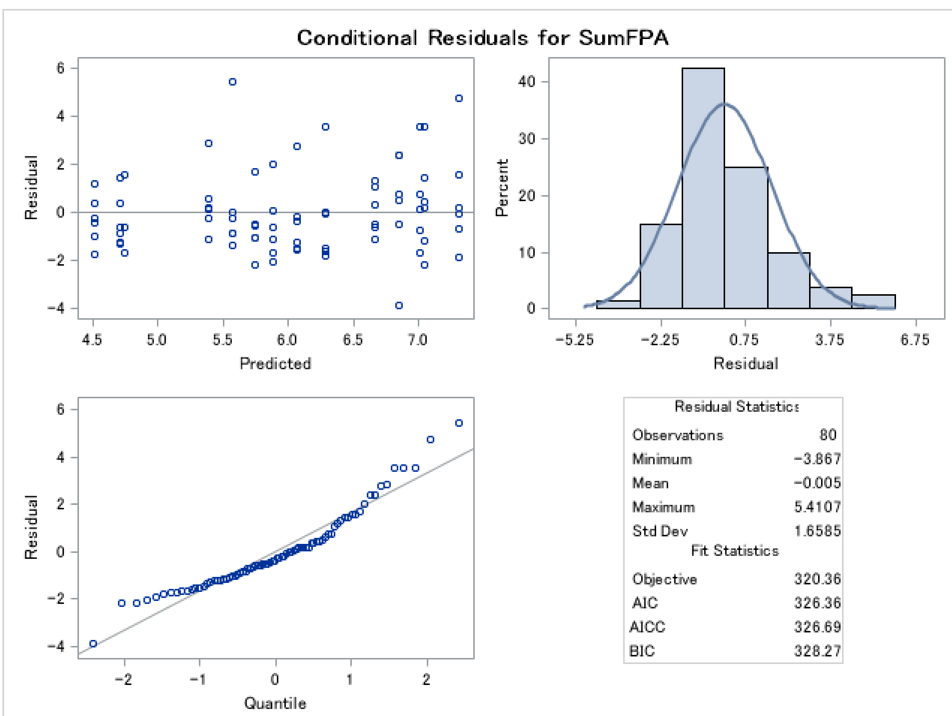


Figure 10. University B plot of the residuals

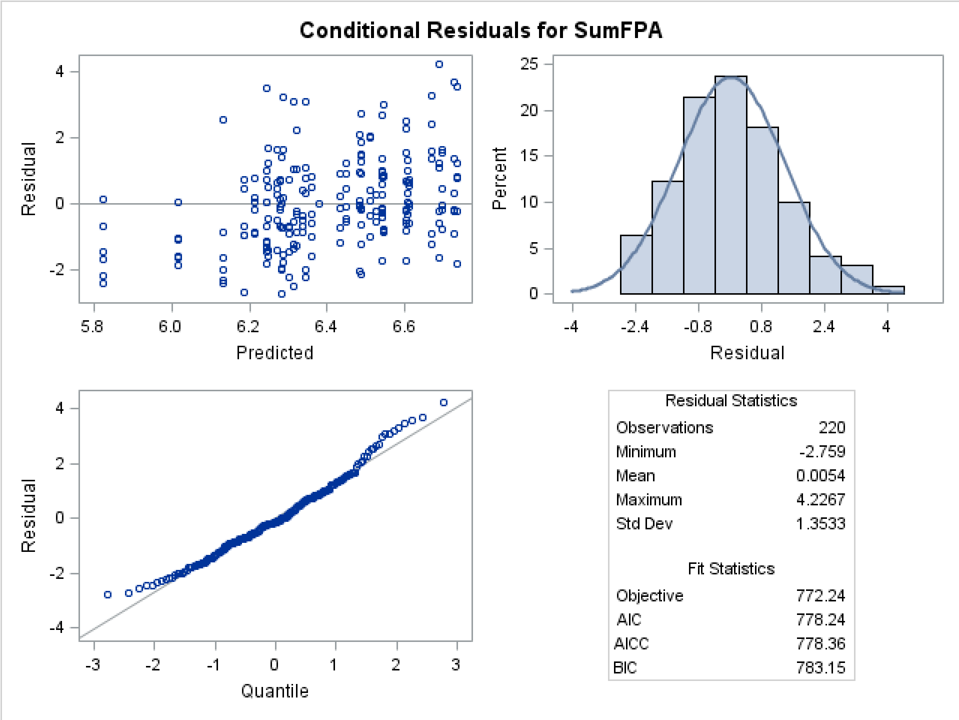


Figure 11. University C plot of the residuals

To start the analysis, the simplest model was initiated first and was comprised of the EvalGRP being the sole factor used to estimate the SumFPA. Tables 6–8 show the fit of this model for each university.

Table 6. University A simplest model

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	30.1	0.30	0.8280

Table 7. University B simplest model

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	10.3	2.26	0.1426

Table 8. University C simplest model

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	34.4	0.26	0.8568

In the models above, universities A and C have *p*-values of 0.8280 and 0.8568, respectively; this shows us that EvalGRP alone is not a good estimator of the SumFPA in those cases. University B, however, has a substantially lower *p*-value of 0.1426. This factor will need to be monitored as additional factors are added to the model to determine if the effect of EvalGRP on SumFPA gets stronger, weaker, or remains constant.

Depending on the willingness of an organization to be wrong in their assertion of the accuracy of the estimators, the *p*-value would need to get substantially lower. A *p*-value less than 0.1000 would be sufficient for the purposes of this study. A *p*-value greater than 0.1000 would need to be assessed for practical significance to determine if it is worth additional inquiry.

The next model that was evaluated incorporated the Pwr factor to see if having power on or off during the approach and an inclusion of an interaction with the EvalGRP has an effect on the SumFPA. Tables 9–11 show the fit of this model for each university.

Table 9. University A fixed-effects model

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	41.1	0.57	0.6405
Pwr	1	165	17.33	<.0001
EvalGRP*Pwr	3	164	2.95	0.0345

Table 10. University B fixed-effects model

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	14.6	2.61	0.0906
Pwr	1	62.5	37.69	<.0001
EvalGRP*Pwr	3	62.3	0.25	0.8628

Table 11. University C fixed-effects model

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	62.9	1.09	0.3613
Pwr	1	146	8.80	0.0035
EvalGRP*Pwr	3	146	1.62	0.1874

With *p*-values of 0.6405 and 0.3613 for universities A and C, respectively, for EvalGRP and a *p*-value of 0.1874 for the interaction between EvalGRP and Pwr for University C, this shows us that neither of these effects are good estimators of the SumFPA. The interaction for EvalGRP and Pwr for University A is significant at a *p*-value of 0.0345. This tells us that the EvalGRPs for University

A do not perform the same during an approach with Pwr On versus Pwr Off. This interaction will need to be analyzed further to understand the impact of this interaction for University A.

Additionally, two universities have a *p*-value <0.0001, and one has a *p*-value of 0.0035 for the factor Pwr alone. This indicates that Pwr is a good estimator of the SumFPA. This should be no surprise. Most pilots are intuitively aware that in the event of an engine failure, the stability of the approach path is highly likely to be affected. It is also interesting to note that the effect of EvalGRP for University B is strengthened from a *p*-value of 0.1426 to 0.0906 when Pwr is added to the model.

The next evaluated model incorporated the VASI effect to the model and included an interaction effect between EvalGRP and VASI. Only University C conducted approaches at an airport where one or more of the runways did not have some sort of visual guidance available. Table 12 shows the fit of this model for University C.

Table 12. University C fixed-effects model

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	62	0.94	0.4273
VASI	1	146	2.02	0.1571
Pwr	1	150	5.43	0.0212
EvalGRP*VASI	3	145	3.18	0.0258
EvalGRP*Pwr	3	150	2.48	0.0632

Similar to the effect of Pwr on SumFPA, the interaction between EvalGRP and VASI is significant at a *p*-value of 0.0632. This tells us that the EvalGRPs for University C do not perform the same during an approach with visual guidance or without visual guidance. This interaction will need to be analyzed further to understand the impact of this interaction for University C. It’s also interesting to note that the strength of the effect of the interaction of EvalGRP and Pwr is increased when VASI is added to the model.

This process is continued throughout all of the potential factors that were recorded in the data-collection process. Any factor that does not have a *p*-value of less than 0.1000 is removed from the model unless the interaction between that factor and EvalGRP is less than 0.1000, in which case it must remain in the model because of the interaction. On completion of this process, the models in the following tables were achieved for each university.

Tables 13–15 indicate that the evaluation groups do not have a significant effect on the stability of an approach for universities A, B, or C at the 0.1000 level. At *p*-values of 0.6405 and 0.4273 for universities A and C, respectively, it is not significant enough to indicate the there is an effect outside of a random occurrence. The *p*-value for EvalGRP for University B is worth further inquiry to determine if there is an effect among specific groups when AOA education or use is evaluated. Further inquiry into the effect of the interaction of EvalGRP and Pwr for University A, the effect of EvalGRP for University B, the effect of the interaction of EvalGRP, and Pwr and EvalGRP and VASI for University C, should be evaluated.

Table 13. University A—Final model

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	41.1	0.57	0.6405
Pwr	1	165	17.33	<.0001
EvalGRP*Pwr	3	164	2.95	0.0345

Table 14. University B—Final model

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	10.1	2.56	0.1130
Pwr	1	65.5	46.12	<.0001

Table 15. University C—Final model

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
EvalGRP	3	62	0.94	0.4273
Pwr	1	150	5.43	0.0212
VASI	1	146	2.02	0.1571
EvalGRP*Pwr	3	150	2.48	0.0632
EvalGRP*VASI	3	145	3.18	0.0258

To analyze the data for the individual situations at each university, an analysis was conducted providing separation of data for various factors. For the cases in which there was an interaction between Pwr and EvalGRP, all EvalGRPs in a Pwr On situation were analyzed without the Pwr Off approaches included in the data. This would be considered a separation of data for Pwr Off. An analysis was then conducted in the Pwr Off situation with a separation of data for Pwr On. The analysis for each situation for each university could then be compared to better understand the information presented in the data.

The approaches analyzed for individual universities in the power-on and power-off conditions are shown in table 16.

Table 16. Breakdown of approaches analyzed in power-on an power-off conditions for AOA display

University A Power On		University B Power On		University C Power On	
Group 1	49	Group 1	10	Group 1	49
Group 2	31	Group 2	20	Group 2	50
Group 3	45	Group 3	12	Group 3	47
Group 4	41	Group 4	24	Group 4	38
Total	166	Total	66	Total	184

University A Power Off		University B Power Off		University C Power Off	
Group 1	13	Group 1	2	Group 1	10
Group 2	9	Group 2	4	Group 2	10
Group 3	9	Group 3	3	Group 3	8
Group 4	10	Group 4	5	Group 4	8
Total	41	Total	14	Total	36

Table 17 provides a comparison of the estimates of the SumFPA for the various situations in the title row for the various combinations. The estimate provided is a comparison of the mean (average) estimates of the various combinations. The *t*-value and Adj P show the statistical comparison of the two estimates and determines if they are statistically different. Even though they are actually different numbers, the difference may not be statistically significant, and the *t*-values and Adj P help to determine the comparison. If the *t*-value is sufficient enough, the associated *p*-value and Adj P of the comparison will be a low number (less than 0.1000 for statistical significance for the purposes of this study), which would indicate that it is more than a random occurrence for the difference in the mean estimates of the SumFPA for each combination.

Table 17. University A—EvalGRP comparisons for power on

Differences of Least Squares Means									
Effect	EvalGRP	_EvalGRP	Estimate	Standard Error	DF	*t* Value	Pr > |t|	Adjustment	Adj P
EvalGRP	1	2	0.1017	0.5626	30.8	0.18	0.8577	Tukey-Kramer	0.9979
EvalGRP	1	3	0.4985	0.5116	29.4	0.97	0.3378	Tukey-Kramer	0.7649
EvalGRP	1	4	0.4623	0.5267	29	0.88	0.3873	Tukey-Kramer	0.8163
EvalGRP	2	3	0.3968	0.5738	30.5	0.69	0.4945	Tukey-Kramer	0.8995
EvalGRP	2	4	0.3605	0.5872	30.1	0.61	0.5439	Tukey-Kramer	0.9268
EvalGRP	3	4	-0.03623	0.5386	28.7	-0.07	0.9468	Tukey-Kramer	0.9999

For example, in row 1, EvalGRP 1 is compared with EvalGRP 2. The estimate in this graph is the difference in the mean estimates of SumFPA of EvalGRP 1 and EvalGRP 2. The mean SumFPA for the group in column 3 is subtracted from the mean SumFPA for the group in column 2, and the result is provided in the Estimate column. Because the number in the Estimate column is a positive number, that indicates that the mean SumFPA for EvalGRP 2 was a lower number, which would indicate that EvalGRP 1 performed worse (higher fluctuation of FPA, which resulted in a higher mean SumFPA). Even though EvalGRP 1 performed worse, the *p*-value is not low enough to indicate that it is enough to be considered a result that is something other than random. In looking at the *p*-values of the comparisons in this condition, it can be seen that none of the relationships between any of the groups for University A in the Pwr On situation are statistically significant.

Table 18 shows the comparison of the evaluation groups for University A in the power-off situation and the differences starting to develop. In the second row, EvalGRP 1 is compared with EvalGRP 3. Because the number in the Estimate column is negative, it indicates that the mean SumFPA for EvalGRP 3 is a higher number, which would indicate that EvalGRP 1 performed better (lower fluctuation of FPA, which resulted in a lower mean SumFPA). When looking at the basic t-test in the analysis, it can be seen that the relationship is statistically significant, but when it is adjusted for the type of statistical analysis that was conducted, it moves outside of statistical significance. There are other relationships worth noting. EvalGRP 2 and 4 do better than EvalGRP 3 in a similar relationship as EvalGRPs 1 and 3. To further understand this relationship and to determine if it was the AOA education, the AOA usage, or a combination of both, a contrast statement was run to compare the combinations of various groups. Because EvalGRP 1 and 2 both received AOA education, that could be a contributing effect to their performance on the approach. Likewise, EvalGRPs 1 and 3 were both allowed access to the AOA display during the evaluation flights. A contrast analysis will compare the effect of AOA education, the effect of AOA usage, and the effect of the combination of AOA usage and education.

Table 18. University A—EvalGRP comparisons for power off

Differences of Least Squares Means									
Effect	EvalGRP	_EvalGRP	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
EvalGRP	1	2	-0.9805	0.6199	6.48	-1.58	0.1612	Tukey-Kramer	0.4321
EvalGRP	1	3	-1.6372	0.7406	35.6	-2.21	0.0336	Tukey-Kramer	0.1889
EvalGRP	1	4	-0.01975	0.5710	5.67	-0.03	0.9736	Tukey-Kramer	1.0000
EvalGRP	2	3	-0.6567	0.7857	32.2	-0.84	0.4094	Tukey-Kramer	0.8364
EvalGRP	2	4	0.9608	0.6283	5.89	1.53	0.1780	Tukey-Kramer	0.4590
EvalGRP	3	4	1.6174	0.7477	33.4	2.16	0.0378	Tukey-Kramer	0.2021

Table 19 shows that the effects of the combination of AOA education and AOA access during a power-off situation are statistically significant. Based on the earlier comparisons of the groups, it can be determined that EvalGRP 3 had the most variation in the SumFPA. One possibility for this effect is the level of proficiency of the participants in this analysis. A power-off accuracy landing is conducted on a routine basis in training. For EvalGRPs 2 and 4, the performance of the power-off approach and the lack of an AOA display would be familiar to this group. EvalGRP 1 had the most familiarity with the AOA displays and, therefore, could use the information to assist in the performance of the maneuver. EvalGRP 3 did not receive any training on the AOA display indications and had the potential for the display to be a distracter in the completion of the power-off landing, which could explain why its performance was the most unstable.

Table 19. University A—Estimates and contrast for power off

Estimates					
Label	Estimate	Standard Error	DF	t Value	Pr > |t|
Education–No Education	-0.6764	0.9713	18.7	-0.70	0.4947
AOA–No AOA	0.6369	0.9713	18.7	0.66	0.5200
Education*AOA	-2.5980	0.9713	18.7	-2.67	0.0151

Contrasts				
Label	Num DF	Den DF	F Value	Pr > F
Education–No Education	1	18.7	0.49	0.4947
AOA–No AOA	1	18.7	0.43	0.5200
Education*AOA	1	18.7	7.15	0.0151

When looking at the comparison of the evaluation groups for University B in the power-on situation, as shown in table 20, some differences can be seen among the various groups. In rows 1, 3, 4, and 6, the relationships among the groups reflect statistical significance based on a basic t-test, with weakening significance in the Adj P measure. It appears that EvalGRPs 1 and 3 tend to do better than EvalGRPs 2 and 4, but to confirm this possibility, a contrast statement will help show the dynamics.

Table 20. University B—EvalGRP comparisons for power on

Differences of Least Squares Means									
Effect	EvalGRP	_EvalGRP	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
EvalGRP	1	2	-1.3452	0.7584	9.52	-1.77	0.1080	Tukey-Kramer	0.3390
EvalGRP	1	3	0.1557	0.8281	10.3	0.19	0.8545	Tukey-Kramer	0.9975
EvalGRP	1	4	-1.4352	0.7354	9.63	-1.95	0.0806	Tukey-Kramer	0.2674
EvalGRP	2	3	1.5010	0.7028	10.7	2.14	0.0568	Tukey-Kramer	0.2064
EvalGRP	2	4	-0.09001	0.5908	9.69	-0.15	0.8820	Tukey-Kramer	0.9987
EvalGRP	3	4	-1.5910	0.6779	10.9	-2.35	0.0389	Tukey-Kramer	0.1511

The estimates in table 21 show that the use of AOA resulted in a lower estimate for the SumFPA versus not having the use of the AOA. This would indicate that there is an effect for University B when having access to an AOA device.

Table 21. University B—Estimates and contrast for power on

Estimates					
Label	Estimate	Standard Error	DF	t Value	Pr > |t|
Education–No Education	0.06571	1.0172	10.1	0.06	0.9498
AOA–No AOA	-2.9362	1.0172	10.1	-2.89	0.0161
Education*AOA	0.2457	1.0172	10.1	0.24	0.8140

Contrasts				
Label	Num DF	Den DF	F Value	Pr > F
Education–No Education	1	10.1	0.00	0.9498
AOA–No AOA	1	10.1	8.33	0.0161
Education*AOA	1	10.1	0.06	0.8140

When comparing the EvalGRPs for University B in the power-off condition, table 22 shows that although there are differences among the estimates for the SumFPA for the various groups, none of them are statistically significant enough to indicate an occurrence beyond random effects.

Table 22. University B—EvalGRP comparisons for power off

Differences of Least Squares Means									
Effect	EvalGRP	_EvalGRP	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
EvalGRP	1	2	-1.1492	2.2512	10	-0.51	0.6208	Tukey-Kramer	0.9547
EvalGRP	1	3	1.0499	2.3730	10	0.44	0.6676	Tukey-Kramer	0.9696
EvalGRP	1	4	-1.6271	2.1749	10	-0.75	0.4716	Tukey-Kramer	0.8754
EvalGRP	2	3	2.1991	1.9854	10	1.11	0.2939	Tukey-Kramer	0.6932
EvalGRP	2	4	-0.4780	1.7438	10	-0.27	0.7896	Tukey-Kramer	0.9923
EvalGRP	3	4	-2.6771	1.8984	10	-1.41	0.1888	Tukey-Kramer	0.5212

Likewise, the estimates for the contrasts of education and AOA usage in table 23 show that there are estimated differences but none that show statistical significance for the power-off condition for University B.

Table 23. University B—Estimates and contrast for power off

Estimates					
Label	Estimate	Standard Error	DF	t Value	Pr > |t|
Education–No Education	0.5720	2.9448	10	0.19	0.8499
AOA–No AOA	-3.8262	2.9448	10	-1.30	0.2230
Education*AOA	1.5279	2.9448	10	0.52	0.6152

Contrasts				
Label	Num DF	Den DF	F Value	Pr > F
Education–No Education	1	10	0.04	0.8499
AOA–No AOA	1	10	1.69	0.2230
Education*AOA	1	10	0.27	0.6152

University C had an interaction effect worthy of analyzing for both the EvalGRP*Pwr and the EvalGRP*VASI conditions. Like University A, the data are analyzed with a separation of data on various conditions to determine if the EvalGRPs perform differently under varying circumstances as shown in table 24.

Table 24. University C—EvalGRP comparisons for power on

Differences of Least Squares Means									
Effect	EvalGRP	_EvalGRP	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
EvalGRP	1	2	0.1371	0.3763	34.2	0.36	0.7178	Tukey-Kramer	0.9832
EvalGRP	1	3	-0.01537	0.3815	34.4	-0.04	0.9681	Tukey-Kramer	1.0000
EvalGRP	1	4	-0.01493	0.4035	35.2	-0.04	0.9707	Tukey-Kramer	1.0000
EvalGRP	2	3	-0.1525	0.3800	34	-0.40	0.6908	Tukey-Kramer	0.9778
EvalGRP	2	4	-0.1520	0.4021	34.8	-0.38	0.7077	Tukey-Kramer	0.9813
EvalGRP	3	4	0.000434	0.4070	35	0.00	0.9992	Tukey-Kramer	1.0000

Like University A, the *p*-values of the comparisons in this condition show that none of the relationships between any of the groups for University C in the power-on condition are statistically significant.

In table 25, the *p*-values of the comparisons in this condition show that none of the relationships between any of the groups for power-off condition are statistically significant, but the *p*-values do approach statistical significance for the relationship of EvalGRPs 2 and3 with respect to EvalGRP 4, and the relationship of EvalGRP 1 strengthens with respect to EvalGRPs 2 and 3. The estimate and contrast assessments in table 26 help to explain this relationship.

Table 25. University C—EvalGRP comparisons for power off

Differences of Least Squares Means									
Effect	EvalGRP	_EvalGRP	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
EvalGRP	1	2	0.6679	0.7272	32	0.92	0.3652	Tukey-Kramer	0.7952
EvalGRP	1	3	0.6717	0.7713	32	0.87	0.3903	Tukey-Kramer	0.8197
EvalGRP	1	4	-0.4799	0.7713	32	-0.62	0.5382	Tukey-Kramer	0.9242
EvalGRP	2	3	0.003833	0.7713	32	0.00	0.9961	Tukey-Kramer	1.0000
EvalGRP	2	4	-1.1478	0.7713	32	-1.49	0.1465	Tukey-Kramer	0.4562
EvalGRP	3	4	-1.1516	0.8130	32	-1.42	0.1663	Tukey-Kramer	0.4986

Table 26. University C—Estimates and contrast for power off

Estimates					
Label	Estimate	Standard Error	DF	t Value	Pr > |t|
Education–No Education	-0.4760	1.0907	32	-0.44	0.6654
AOA–No AOA	-0.4837	1.0907	32	-0.44	0.6604
Education*AOA	1.8195	1.0907	32	1.67	0.1050

Contrasts				
Label	Num DF	Den DF	F Value	Pr > F
Education–No Education	1	32	0.19	0.6654
AOA–No AOA	1	32	0.20	0.6604
Education*AOA	1	32	2.78	0.1050

The differences in education versus no education indicate that participants who receive education have a lower mean SumFPA than those who do not. Likewise, participants who are allowed access to the AOA display have a lower mean SumFPA than those not allowed access to the AOA. However, neither of these relationships are statistically significant. The combination of education and AOA usage results in a positive estimate, but at the 0.1000 *p*-value level, it is not statistically significant. Comparisons of the groups show that EvalGRPs 2 and 3 were more stable than EvalGRP 4, but at *p*-values of 0.1465 and 0.1663, respectively, they are still too far away from statistical significance to draw conclusions. There are differences among the various groups during a power-off approach, whereas little difference is present during a power-on approach.

University C also had an interaction between EvalGRP and VASI. Universities A and B did not conduct approaches at airports where at least one of the runways used did not have visual guidance available for the participants to use. The following analysis could only be conducted for University C.

The approaches analyzed for the VASI condition are shown in table 27.

Table 27. University C—Approaches analyzed for VASI condition

University C Power On VASI Available		University C Power On No VASI Available	
Group 1	35	Group 1	14
Group 2	38	Group 2	12
Group 3	33	Group 3	14
Group 4	29	Group 4	9
Total	135	Total	49

Table 28 shows that when a visual guidance system is available, there is little difference in the SumFPA among the EvalGRPs.

Table 28. University C—EvalGRP comparisons for VASI

Differences of Least Squares Means									
Effect	EvalGRP	_EvalGRP	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
EvalGRP	1	2	0.5120	0.4241	32.1	1.21	0.2362	Tukey-Kramer	0.6267
EvalGRP	1	3	0.3785	0.4352	34.2	0.87	0.3906	Tukey-Kramer	0.8204
EvalGRP	1	4	0.1420	0.4532	32.9	0.31	0.7560	Tukey-Kramer	0.9891
EvalGRP	2	3	-0.1335	0.4292	32.7	-0.31	0.7577	Tukey-Kramer	0.9894
EvalGRP	2	4	-0.3700	0.4475	31.5	-0.83	0.4145	Tukey-Kramer	0.8413
EvalGRP	3	4	-0.2365	0.4580	33.4	-0.52	0.6091	Tukey-Kramer	0.9546

Table 29 shows that when a visual guidance system is not available, there is a strengthened relationship among the groups. None of the specific relationships become statistically significant, but it does warrant further inquiry to determine if AOA education or AOA usages have an effect on SumFPA when a visual guidance system is not available for use.

Table 29. University C—EvalGRP comparisons for no VASI

Differences of Least Squares Means									
Effect	EvalGRP	_EvalGRP	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
EvalGRP	1	2	-0.9487	0.6163	28.8	-1.54	0.1346	Tukey-Kramer	0.4283
EvalGRP	1	3	-0.8450	0.6163	25.4	-1.37	0.1824	Tukey-Kramer	0.5272
EvalGRP	1	4	-0.2870	0.6741	28.3	-0.43	0.6735	Tukey-Kramer	0.9736
EvalGRP	2	3	0.1038	0.6163	28.8	0.17	0.8675	Tukey-Kramer	0.9983
EvalGRP	2	4	0.6617	0.6740	31.4	0.98	0.3338	Tukey-Kramer	0.7609
EvalGRP	3	4	0.5579	0.6741	28.3	0.83	0.4148	Tukey-Kramer	0.8409

In table 30, the differences in education versus no education indicate that participants receiving education have a lower mean SumFPA than those who do not. Likewise, participants who are allowed access to the AOA display have a lower mean SumFPA than those who are not allowed access to the AOA. However, neither of these relationships are statistically significant. It can be seen that the combination of education and AOA usage results in a negative estimate, but at the 0.1000 *p*-value level, it is not statistically significant.

Table 30. University C—Estimates and contrast for no VASI

Estimates					
Label	Estimate	Standard Error	DF	t Value	Pr > |t|
Education–No Education	-0.1833	0.9133	28.6	-0.20	0.8424
AOA–No AOA	-0.3908	0.9133	28.6	-0.43	0.6719
Education*AOA	-1.5066	0.9133	28.6	-1.65	0.1100

Contrasts				
Label	Num DF	Den DF	F Value	Pr > F
Education–No Education	1	28.6	0.04	0.8424
AOA–No AOA	1	28.6	0.18	0.6719
Education*AOA	1	28.6	2.72	0.1100

In summary, based on these results, it is appropriate to determine that when a landing situation presents itself with normal characteristics, there is no significant difference in the stability of an approach whether or not an AOA device is used. However, when complexity is introduced into the equation, such as the lack of visual guidance information, (e.g., VASI, PAPI, or a power-off situation), there is an attributable difference in the stability of the FPA variation when an AOA device is or is not used and whether the participant received education on the display.

4.7.1 Tailwind Considerations

There were 94 approaches conducted at airports where a tailwind situation was present on base to final. When those approaches were evaluated for the airport location, the runway used, and the direction of turn, there were 13 approaches at KMLB to runway 5 that were conducted under similar circumstances and 13 approaches at KCFJ to runway 4 that were conducted under similar circumstances. Of the approaches at KMLB, two were conducted by EvalGRP 1, two were conducted by EvalGRP 2, seven were conducted by EvalGRP 3, and two were conducted by EvalGRP 4. Of the approaches at KCFJ, four were conducted by EvalGRP 1, four were conducted by EvalGRP 2, three were conducted by EvalGRP 3, and two were conducted by EvalGRP 4.

Because of the low number of approaches conducted under circumstances similar enough for evaluation, this portion of the analysis cannot be conducted with enough strength to draw conclusions regarding the effect of the AOA devices on the base to final turn and whether they facilitated the participants in establishing a square pattern during approach. The information contained in figures 12–14 is a representation of the approaches that were captured and the corresponding maximum overshoot beyond the extended centerline of the runway.

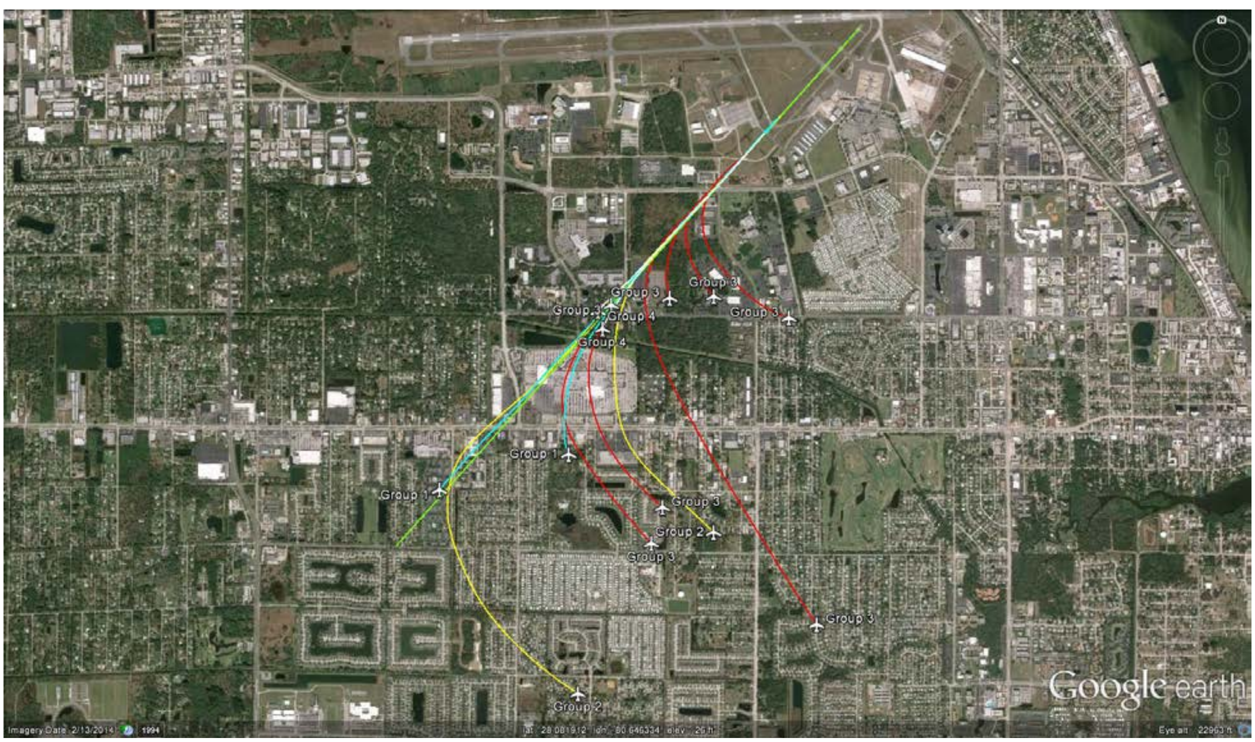


Figure 12. Overhead image of approaches at KMLB

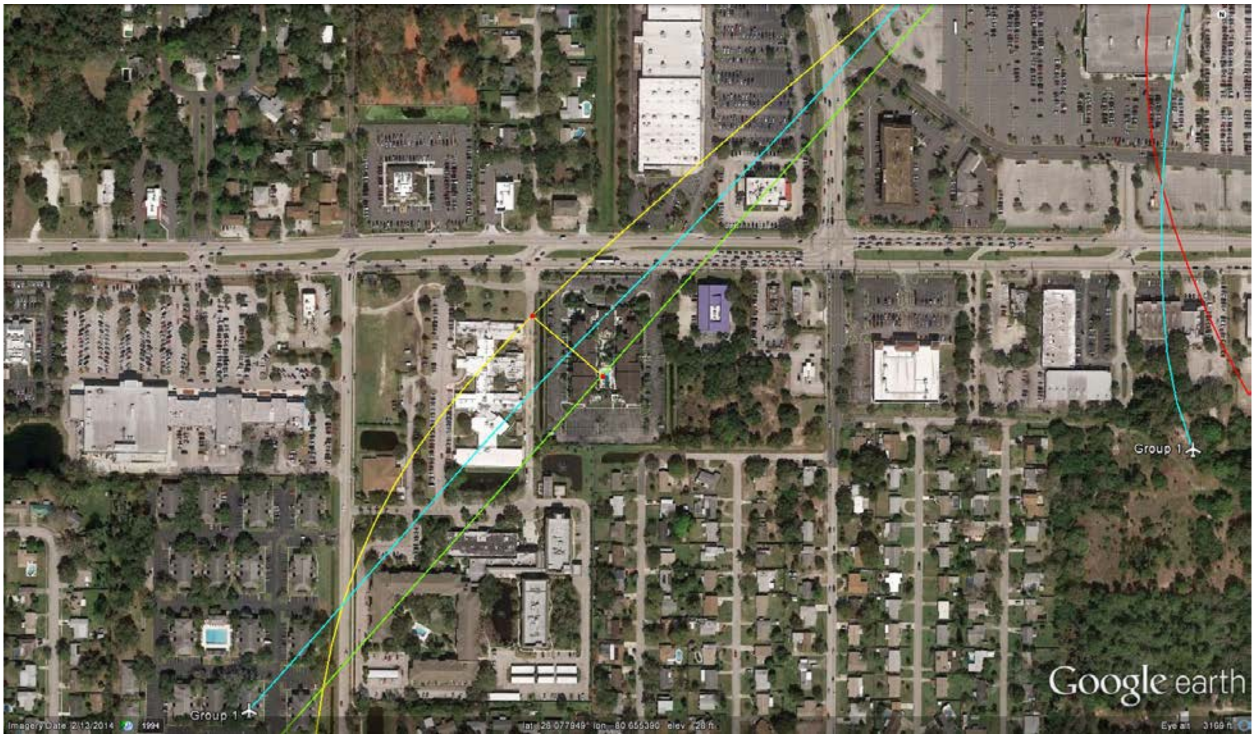


Figure 13. Measurements of overshoot beyond extended runway centerline

Measurements of maximum exceedances for all groups at KMLB:

Group 1—Largest overshoot was 126 feet beyond centerline at 1.51 nautical miles (NM) away from the threshold.

Group 2—Largest overshoot was 270 feet beyond centerline at 1.45 NM away from the threshold.

Group 3—Largest overshoot was 99 feet beyond centerline at .45 NM away from the threshold.

Group 4—Largest overshoot was 132 feet beyond centerline at .85 NM away from the threshold.

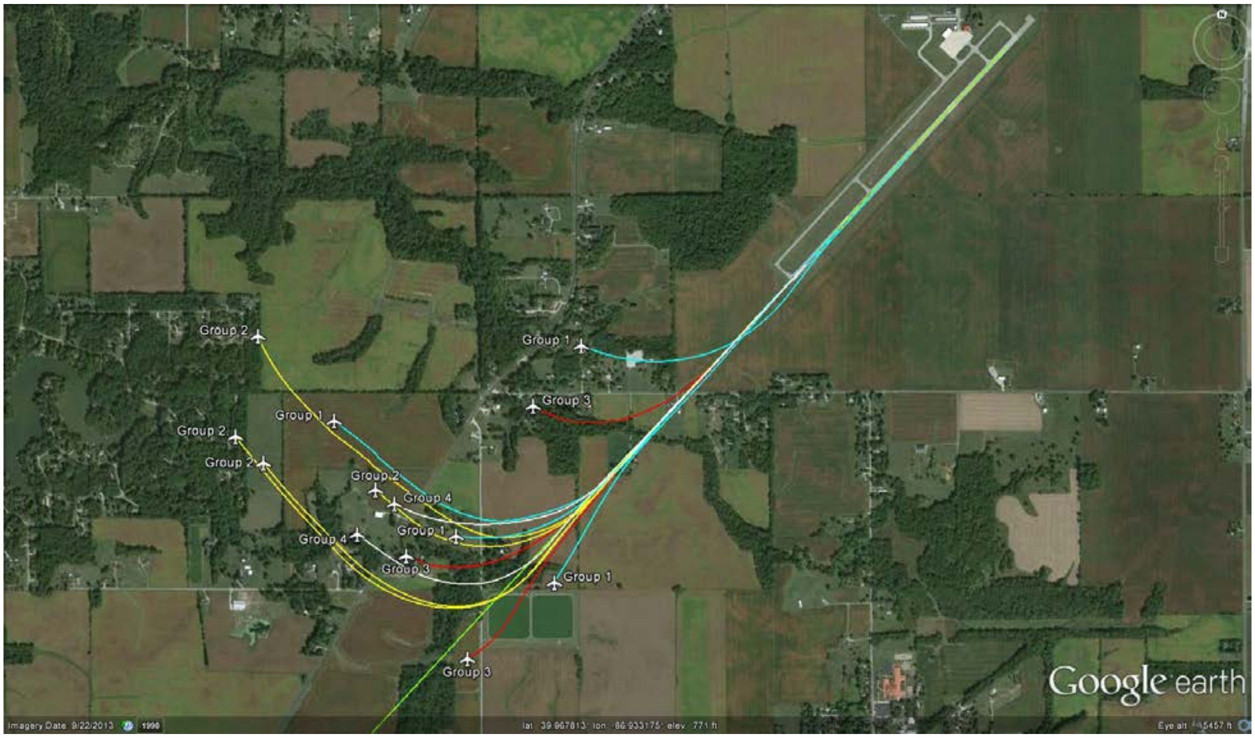


Figure 14. Overhead image of approaches at KCFJ

Measurements of maximum exceedances for all groups at KCFJ

Group 1—Had two overshoots that were worth mentioning. One overshoot was 118 feet beyond centerline at 332 feet away from the threshold. The other overshoot was 419 feet beyond the centerline at .85 NM away from the threshold.

Group 2—Largest overshoot was 103 feet beyond centerline at .86 NM away from the threshold.

Group 3—Largest overshoot was 341 feet beyond centerline at 1.01 NM away from the threshold.

Group 4—Largest overshoot was 20 feet beyond centerline at .8 NM away from the threshold.

4.7.2 Conclusions for Experimental Hypothesis

This section will discuss the experiment's hypotheses. The statistical analysis used for these hypotheses was the Analysis of Variance (ANOVA) technique. It was theorized by the researchers and the sponsors for this research project that the use of an angle of attack (AOA) system would result in more stable approaches for general aviation (GA) pilots.

The statistical results of this project did not show the expected results when looking at all of the participants in their entirety. This result could be for several reasons, one of which may be that the majority of pilots used as participants in this study are those participating in an advanced flight school environment, are flying regularly, and are therefore quite proficient.

Hypothesis 1

Training about AOA, the use and operation of an AOA system, and the use of the AOA system in flight will allow GA pilots to conduct a more stable approach to landing.

The statistical analysis of the evaluation groups did not support the hypothesis that training pilots in the use of an AOA system and the use and operation of an AOA system would allow GA pilots to conduct a more stable approach to landing while using an AOA system for approaches to landing in all conditions.

Hypothesis 2

Training about AOA and the use and operation of an AOA system will allow GA pilots to conduct a more stable approach to landing, even without the use of an AOA system in flight.

The statistical analysis of the evaluation groups did not support the hypothesis that training pilots in the use and operation of an AOA system would allow GA pilots to conduct a more stable approach to landing, even without the use of an AOA system.

Hypothesis 3

The use of an AOA system in flight will allow GA pilots to conduct a more stable approach to landing, even without training on the use of an AOA system.

The statistical analysis of the evaluation groups did not support the hypothesis that the use of an AOA system in flight would allow GA pilots to conduct a more stable approach to landing, even without training in the use of an AOA system.

4.7.3 Conclusions for Research Questions

Research Question 1

Of the groups evaluated, which pilots had a more stable approach?

The overall experimental results and analysis concluded that all groups had an equal chance of having a stable approach. Any differences found in approach stability did not meet the criteria for statistical significance and could be the result of random effects. More detail is available in the results interpretation provided in this section. Although experimental treatments, such as AOA display access, training on AOA usage, or a combination of both sometimes decreased the mean SumFPA, they did not reveal a statistical significance that could be determined beyond the *p*-value of less than a 0.1000 level.

The exception to this conclusion was when the approaches conducted by University B were evaluated in the power-on condition only. Groups 1 and 3 at University B (which had access to the AOA display) had more stable approaches than Groups 2 and 4, which did not have AOA access during the power-on approaches.

Research Question 2

What difference does it make on approach stability whether AOA training occurs?

Groups 1 and 2 were given training on the use of AOA technology; however, only Group 1 was allowed to use the AOA display during the evaluation flight. After the statistical analysis of power-on and power-off approaches at all three universities, there was no notable correlation between AOA training and the stability of approaches. Participants who received AOA training did have a lower SumFPA than those who did not in some cases; however, it was not possible to find a statistical significance that appeared to be more than random effects in any of the models.

Research Question 3

What difference does it make on approach stability whether AOA is visible?

In our sample, universities A and C did not show any statistical differences in approach stability, whether power on or off, when comparing approaches with access to an AOA display versus those that did not have access to an AOA device. However, participants at University B revealed a statistically significant result when power-on approaches with AOA access were compared to those without access to the AOA display.

Because this result was not consistent across all three universities, further exploration of the reasoning for this outcome is necessary. Universities A and C both used low-wing training aircraft on which most participants flew on a regular basis as students in the respective collegiate flight programs. University B used a complex aircraft for this experiment. (A complex airplane has retractable landing gear, adjustable pitch propeller, and wing flaps.) Many participants, either enrolled as students or from the local pilot community, had never flown this make and model of aircraft or had very little experience with complex aircraft in general. Despite operational training occurring during training and evaluation flights, this could have resulted in opportunities for distraction while participants adjusted to the unique flying characteristics of the complex aircraft.

Of the data analyzed at University B, 29% of participants were not flight students enrolled in the collegiate aviation program. Although the other 71% were recruited from within the university's aviation flight program, an evaluation of the intake information provided to researchers by recruited participants reveals that the frequency at which these pilots flew varied, and not all of those students had progressed to flying the complex aircraft. Formal demographic data pertaining to proficiency, currency, or experience in complex aircraft were not recorded by researchers.

Therefore, it is possible that pilots who were less or not at all familiar with an aircraft have more stabilized approaches when given visual access to an AOA display than those who are current and proficient in flying a particular make and model of aircraft.

Research Question 4

What difference does it make on approach stability between the different aircraft?

Each university used different aircraft while conducting this experiment. The aircraft used in the study were a Piper Warrior aircraft with an Avidyne Entegra flight deck system, a Piper Arrow with an Avidyne Entegra flight deck system, and a Cirrus SR-20 with Garmin G-1000 flight deck equipment. The Piper Arrow is a complex aircraft with retractable landing gear, whereas the Cirrus SR-20 and the Piper Warrior are both fixed-gear aircraft.

To determine if the use of an AOA device would assist in the stability of an approach on the different aircraft, further information needs to be collected in future studies. The factor "university" incorporates not only the type of aircraft used but also many other components that it is not possible to separate at this time.

<u>Research Question 5</u>

What difference does it make on approach stability during "normal" versus "engine-off" approaches?

During the evaluation flights, the safety pilot/flight instructor pulled the throttle to idle on the second approach to landing at the second airport. The participant was to attempt the power-off landing. The research question asks if the AOA system helped the participants who had access to the AOA display to make a better approach during the power-off landing.

The data analysis shows that the use of power during the approach was statistically significant for the measurement of SumFPA for all participants. This indicates that the stability of an approach is affected by the availability of engine power. When looking at whether the presence of an AOA device was a contributing factor in the stability of the approach, there were only two situations in which this component of complexity approached statistical significance. The interaction of the Power and EvalGRP (Pwr*EvalGRP) was slightly higher than a *p*-value of 0.1000 for universities A and C during the power-off condition. The stability of the approaches for University B as measured by the SumFPA was not statistically different among the EvalGRPs.

University A EvalGRP 3 had the most variation in the SumFPA during power-off approaches. EvalGRP 3 did not receive any training on the AOA display indications and had the potential for the display to be a distracter in the completion of the power-off landing, which could explain why its performance was the most unstable.

University C EvalGRPs 2 and 3 had less variation in the SumFPA during power-off approaches than EvalGRP 4. EvalGRP 1 was not statistically different from EvalGRPs 2, 3, or 4.

When combining the results of the universities, the exact relationship of AOA usage and approach stability during a power-off approach situation is unclear. The contrast statement assessments for universities A and C and the performance results of the various groups seem to indicate that additional factors need to be considered. Factors such as the length of time between AOA education and performance, the determination of participant proficiency in the use of AOA, and the familiarity of the participants with satellite airport operations could all be contributors to approach-stability variability. Each of these factors, and likely others, would need to be considered to fully understand this relationship. At this point, a definitive conclusion cannot be made.

<u>Research Question 6</u>

What difference does it make if visual guidance is available for each of the groups?

The two most common types of visual-guidance information available for approaches are Visual Approach Slope Indicator (VASI) and Precision Approach Path Indicator (PAPI). The descriptions of the visual systems from the Aeronautical Information Manual (AIM) are below:

AIM 2-1-2 (a) (3-4): The basic principle of the VASI is that of color differentiation between red and white. Each light unit projects a beam of light having a white segment in the upper part of the beam and red segment in the lower part of the beam. The light units are arranged so that the pilot using the VASIs during an approach will see the combination of lights shown in figure 15.

2−Bar VASI

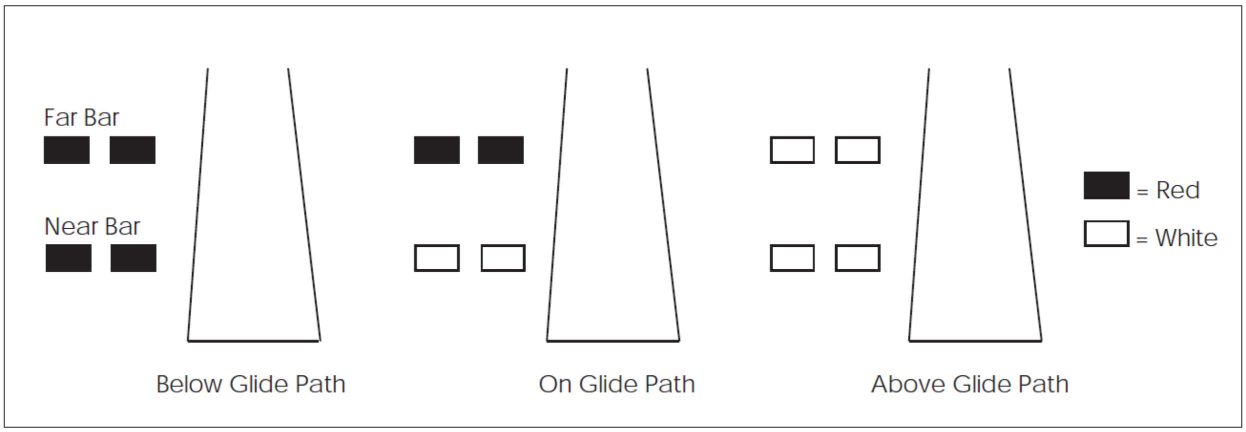


Figure 15. Two-bar VASI system (AIM, 2014)

The VASI is a system of lights arranged to provide visual descent guidance information during the approach to a runway. These lights are visible from 3–5 miles away during the day and up to 20 miles or more at night. The visual glide path of the VASI provides safe obstruction clearance within plus or minus 10 degrees of the extended runway centerline and to 4 NM from the runway threshold.

AIM 2-1-2 (b): The PAPI uses light units similar to the VASI but is installed in a single row of either two or four light units, as shown in figure 16. These lights are visible from approximately 5 miles during the day and up to 20 miles at night. The visual glide path of the PAPI typically provides safe obstruction clearance within plus or minus 10 degrees of the extended runway centerline and to 4 statute mile (SM) from the runway threshold.

Precision Approach Path Indicator (PAPI)

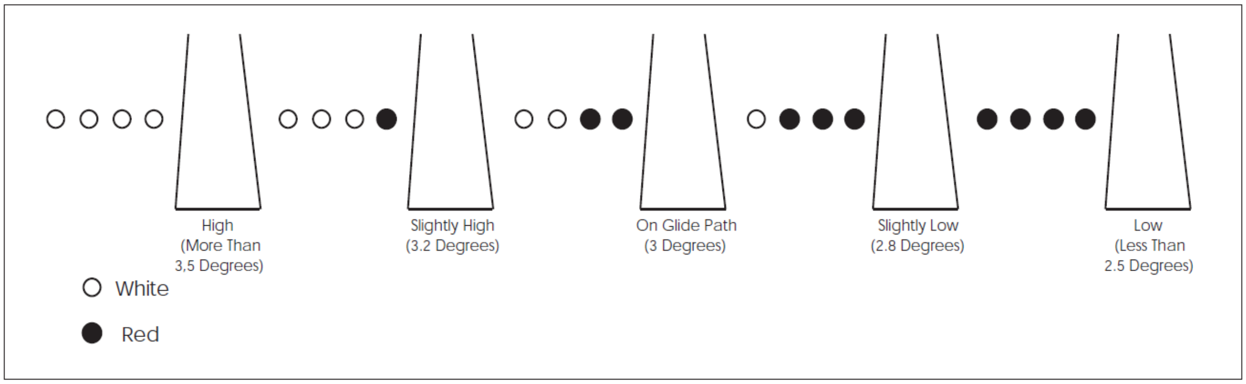


Figure 16. PAPI (AIM, 2014)

There was only one airport in the study that did not have visual guidance available to assist in the visual approach to landing. For the purposes of answering this research question, only the approaches conducted by the university having potential for an approach without visual guidance were evaluated, and of those approaches only the ones that were conducted in a power-on condition were considered because the airport where power-off approaches were conducted all had visual guidance information available for use.

It can be determined from the statistical analysis that visual guidance alone is not a significant factor in the determination of the stability of an approach under normal circumstances. There was an interaction effect between the evaluation groups and visual guidance, which warranted further inquiry. On further inquiry, it was determined that at an alpha level of 0.1000, there was no statistically significant difference in the group performance when visual guidance was or was not available. However, the combination of AOA education and AOA usage was a *p*-value of 0.1100, and it should be considered for practical significance. When looking at the differences in the group performance, Group 1 performed better than the rest of the groups. Group 4 performed better than Groups 2 and 3. A conclusion can be drawn that with both AOA education and access to AOA displays, approaches are more stable. For instances in which either just AOA access or just AOA education are provided, and a pilot is attempting an approach without visual guidance, the approaches are then more stable when the pilot has not been influenced by an AOA device. This indicates that proper education and proper usage are important to the stability of an approach when conducted to runways without visual guidance information.

4.8 COST/BENEFIT/RISKS ASSESSMENT

4.8.1 Cost Summary

Details and Explanations for:

1. Training
2. Equipment installed; equipment acquisition and installation (including all paperwork and approvals)
3. Equipment maintenance
4. Recurring training

Table 31 shows a typical cost for purchasing, installing, and training with an AOA system in a GA aircraft. Alpha Systems' equipment prices are from their website. Other costs are from analysis of traditional hourly rates for aircraft and instructor costs.

Table 31. Estimated cost for a typical AOA in GA aircraft

Item	Cost	Qty	Total Cost
Instructor cost for initial training	$35/Hr	1.5	$52.50
Aircraft cost for initial training	$150/Hr	1.5	$225
Labor cost for A&P installation	$85/Hr	3–5	$255–425
Labor cost for continued maintenance	$85/Hr	0.5	$42.50
Time on AOA during flight review for aircraft & instructor	$185/Hr	0.5	$92.50
Alpha Systems Legacy AOA Display	$1600	1	$1600
Alpha Systems Vertical Swivel Mount	$90	1	$90
		Total	$2357.50–$2527.50

4.8.2 Benefit Summary

Training

From the data collected during the planned experiments and a critical alpha of 0.10, a statistically significant difference cannot be shown in approach stability measures when AOA training has occurred versus when it has not. The difference in the averages of the approach stability measure is not statistically significant and is regarded as negligible based on this study. In this study, the cost of AOA training is 1 hour of classroom training using recorded video instruction and a 1.5-hour educational flight conducted with a certified flight instructor proficient in the specific AOA equipment.

AOA equipment

From the data collected during the planned experiments and a critical alpha of 0.10, it can be shown that there is a statistically significant difference in approach stability at University B measures when AOA equipment is installed and used versus when it was not used. The difference in the averages of the approach stability measure is 2.9362. As of October 2013, the total cost of the

Alpha Systems AOA device was $1856.00. The installation for the Cirrus SR-20 also required a specialized mounting plate that cost an additional $400. In a practical analysis, the cost of AOA equipment is to include acquisition cost, installation, all required paperwork and approvals, and manufacturer-recommended recurring maintenance.

AOA Equipment Training

From the data collected during the planned experiments and a critical alpha of 0.10, a statistically significant difference cannot be seen.

The assessment as to whether the gain in approach stability is worth the cost of the equipment is largely an individual question. Even with the approach stability varying among the groups in the various conditions at each university, the approaches were within acceptable conditions and resulted in acceptable landings. The qualitative feedback received from the participants does indicate that there is value for interpretation of approach stability during the approach to landing, and it is a useful tool to facilitate consistency.

5. RECOMMENDATIONS FOR FUTURE EXPERIMENTS

The main potential benefit of an AOA device is in reducing accidents due to loss of control in flight, predominately during departure and arrival operations. To determine the true impact of this device, it would be necessary to create situations in which individual pilots make decisions that put them in a position where a stall or stall/spin is likely to occur. Then, the degree to which an AOA device provides guidance information could be measured and compared against other scenarios. To conduct safe research using AOA systems for the loss of control issue, the research should be conducted using simulators (or high-fidelity advanced aviation training devices) that are equipped with an AOA system display. This would facilitate creating a more realistic scenario that has caused the most fatal accidents during approach to landing for GA (the base turn to final). Using a simulator, researchers can better control the environment and cause situations that would exacerbate a possible loss of control situation during each phase of a departure or an approach to landing without it being obvious to the participant. Additional parameters that could be considered for the impact of an AOA display could also be measured and incorporated into the analysis. Factors such as the pilot’s degree of overall proficiency and experience, the pilot’s degree of aircraft-specific proficiency and experience, the pilot’s familiarity with the intended landing airport and runway, the presence or lack thereof of visual guidance information, and the pilot’s response to emergency situations should also be considered. Additionally, eye-tracking equipment and software could be incorporated to determine the degree of the AOA display use by various participants and how that correlates to the overall approach stability.

6. REFERENCES

1. Federal Aviation Administration. (2014). *Aeronautical Information Manual.* Section 2-1-2 (a) (3-4). Retrieved from http://www.faa.gov/air_traffic/publications/atpubs/AIM/Index.htm.

2. Federal Aviation Administration. (2014). *Aeronautical Information Manual.* Section 2-1-2 (b). Retrieved from http://www.faa.gov/air_traffic/publications/atpubs/AIM/Index.htm.

3. Alpha Systems AOA/DepotStar, Inc. (2010). *Installation and Operations Manual for the "Legacy" Angle of Attack (AOA) Indicator*. Retrieved September 14, 2014.

APPENDIX A—SMALL AIRCRAFT DIRECTORATE LETTER

Small Airplane Directorate
901 Locust, Room 301
Kansas City, MO 64106

U.S. Department
of Transportation
Federal Aviation Administration

DEC 1 5 2011

DepotStar Inc.
Attn: Mark Korin
6180 140th Avenue NW
Ramsey, Minnesota 55303

Dear Mr. Korin:

This letter is in regards to the installation of your Alpha Systems - AOA system on Normal, Utility, Acrobatic, and Commuter Category airplanes.

The installation of any component on an aircraft must be evaluated for its affect on weight, balance, structural strength, performance, powerplant operation, flight characteristics, or other qualities affecting airworthiness.

The Small Airplane Directorate views your system as non-required equipment that provides a safety benefit. We also recognize that there appears to be a conflict between 14 CFR parts 1, 21 and 43 regarding the classification of a major change. 14 CFR part 43, Appendix A does not use the word "appreciable" when classifying a change as do parts 1 and 21. As such, the Small Airplane Directorate and the Flight Standards Service, Aircraft Maintenance Division has evaluated the installation of the Alpha Systems - AOA system on Normal, Utility, Acrobatic CAR 3 or Part 23 airplanes. We conclude the installation can be considered a minor alteration, provided the following provisions are met:

1. The system is non-required and used in an advisory or supplementary manner. The system will not be used in lieu of the airspeed indicator or aircraft stall warning system. No operational credit may be taken for the installation, such as reduced stall speeds, reduced approach speeds, reduced takeoff or landing distances, etc.
2. Accuracy of indication of stall must coincide with the stall horn, or be conservative (indicate stall at a higher airspeed) as compared to existing stall warning devices.
3. The installation of the system is on an unpressurized aircraft.
   NOTE: The installation on a pressurized aircraft may be a minor alteration; however, the installations will have to be evaluated on a case by case basis.
4. The installation of the AOA system does not require interface with the pitot-static system; the installation does not rely on direct pressure input from the pitot-static system.
5. The AOA system cannot be used as an input source to any automation or system that controls the aircraft, such as an autopilot or stick pusher unless done by STC.
6. If the system provides an aural warning, it should not be a source of nuisance warnings.
7. The installation of the AOA probe is:
   a. On the wing:
      i. On an inspection panel, or is substituting for an inspection panel, provided that the probe is located where it does not interfere with the functioning of a flight

control surface (aileron or spoiler) and does not interfere with the pitot-static system or aircraft stall warning system.

b. On the fuselage of an unpressurized aircraft:
   i. On an inspection panel, or is substituting for an inspection panel, provided that the probe is located in an area that does not interfere with pitot-static system or aircraft stall warning system.
   ii. On an area of the fuselage that would accommodate a like installation of an antenna, and is installed in accordance with acceptable practices such as the aircraft maintenance manual or Advisory Circulars AC 43.13-1B and AC 43.13-2B.

8. The installation of the AOA probe pressure tubes and wiring does not require adding additional openings within the aircraft wing or fuselage primary structure.
9. The installation of the AOA display does not interfere with the pilot's view of the primary flight instruments.
10. The electrical load requirements of the AOA system do not exceed the total generating capacity of the aircraft when operating in conjunction with the required equipment.
11. All electrical wiring is installed in accordance with acceptable practices such as the aircraft maintenance manual or Advisory Circulars AC 43.13-1B and AC 43.13-2B.
12. The calibration procedure must be simple, and repeatable.
13. Calibration procedures, if done in flight, can be accomplished by a pilot of average skill.

If you have any questions or need additional information, please contact Peter Rouse at 816-329-4135, or by e-mail at peter.rouse@faa.gov.

Sincerely,

Earl Lawrence
Manager, Small Airplane Directorate

Flight Instructor Checklist

Education

Date: _____/_____/_____
Airplane (Circle One): **N586PU or N591PU**
Flight Instructor: ________________
Participant Numer: ________________

		Comments
Pre-Flight:		
Verify Student's Medical & Pilot Certificate	☐	
Student's Total Cirrus Time (Approximate)	☐	
Push in AOA Circuit Breaker	☐	
Remove AOA Device Sticker	☐	
Verify Volume Toggle Switch is Down	☐	
Record "Start" Time (hh:mm)	☐	
In-Flight:		
Power Off Stall	☐	
Power On Stall	☐	
Accelerated Stall (CFI Demonstration)	☐	
Crawfordsville Municipal Airport (KCFJ):		
Touch & Go #1	☐	
Touch & Go #2	☐	
Was Visual Guidance Available?	☐	Yes / No
Frankfort Municipal Airport (KFKR):		
Full Stop #1	☐	
Full Stop #2	☐	
Was Visual Guidance Available?	☐	Yes / No
Purdue University Airport (KLAF):		
Touch & Go #1	☐	
Full Stop Landing	☐	
Was Visual Guidance Available?	☐	Yes / No
Post Flight:		
Record "Stop" Time (hh:mm)	☐	
Record Total Hobbs Time	☐	
Return Sticker to AOA Device	☐	
Pull Out AOA Circuit Breaker	☐	
Check In Aircraft/iPad (No Logbook Entry)	☐	
Return to AOA Office With Participant	☐	

Additional Notes or Comments

Flight Instructor Checklist

Evaluation - Group 1

Date: _____/_____/_____
Airplane (Circle One): N586PU or N591PU
Flight Instructor: _________________
Participant Number: _________________

		Comments
Pre-Flight:		
Verify Student's Medical & Pilot Certificate	☐	
Student's Total Cirrus Time (Approximate)	☐	
Push in AOA Circuit Breaker	☐	
Remove AOA Device Sticker	☐	
Verify Toggle Switch is Down	☐	
Record "Start" Time (hh:mm)	☐	
Crawfordsville Municipal Airport (KCFJ):		
Touch & Go #1	☐	
Touch & Go #2	☐	
Was Visual Guidance Available?	☐	Yes / No
Frankfort Municipal Airport (KFKR):		
Full Stop #1	☐	
Full Stop #2 **(Simulated Engine Failure)**	☐	
Was Visual Guidance Available?	☐	Yes / No
Purdue University Airport (KLAF):		
Touch & Go #1	☐	
Full Stop Landing	☐	
Was Visual Guidance Available?	☐	Yes / No
Post Flight:		
Record "Stop" Time (hh:mm)	☐	
Record Total Hobbs Time	☐	
Return Sticker to AOA Device	☐	
Pull Out AOA Circuit Breaker	☐	
Checkin Aircraft/iPad	☐	
Return to AOA Office With Participant	☐	

Additional Notes or Comments

Flight Instructor Checklist

Evaluation - Group 2

Date: _____/_____/_____
Airplane (Circle One): N586PU or N591PU
Flight Instructor: ________________
Participant Number: ________________

		Comments
Pre-Flight:		
Verify Student's Medical & Pilot Certificate	☐	
Student's Total Cirrus Time (Approximate)	☐	
Pull Out AOA Circuit Breaker	☐	
Leave AOA Device Sticker in Place	☐	
Verify Toggle Switch is Down	☐	
Record "Start" Time (hh:mm)	☐	
Crawfordsville Municipal Airport (KCFJ):		
Touch & Go #1	☐	
Touch & Go #2	☐	
Was Visual Guidance Available?	☐	Yes / No
Frankfort Municipal Airport (KFKR):		
Full Stop #1	☐	
Full Stop #2 **(Simulated Engine Failure)**	☐	
Was Visual Guidance Available?	☐	Yes / No
Purdue University Airport (KLAF):		
Touch & Go #1	☐	
Full Stop Landing	☐	
Was Visual Guidance Available?	☐	Yes / No
Post Flight:		
Record "Stop" Time (hh:mm)	☐	
Record Total Hobbs Time	☐	
Checkin Aircraft/iPad	☐	
Return to AOA Office With Participant	☐	

Additional Notes or Comments

Flight Instructor Checklist

Evaluation - Group 3

Date: _____/_____/_____
Airplane (Circle One): N586PU or N591PU
Flight Instructor: ________________
Participant Number: ________________

		Comments
Pre-Flight:		
Verify Student's Medical & Pilot Certificate	☐	
Student's Total Cirrus Time (Approximate)	☐	
Push in AOA Circuit Breaker	☐	
Remove AOA Device Sticker	☐	
Verify Toggle Switch is Down	☐	
Record "Start" Time (hh:mm)	☐	
Crawfordsville Municipal Airport (KCFJ):		
Touch & Go #1	☐	
Touch & Go #2	☐	
Was Visual Guidance Available?	☐	Yes / No
Frankfort Municipal Airport (KFKR):		
Full Stop #1	☐	
Full Stop #2 **(Simulated Engine Failure)**	☐	
Was Visual Guidance Available?	☐	Yes / No
Purdue University Airport (KLAF):		
Touch & Go #1	☐	
Full Stop Landing	☐	
Was Visual Guidance Available?	☐	Yes / No
Post Flight:		
Record "Stop" Time (hh:mm)	☐	
Record Total Hobbs Time	☐	
Return Sticker to AOA Device	☐	
Pull Out AOA Circuit Breaker	☐	
Checkin Aircraft/iPad	☐	
Return to AOA Office With Participant	☐	

Additional Notes or Comments

Flight Instructor Checklist

Evaluation - Group 4

Date: _____/_____/_____
Airplane (Circle One): N586PU or N591PU
Flight Instructor: ________________
Participant Number: ________________

		Comments
Pre-Flight:		
Verify Student's Medical & Pilot Certificate	☐	________________
Student's Total Cirrus Time (Approximate)	☐	________________
Pull Out AOA Circuit Breaker	☐	________________
Leave AOA Device Sticker in Place	☐	________________
Verify Toggle Switch is Down	☐	________________
Record "Start" Time (hh:mm)	☐	________________
Crawfordsville Municipal Airport (KCFJ):		
Touch & Go #1	☐	________________
Touch & Go #2	☐	________________
Was Visual Guidance Available?	☐	Yes / No
Frankfort Municipal Airport (KFKR):		
Full Stop #1	☐	________________
Full Stop #2 **(Simulated Engine Failure)**	☐	________________
Was Visual Guidance Available?	☐	Yes / No
Purdue University Airport (KLAF):		
Touch & Go #1	☐	________________
Full Stop Landing	☐	________________
Was Visual Guidance Available?	☐	Yes / No
Post Flight:		
Record "Stop" Time (hh:mm)	☐	________________
Record Total Hobbs Time	☐	________________
Checkin Aircraft/iPad	☐	________________
Return to AOA Office With Participant	☐	________________

Additional Notes or Comments

____
____
____
____
____

APPENDIX C—AOA CALIBRATION PROCEDURE

Manufactured by DepotStar, Inc.

Legacy AOA Kit
AOA Set Points Calibration Procedure

From the factory, all Alpha Systems AOA Displays are not calibrated

AOA Set Point Calibration – 3 steps:

1. Ground
2. Optimum Alpha Angle
3. Cruise

All LEDs flash then display goes dark – indicates a non-calibrated unit

#1 – Put Display into Ground Set Point Calibration Mode:

To calibrate the Ground Set Point:

- Make sure aircraft is in a zero pressure condition, preferably a no wind environment, such as in a hanger.
- Make sure power is off to the system
- Press and hold the calibration button
- Apply power
- Continue to hold the calibration button for about 6-8 seconds after power is applied

If NO LEDs are illuminated, the ground calibration procedure was a success and the ground set point has been entered into the system.

Upon releasing the calibration button, or system power up, the blue and last green LEDs will flash five times then display turns dark.

- This lets you know that the unit has successfully completed ground calibration but is not functional at this time as the last two calibration set points must be calibrated.

After this step, ground calibration will never have to be recalibrated again unless the system is reset to factory defaults.

6180 140th Ave NW, Ramsey, MN 55303
Telephone: 763.506.9990 * Fax: 763.506.9988 * Email: aoa@depotstar.com
www.alphasystemsaoa.com

Manufactured by DepotStar, Inc.

Legacy AOA Kit
AOA Set Points Calibration Procedure

#2a – Put Display into Optimum Alpha Angle (OAA) Set Point Calibration Mode:

To put the display into OAA calibration mode:

- powering the unit on
- after the unit is powered on, press and hold brightness button for eight (8) seconds

If the above two steps were done correctly the Display will flash the Green Donut three times, and then continue to repeat a flashing pattern of: two flashes every six seconds until unit is out of OAA calibration mode.

#2b –Flying the correct configuration for OAA calibration:

To get into the correct flying configuration for OAA calibration, we ask you fly:

- at a safe altitude
- at a low, constant power setting
- clean (flaps up)

Then, once in this flight configuration, slowly pitch back until your aircraft no longer increases in altitude but also does not decrease in altitude. We call this point: minimum maneuverability.

ANOTHER way to reach configuration for OAA calibration is to determine Vstall for your aircraft weight on that day, for that particular flight. Once you have determined Vstall, fly:

- *at 1.3 x Vstall*
- *straight and level (no increase or decrease in vertical speed)*
- *clean*

and calibration the OAA set point in this configuration.

#2c –Calibrating the OAA Set Point:

To calibrate the OAA set point on the Display:

- Press and release only the calibration button (recessed black button) on the Display.

If the above was done correctly, then the Display will stop flashing the Green Donut twice every six seconds and instead will:

- Illuminate the Green Donut – OAA set point successful
  - *display will go back to flashing donut, but donut will stay illuminated between flashes*
- Flash the Green Donut and Red Chevron three times – Probe Angle must be increased
- Flash the Green Donut and Yellow Chevron three times – Probe Angle must be decreased

6180 140th Ave NW, Ramsey, MN 55303
Telephone: 763.506.9990 * Fax: 763.506.9988 * Email: aoa@depotstar.com
www.alphasystemsaoa.com

Legacy AOA Kit
AOA Set Points Calibration Procedure

#3a – Put Display into Cruise Set Point Calibration Mode:

To put the display into cruise calibration mode:

- After OAA has been calibrated, press and hold brightness button for eight (8) seconds

If the above step is done correctly, then the Display will flash the Blue Bar three times, and then continue to repeat a flashing pattern of: two flashes every six seconds until unit is out of Cruise calibration mode.

#3b –Flying Configuration for Cruise Calibration:

To get into the correct flying configuration for Cruise calibration we ask you fly:

- straight and level (no increase or decrease in vertical speed)
- at 70% Power

ANOTHER way to reach configuration for Cruise calibration is to fly:

- *straight and level (no increase or decrease in vertical speed)*
- *at 70% Power*

and calibration the Cruise set point in this configuration.

#3c –Calibrating the Cruise Set Point:

To calibrate the Cruise set point on the Display:

- Press and release only the calibration button (recessed black button) on the Display.

If the above was done correctly, then the Display will stop flashing the Blue Bar twice every six seconds and instead will:

- Illuminate the Blue Bar – Cruise set point successful
- Flash the Blue Bar three times – Cruise set point unsuccessful

#4 – Storing your Calibrated OAA and Cruise Set Points:

To save both the OAA and Cruise set points, on the Display:

- press and hold brightness button for eight (8) seconds.

If the above was done correctly, then the Display will:

- Illuminate it's light segments upwards and then downwards, one by one – Calibration complete, OAA and Cruise set points are saved.

If the above was not done correctly, the Display will:

- Flash the Blue Bar three times – Cruise set point unsuccessful, systems will remain at Cruise Calibration mode

6180 140th Ave NW, Ramsey, MN 55303
Telephone: 763.506.9990 * Fax: 763.506.9988 * Email: aoa@depotstar.com
www.alphasystemsaoa.com

APPENDIX D—IRB CONSENT FORMS

RESEARCH PARTICIPANT CONSENT FORM - PARTICIPANTS

Angle of Attack Equipment General Aviation Operations

Brian Dillman, Associate Professor

Aviation Technology

Purdue University

<u>What is the purpose of this study?</u>

Purdue University, in conjunction with The Ohio State University and Florida Institute of Technology, has received funding from the FAA Center of Excellence Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS) to conduct the following research.

The central analysis of this research is the ability of an angle of attack (AOA) display to enhance the situational awareness of a pilot concerning AOA and assist in the representation of the flight approach path in conjunction with the traditional means of approach path analysis. The experimental design will be such that pilots will be trained in an actual aircraft to understand the dynamics of AOA displays and their functionality and use in regards to angle of attack awareness and the proximity to a stalled condition. You, along with approximately 50 other individuals, have been selected to participate in this study because you meet the flight experience qualifications. These qualifications include total flight hours between 50 and 200, as well as a Private Pilot Certificate.

<u>What will I do if I choose to be in this study?</u>

You, as a participant, will be divided into one of four possible groups shown in the table below.

		Education	
		None	AOA Ground Instruction
AOA Displays	No Access	10 Participants	10 Participants
	AOA Display Access	10 Participants	10 Participants

Prior to any training or flight evaluation, you will be asked to complete a survey regarding your flight experience and your knowledge of angle of attack in regards to its use for approach stabilization. You must complete this survey to progress with the experiment.

If assigned to a group scheduled to receive training on the use of angle of attack devices. You will receive approximately .5 hours of ground training and 1.5 hours flight training with a certified flight instructor.

Regardless of the group you are assigned, you will then all fly visual approaches to landing during a 2 hour evaluation period. An evaluator will be present in the cockpit that is a certified flight instructor. The certified flight instructor is present primarily for safety purposes. However, because of their presence in the cockpit, they will also be taking notes on your performance. Your performance will be measured via accuracy of approach path stabilization and the length of time between the recognition of a deviation situation and a corresponding input for correction.

Finally, you will complete a qualitative, open-ended interview on the your impression of angle of attack displays for stabilized approaches and whether or not the training module was sufficient to facilitate proficiency in analysis and control. Either the principal investigator or a co-investigator will be conducting this interview.

How long will I be in the study?

If assigned to a group in which you will receive training prior to the evaluation, you will receive one session of ground training lasting .5 hours, one session of flight training lasting 1.5 hours, and then a 2 hour evaluation session. These sessions may be broken up over numerous days. If assigned to a group without training prior to evaluation, you will only complete the 2 hour evaluation session. **The total time commitment will vary from 3 to 6 total hours over 5 days**.

What are the possible risks or discomforts?

The risk associated with this study is not greater than that of every day activates associated with the Professional Flight Program. The presence of the flight instructor in the cockpit is for observational purposes only, but will assist in the event of an emergency.

It is possible that a breach of confidentiality may occur. They provisions taken to ensure this does not occur are outlined in the confidentiality section of this document. The device installed does not pose any additional safety risk than that of normal flight.

Are there any potential benefits?

Benefits to you are the provision of information that could potentially help the pilots to better interpret the flight path & aircraft attitude relationship. Additionally, you will receive between 2 and 3.5 flight hours at no cost. Benefits gained by the general aviation community are potentially the reduction of loss of control incidents/accidents and an improvement of safety in general aviation.

What alternatives are available?

You will be randomly assigned to one of four different experimental groups. You, as a participant, do not have control over which group you are assigned to. Participation in this study is completely voluntary and you may choose not to participate in this study.

Will I receive payment or other incentive?

As a participant, you will be monetarily compensated for this study. Compensation is allocated per flight hour in the amount of $10 per hour. All payments will be made in cash and checks.

Information will be recorded on each individual paid for their participation and will be reported to the business office. Provisions for international students will be made. In the event that you choose to withdraw from the study, you will be compensated based on the total flight hours flown at the time of withdrawal.

Are there costs to me for participation?

You are responsible for transportation to and from the Purdue University Airport where the study will be conducted.

Will information about me and my participation be kept confidential?

The project's research records may be reviewed by the principal investigator, co-investigators, and by departments at Purdue University responsible for regulatory and research oversight.

You will be assigned a random number code determined using a random number generator. Your results will only be identifiable by the randomly assigned code. Recorded data, both physical and numerical will be stored in the office of the principal investigator, Brian Dillman. This office will remain locked when he is not present. Any physical identifiers found in the video recordings will be erased, along with the video, after use. Any and all personal information will remain confidential and only be viewable by the principal and co-investigators. All personal data will be destroyed upon the completion of the experiment (Expected: September 31, 2014).

Flight instructors present in the cockpit during your training and evaluation will have signed a confidentiality agreement to ensure that your privacy is maintained.

What are my rights if I take part in this study?

Your participation in this study is voluntary. You may choose not to participate or, if you agree to participate, you can withdraw your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Any re-existing relationships you may have with a participant, evaluator, or investigator will not be affected if you choose to withdraw form this study.

If you choose to withdraw from this study, please alert the principal investigator, a co-investigator, or the flight instructor observing the flight at any time. If you wish to withdraw from the study after data has already been collected, please contact the principal investigator or a co-investigator.

However, upon completion of the experiment, when the code identifier key is destroyed, it will not be possible to withdraw your data.

Who can I contact if I have questions about the study?

If you have questions, comments or concerns about this research project, please contact any of the researchers listed below:

Brian Dillman	Principal Investigator	765-494-9978	dillman@purdue.edu
Gil Jones	Co-Investigator	203-927-1421	jones273@purdue.edu
Lucas Rudari	Co-Investigator	765-637-1361	lrudari@purdue.edu

If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu) or write to:

Human Research Protection Program - Purdue University

Ernest C. Young Hall, Room 1032

155 S. Grant St.

West Lafayette, IN 47907-2114

<u>Documentation of Informed Consent</u>

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research study, and my questions have been answered. I am prepared to participate in the research study described above. I will be offered a copy of this consent form after I sign it.

______________________________________ ________________________

Participant's Signature Date

____

Participant's Name

______________________________________ ________________________

Researcher's Signature Date

RESEARCH PARTICIPANT CONSENT FORM - PARTICIPANTS

Angle of Attack Equipment General Aviation Operations

Steve Cusick, Associate Professor

College of Aeronautics

Florida Institute of Technology

What is the purpose of this study?

Florida Institute of Technology, in conjunction with The Ohio State University and Purdue University, has received funding from the FAA Center of Excellence Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS) to conduct the following research.

The purpose of this study is to compare how use of an angle of attack (AOA) gauge influences participant's knowledge and awareness of aircraft stalls in an experimental setting. The experimental design will be such that pilots will be trained in an actual aircraft to understand the dynamics of AOA displays and their functionality and use in regards to angle of attack awareness and the proximity to a stalled condition.

The research question will be: does the usage of an Angle of Attack indicator increase student performance and situational awareness of stall angle when completing a straight in approach to landing?

What will I do if I choose to be in this study?

Prior to any training or flight evaluation, you will be asked to complete a survey regarding your flight experience and your knowledge of angle of attack in regards to its use for approach stabilization. You must complete this survey to progress with the experiment.

Participants will receive a ground briefing and you will then all fly visual approaches to landing during a 2 hour evaluation period. An evaluator will be present in the cockpit that is a certified flight instructor. The certified flight instructor is present primarily for safety purposes. However, because of their presence in the cockpit, they will also be taking notes on your performance. Your performance will be measured via accuracy of approach path stabilization and the length of time between the recognition of a deviation situation and a corresponding input for correction.

Finally, you will complete a qualitative, open-ended interview on your impression of angle of attack displays for stabilized approaches.

How long will I be in the study?

The total time commitment will vary from 3 to 6 total hours over 5 days.

What are the possible risks or discomforts?

The risk associated with this study is not greater than that of everyday activities associated with the Flight Program. The presence of the flight instructor in the cockpit is for observational purposes only, but will assist in the event of an emergency.

The provisions taken to ensure this does not occur are outlined in the confidentiality section of this document. The device installed does not pose any additional safety risk than that of normal flight.

Are there any potential benefits?

The potential benefits are educational in nature. Learning about Angle of Attack indicator systems and their potential for reducing loss of control is of benefit to all pilots that are unaware of these systems. Benefits to the General Aviation community are unknown, but could assist in the reduction of loss of control accidents.

Will I receive payment or other incentive?

You will be compensated for this study in flight time. Flight time for each participant is expected to be 2.5 to 3 hours of flight time. Those participants that complete the study will be provided a stipend of $100 as compensation in addition to the flight time.

Are there costs to me for participation?

You are responsible for transportation to and from the Melbourne International Airport and the FIT Aviation Campus where the study will be conducted.

Will information about me and my participation be kept confidential?

The project's research records may be reviewed by the principal investigator, co-investigators, and by departments at Florida Institute of Technology responsible for regulatory and research oversight.

You will be assigned a random number code determined using a random number generator. Your results will only be identifiable by the randomly assigned code. Recorded data, both physical and numerical will be stored in the office of the principal investigator, Steve Cusick. This office will remain locked when he is not present. Any and all personal information will remain confidential and only be viewable by the principal and co-investigators. All personal data will be destroyed upon the completion of the experiment (Expected: December 31, 2014).

Flight instructors present in the cockpit during your training and evaluation will have signed a confidentiality agreement to ensure that your privacy is maintained.

What are my rights if I take part in this study?

You will be randomly assigned to one of four different experimental groups. As a participant, you do not have control over which group you are assigned.

Your participation in this study is voluntary. You may choose not to participate or, if you agree to participate, you can withdraw your participation at any time without penalty or loss of benefits to which you are otherwise entitled. If you withdraw, the $100 stipend for completing the study will not be provided. You will receive the flight time that you have completed up until the time you choose to withdraw. Any of your data that has been collected will be removed from the study and destroyed if you so choose. Any re-existing relationships you may have with a participant, evaluator, or investigator will not be affected if you choose to withdraw form this study.

If you choose to withdraw from this study, please alert the principal investigator, a co-investigator, or the flight instructor observing the flight at any time. If you wish to withdraw from the study after data has already been collected, please contact the principal investigator or a co-investigator.

However, upon completion of the experiment, when the code identifier key is destroyed, it will not be possible to withdraw your data.

Who can I contact if I have questions about the study?

If you have questions, comments or concerns about this research project, please contact any of the researchers listed below:

Steve Cusick Principal Investigator	(321) 674-7628	scusick@fit.edu
Scott Winter Co-Investigator	(321) 674-7639	swinter@fit.edu
Dennis Wilt Co-Investigator	(757) 784-8113	dwilt2012@fit.edu

If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Chairman of the Institutional Review Board of the Florida Institute of Technology, Dr. Lisa Steelman at (321) 674-7316 or e-mail (lsteelma@fit.edu).

Documentation of Informed Consent

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research study, and my questions have been answered. I am prepared to participate in the research study described above. I will be offered a copy of this consent form after I sign it.

______________________________________ _______________________

Participant's Signature Date

____

Participant's Printed Name

______________________________________ _______________________

Researcher's Signature Date

RESEARCH PARTICIPANT CONSENT FORM - PARTICIPANTS

Angle of Attack Equipment General Aviation Operations

Shawn Pruchnicki, Research Coordinator

Center for Aviation Studies

The Ohio State University

What is the purpose of this study?

The Ohio State University, in conjunction with Purdue University and Florida Institute of Technology, has received funding from the FAA Center of Excellence Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS) to conduct the following research.

The central analysis of this research is the ability of an angle of attack (AOA) display to enhance the situational awareness of a pilot concerning AOA and assist in the representation of the flight approach path in conjunction with the traditional means of approach path analysis. The experimental design will be such that pilots will be trained in an actual aircraft to understand the dynamics of AOA displays and their functionality and use in regards to angle of attack awareness and the proximity to a stalled condition. You, along with approximately 40 other individuals, have been selected to participate in this study because you meet the flight experience qualifications. These qualifications include total flight hours between 50 and 200, as well as a Private Pilot Certificate

What will I do if I choose to be in this study?

You, as a participant, will be randomly assigned into one of four possible groups shown in the table below.

		Education	
		None	AOA Ground Instruction
AOA Displays	No Access	10 Participants	10 Participants
	AOA Display Access	10 Participants	10 Participants

Prior to any training or flight evaluation, you will be asked to complete a survey regarding your flight experience and your knowledge of angle of attack in regards to its use for approach stabilization. You must complete this survey to progress with the experiment.

If assigned to a group scheduled to receive training on the use of angle of attack devices. You will receive approximately .5 hours of ground training and 1.5 hours flight training with a certified flight instructor.

Regardless of the group you are assigned to, you will then fly several touch-n-goes in visual conditions during a 2 hour period. A certified flight instructor will be with you at all times and is there to act primarily for safety purposes. However, because of their presence in the cockpit, they will also be collecting data as you perform several maneuvers. Your performance will be measured via accuracy of approach path stabilization and the length of time between the recognition of a deviation situation and a corresponding input for correction.

Finally, you will complete a qualitative, open-ended interview on the your impression of angle of attack displays for stabilized approaches and whether or not the training module was sufficient to facilitate proficiency in analysis and control. Either the principal investigator or a co-investigator will be conducting this interview.

How long will I be in the study?

If assigned to a group in which you will receive training prior to the evaluation, you will receive one session of ground training lasting .5 hours, one session of flight training lasting 1.5 hours, and then a 2 hour evaluation session. These sessions may be broken up over numerous days. If assigned to a group without training prior to evaluation, you will only complete the 2 hour evaluation session. The total time commitment will vary from 3 to 6 total hours depending on your group assignment.

What are the possible risks or discomforts?

The risk associated with this study is not greater than that of every day activates associated with the Professional Pilot Program. The presence of the flight instructor in the cockpit is for observational purposes only, but will assist in the event of an emergency.

It is possible that a breach of confidentiality may occur. They provisions taken to ensure this does not occur are outlined in the confidentiality section of this document. The device installed does not pose any additional safety risk than that of normal flight.

Are there any potential benefits?

There are no direct benefits to the participant. Indirect benefits include the provision of information that could potentially help the pilots to better interpret the flight path & aircraft attitude relationship. Additionally, you will receive between 2 and 3.5 flight hours at no cost. Benefits gained by the general aviation community are potentially the reduction of loss of control incidents/accidents and an improvement of safety in general aviation.

What alternatives are available?

You will be randomly assigned to one of four different experimental groups. You, as a participant, do not have control over which group you are assigned to. Participation in this study is completely voluntary and you may choose not to participate in this study.

Will I receive payment or other incentive?

As a participant, you will be monetarily compensated for this study. Compensation is allocated per flight hour in the amount of $10 per hour. Depending on your group assignment, you will have to fly 2 or 3.5 hours. Your maximum compensation is $35, your minimum compensation is $20. All payments will be made by check.

Information will be recorded on each individual paid for their participation and will be reported to the business office. Provisions for international students will be made. In the event that you choose to withdraw from the study, you will be compensated based on the total flight hours flown at the time of withdrawal.

Are there costs to me for participation?

You are responsible for transportation to and from The Ohio State University Airport where the study will be conducted.

Will information about me and my participation be kept confidential?

The project's research records may be reviewed by the principal investigator, co-investigators, and by departments/centers at the Ohio State University responsible for regulatory and research oversight.

You will be assigned a random number code determined using a random number generator. Your results will only be identifiable by the randomly assigned code. Recorded data, both physical and numerical will be stored in the office of the co-investigator, Shawn Pruchnicki. This office will remain locked when he is not present. Any physical identifiers found in the video recordings will be erased, along with the video, after use. Any and all personal information will remain confidential and only be viewable by the principal and co-investigators. All personal data will be destroyed upon the completion of the experiment (Expected: December 31, 2014).

Flight instructors present in the cockpit during your training and evaluation will have signed a confidentiality agreement to ensure that your privacy is maintained.

What are my rights if I take part in this study?

Your participation in this study is voluntary. You may choose not to participate or, if you agree to participate, you can withdraw your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Any re-existing relationships you may have with a participant, evaluator, or investigator will not be affected if you choose to withdraw form this study. Furthermore, if you choose to withdraw from the study, there will be no effect on the grade you receive in any course if you are a student at this university.

If you choose to withdraw from this study, please alert the principal investigator, a co-investigator, or the flight instructor observing the flight at any time. If you wish to withdraw from the study after data has already been collected, please contact the principal investigator or a co-investigator. However, upon completion of the experiment, when the code identifier key is destroyed, it will not be possible to withdraw your data.

Who can I contact if I have questions about the study?

If you have questions, comments or concerns about this research project, please contact any of the researchers listed below:

Seth Young Principal Investigator	(614) 292-4556	young.1460@osu.edu
Shawn Pruchnicki Co-Investigator	(614) 565-8795	pruchnicki.4@osu.edu
Marshall Pomeroy Research Assistant	(814) 574-8764	pomeroy.34@osu.edu
Justin Abrams Research Assistant	(860) 502-9401	abrams.130@osu.edu

If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Office of Responsible Research Practices: Human Research Protection Program at (614) 688-8457, anonymously at (800) 294-9350, email hsconcerns@osu.edu or write to:

Institutional Review Board
c/o Office of Responsible Research Practices
300 Research Administration Building
1960 Kenny Road
Columbus, OH 43210

Documentation of Informed Consent

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research study, and my questions have been answered. I am prepared to participate in the research study described above. I will be offered a copy of this consent form after I sign it.

____________________________________ ______________________

Participant's Signature Date

____

Participant's Name

____________________________________ ______________________

Researcher's Signature Date

APPENDIX E—PILOT QUESTIONNAIRES

Pre-Flight Survey - Angle of Attack Equipment in General Aviation Operations

1. Participant Identification Number (Entered by Examiner)

2. Gender

[ ] Male

[ ] Female

3. Age _____________

4. What Certifications and Ratings do you hold? (Select all that apply)

[ ] Private

[ ] Instrument
[ ] Commercial
[ ] Multi-Engine
[ ] CFI
[ ] CFII
[ ] MEI
[ ] ATP

5. What is your total flight hour experience level?

Number of flight hours ______(total time)

6. During a visual approach to landing, what mechanisms do you use to assist with your approach?

7. To the best of your ability, please describe what causes a wing to stall.

8. To the best of your ability please describe an accelerated stall.

9. To the best of your ability, please describe angle of attack.

10. Which of the following best describes your use of angle of attack devices?

[ ] I have never used an angle of attack device

[ ] I have some experience with angle of attack devices

[ ] I often use angle of attack devices

11. To the best of your ability, please describe how an angle of attack device works.

Post Flight Survey - Angle of Attack Equipment in General Aviation Operations
(Participants **without** access to an AOA display)

1. Participant Identification Number

2. Have you heard of an Angle of Attack system?

[ ] Yes

[ ] No

3. If the answer to question number 2 is yes, describe how you think an Angle of Attack system works.

4. What instruments and visual cues do you use to assist you in your approach?

5. During what phase of the approach would you most often use an AoA indicator and visual cues?

6. Did you encounter a situation while flying as part of this study in which these instruments and visual cues prevented a stall situation (not intentional)?

[ ] Yes

[ ] No

7. Do you have any other additional comments about the study?

Post Flight Survey - Angle of Attack Equipment in General Aviation Operations
(Participants **with** access to an AoA display)

1. Participant Identification Number

2. To the best of your ability, please describe how an angle of attack device works.

3. Did you find that the angle of attack device helped with your approach to landing?

   [ ] Yes

   [ ] No

4. How did you use the device to assist with your approach?

5. If yes, during what phase of the approach did you most often use the device?

6. Did you encounter a situation in which the angle of attack device prevented a stall situation?

7. Do you believe that angle of attack devices would be useful in the cockpit of any aircraft you are flying? Why?

8. What could be better about the device?

9. Did you find the angle of attack device to be distracting? If so, how?

10. Could the device be better positioned in the cockpit? If so, how?

11. Were there any drawbacks to the device that you could share?

12. Did this study change your understanding of angle of attack? If so, how?

13. Are there other phases of flight that this device may be useful?

14. If you received training on AoA as part of this study, are there any aspects of the training that need improvement?

15. Do you have any other additional comments?

APPENDIX F—OSU SAFETY PILOT REFERENCE GUIDE

Instructor Quick Reference Guide: AOA Research Flights

Angle of Attack Equipment in General Aviation Operations

Group 1: Receives AoA Training / Allowed AoA Access

In this condition participants receive training on the use of the AoA and have access to the AoA indicator during the data collection.

This group has both experimental conditions applied allowing researchers to compare findings with the other experimental and control groups. This condition has **two flights**: one to provide AoA training and a second flight to collect data during approach and landings with the AoA ON.

Group 2: Receives AoA Training / No AoA Access

In this condition participants are trained on the use of the AoA but do not have access to the AoA indicator during the data collection.

The purpose of this group is to investigate participants that must revert back to not having an AoA during flight and seeks to determine if the AoA training provides an educational transfer of AoA information. This condition has **two flights**: one to provide AoA training and a second flight to collect data during approach and landings with the AoA OFF.

Group 3: No AoA Training / Allowed AoA Access

In this condition participants do not receive training on the use of the AoA but have access to the AoA indicator during the data collection.

Having a group that does not receive AoA training but access in flight to an AoA indicator will help to determine if the AoA education and training is beneficial. It also simulates a scenario where pilots fly an aircraft with an AoA installed but have not received training on the use of the AoA. This condition has only one flight to collect data during approach and landings with the AoA ON.

Group 4: No AoA Training / No AoA Access

In this condition participants do not receive AoA training and do not have access to the AoA indicator during the data collection.

This is the control group. It allows investigators to compare pilots in this group to pilots in groups 1, 2, or 3 who have experimental conditions applied. This condition has only one flight to collect data during approach and landings with the AoA OFF.

What is "AoA Training"?

Training involves two parts:

1. Watching the AoA training video
2. In-flight instruction on the use of AoA during the following maneuvers: power off stall, power on stall, accelerated stall (instructor demo only) and 6 takeoffs/landings (2 at each airport)

What is "AoA Access"?

AoA access refers to the use of the AoA indicator by the participant during the data collection flight.

All participants complete a flight where flight data is recorded. However, only two of the groups will have access to the AoA indicator during this flight.

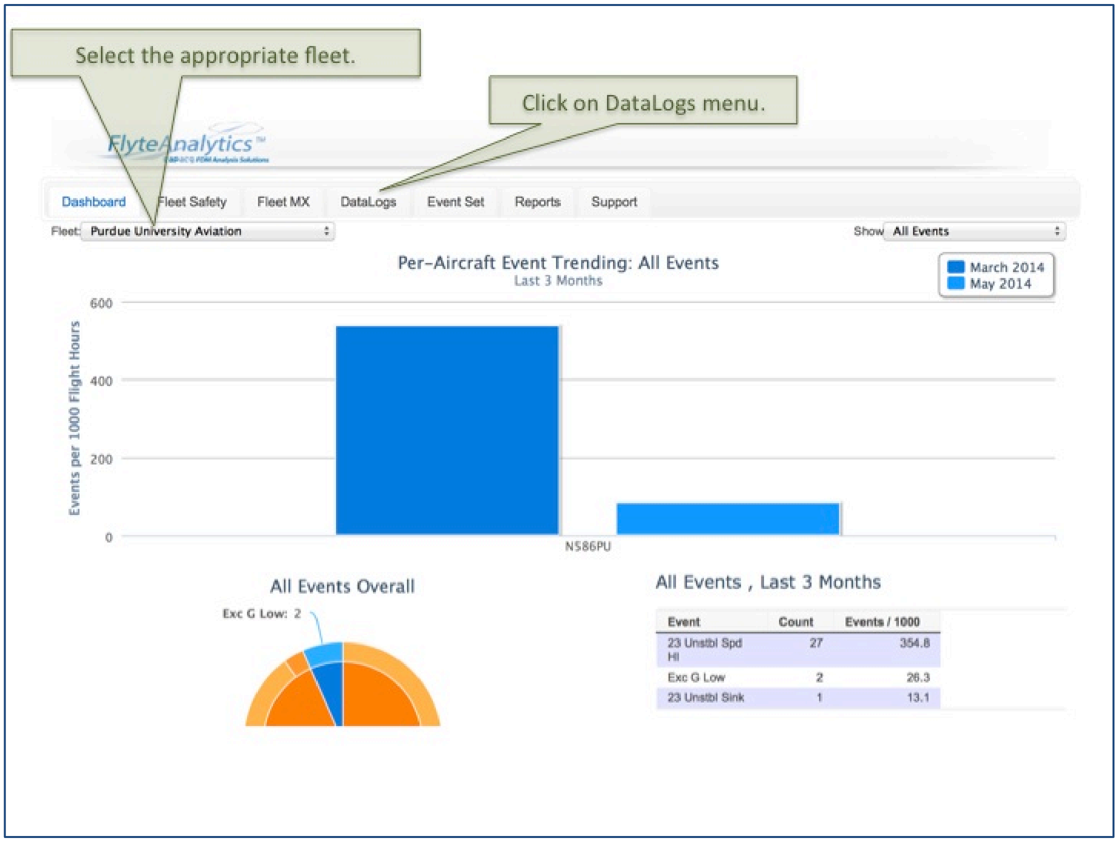
Center for Aviation Studies PEGASAS The Ohio State University

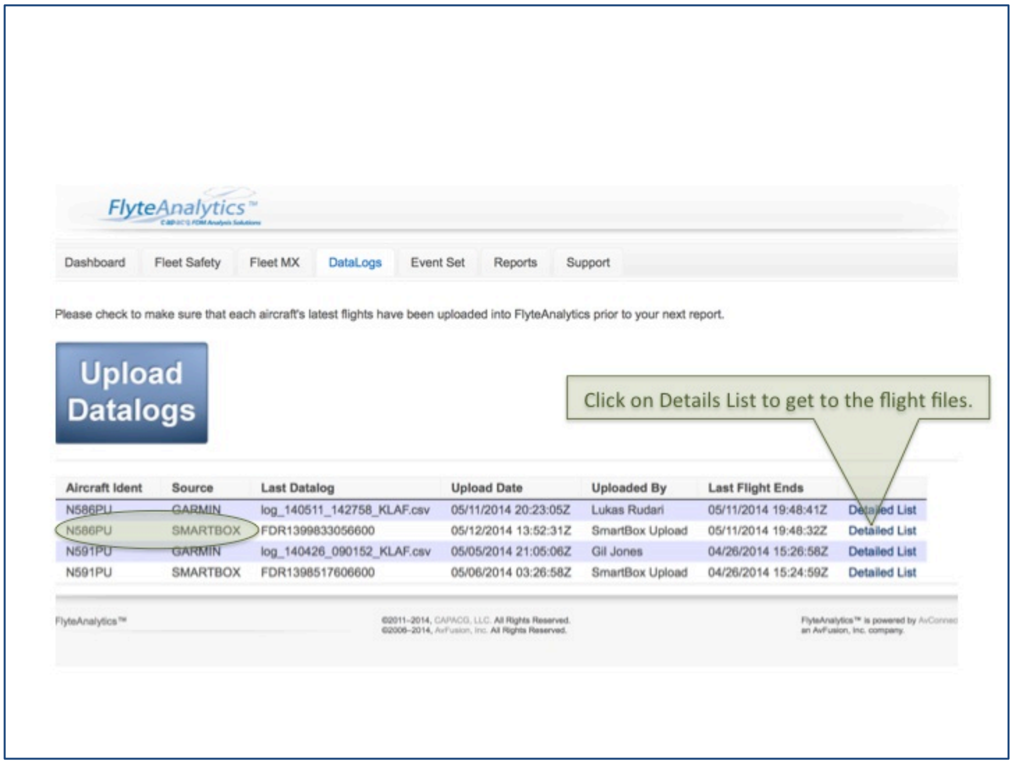
Please feel free to contact the research team with any questions!
Shawn Pruchnicki (614) 595-8765 Marshall Pomeroy (814) 574-8764 Justin Abrams (860)502-9401

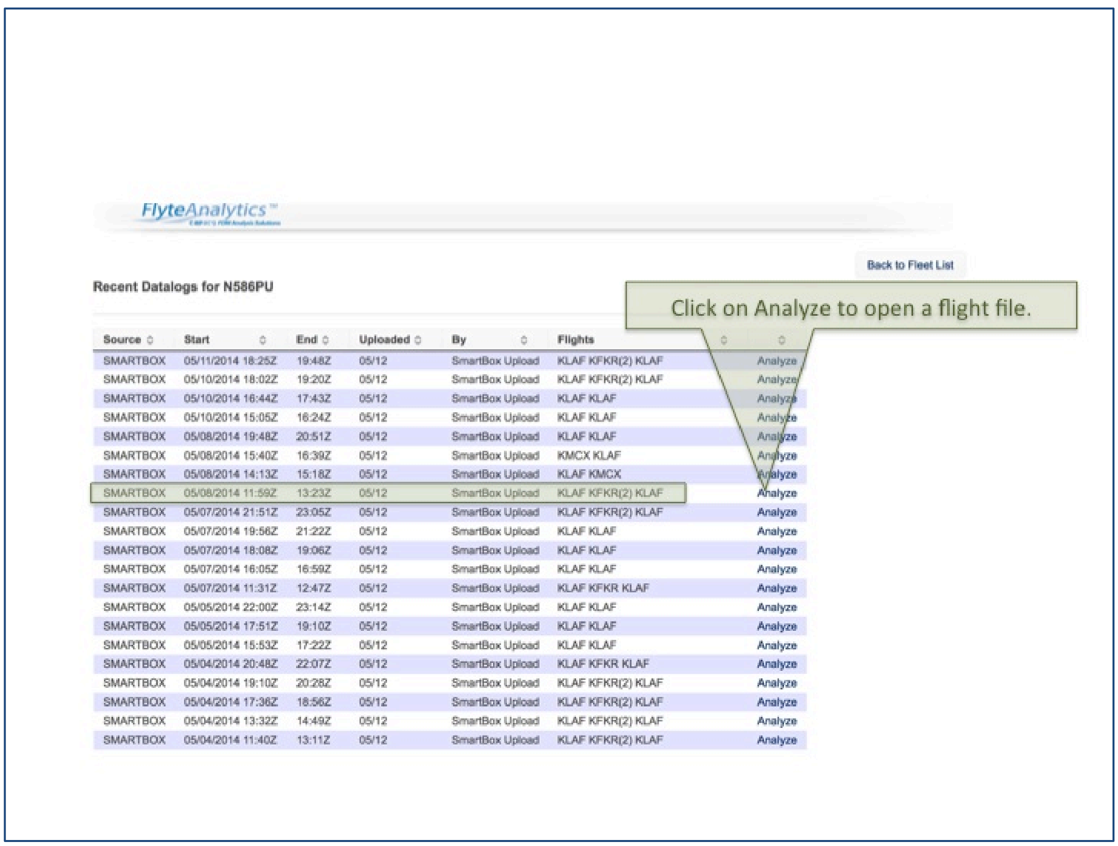
APPENDIX G—PROCEDURE FOR FPA ANALYSIS

Procedure: How to analyze FPA using FlyteAnalytics

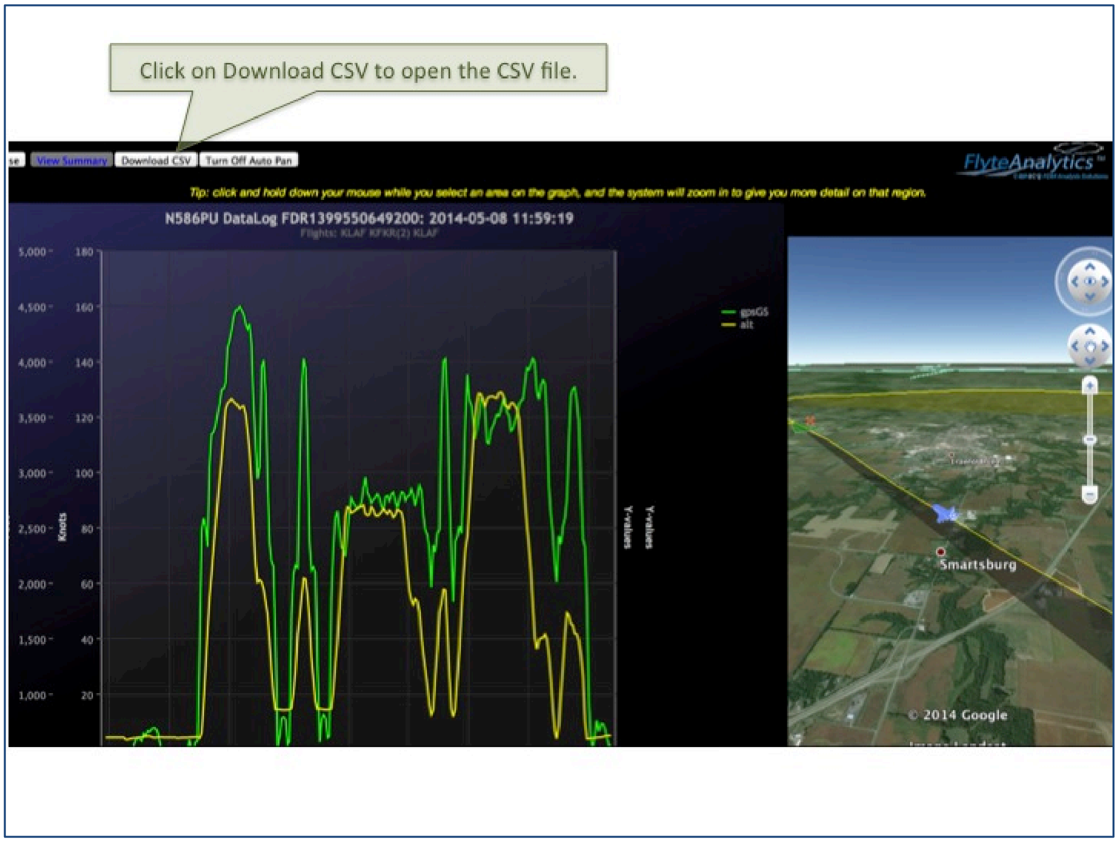
The first thing to do is to get used to FlyteAnalytics (FA) Portal and how to locate a specific flight listed as participant in the study. The flights are organized by aircraft and time. So, first determine which aircraft will be used to extract the data and then locate its file using the date and time of flight. Remember that FA portal uses GMT, so it is necessary to add hours to the time indicated by the university to find the actual flight on FA portal. There might also be some slight differences (5 minutes maximum) between what the university provides and what is recorded on FA Portal. The following figures help you with FA Portal design.




FlyteAnalytics™
Dashboard
Fleet Safety
Fleet MX
DataLogs
Event Set
Reports
Support
Please check to make sure that each aircraft's latest flights have been uploaded into FlyteAnalytics prior to your next report.
Upload Datalogs
Click on Details List to get to the flight files.
Aircraft Ident | Source | Last Datalog | Upload Date | Uploaded By | Last Flight Ends
N586PU | GARMIN | log_140511_142758_KLAF.csv | 05/11/2014 20:23:05Z | Lukas Rudari | 05/11/2014 19:48:41Z | Detailed List
N586PU | SMARTBOX | FDR1399833056600 | 05/12/2014 13:52:31Z | SmartBox Upload | 05/11/2014 19:48:32Z | Detailed List
N591PU | GARMIN | log_140426_090152_KLAF.csv | 05/05/2014 21:05:06Z | Gil Jones | 04/26/2014 15:26:58Z | Detailed List
N591PU | SMARTBOX | FDR1398517606600 | 05/06/2014 03:26:58Z | SmartBox Upload | 04/26/2014 15:24:59Z | Detailed List
FlyteAnalytics™


FlyteAnalytics™
Back to Fleet List
Recent Datalogs for N586PU
Click on Analyze to open a flight file.
Source | Start | End | Uploaded | By | Flights
SMARTBOX | 05/11/2014 18:25Z | 19:48Z | 05/12 | SmartBox Upload | KLAF KFKR(2) KLAF | Analyze
SMARTBOX | 05/10/2014 18:02Z | 19:20Z | 05/12 | SmartBox Upload | KLAF KFKR(2) KLAF | Analyze
SMARTBOX | 05/10/2014 16:44Z | 17:43Z | 05/12 | SmartBox Upload | KLAF KLAF | Analyze
SMARTBOX | 05/10/2014 15:05Z | 16:24Z | 05/12 | SmartBox Upload | KLAF KLAF | Analyze
SMARTBOX | 05/08/2014 19:48Z | 20:51Z | 05/12 | SmartBox Upload | KLAF KLAF | Analyze
SMARTBOX | 05/08/2014 15:40Z | 16:39Z | 05/12 | SmartBox Upload | KMCX KLAF | Analyze
SMARTBOX | 05/08/2014 14:13Z | 15:18Z | 05/12 | SmartBox Upload | KLAF KMCX | Analyze
SMARTBOX | 05/08/2014 11:59Z | 13:23Z | 05/12 | SmartBox Upload | KLAF KFKR(2) KLAF | Analyze
SMARTBOX | 05/07/2014 21:51Z | 23:05Z | 05/12 | SmartBox Upload | KLAF KFKR(2) KLAF | Analyze
SMARTBOX | 05/07/2014 19:56Z | 21:22Z | 05/12 | SmartBox Upload | KLAF KLAF | Analyze
SMARTBOX | 05/07/2014 18:08Z | 19:06Z | 05/12 | SmartBox Upload | KLAF KLAF | Analyze
SMARTBOX | 05/07/2014 16:05Z | 16:59Z | 05/12 | SmartBox Upload | KLAF KLAF | Analyze
SMARTBOX | 05/07/2014 11:31Z | 12:47Z | 05/12 | SmartBox Upload | KLAF KFKR KLAF | Analyze
SMARTBOX | 05/05/2014 22:00Z | 23:14Z | 05/12 | SmartBox Upload | KLAF KLAF | Analyze
SMARTBOX | 05/05/2014 17:51Z | 19:10Z | 05/12 | SmartBox Upload | KLAF KLAF | Analyze
SMARTBOX | 05/05/2014 15:53Z | 17:22Z | 05/12 | SmartBox Upload | KLAF KLAF | Analyze
SMARTBOX | 05/04/2014 20:48Z | 22:07Z | 05/12 | SmartBox Upload | KLAF KFKR KLAF | Analyze
SMARTBOX | 05/04/2014 19:10Z | 20:28Z | 05/12 | SmartBox Upload | KLAF KFKR(2) KLAF | Analyze
SMARTBOX | 05/04/2014 17:36Z | 18:56Z | 05/12 | SmartBox Upload | KLAF KFKR(2) KLAF | Analyze
SMARTBOX | 05/04/2014 13:32Z | 14:49Z | 05/12 | SmartBox Upload | KLAF KFKR(2) KLAF | Analyze
SMARTBOX | 05/04/2014 11:40Z | 13:11Z | 05/12 | SmartBox Upload | KLAF KFKR(2) KLAF | Analyze

After identifying the correct flight file, download the CSV file and save it in a hard drive or in the cloud. The idea is to have all flights saved in a location in which they can be reanalyzed as many times as necessary. It is also important to remember that some changes can be made to the study parameters or methods and having the file ready to change is essential to avoid working on the same file again if necessary.



On each flight file, copy the spreadsheet named "Approach X" to the file and start looking for the approaches that are the scope of the study. The best way of doing it is going to the end of the file and move backwards, looking at the altitude as a parameter to limit each approach. After establishing each approach boundaries (use a background color to make it easier to identify them), copy and paste the parameters listed in the "Approach" spreadsheet and the calculations will be completed automatically. Copy the calculated cells to the "Data Collection" MS Excel file.

After finishing each approach, rename the spreadsheet as "Approach Y", using Y to identify the approach, numbering from 1 to 6, from the last to the first. This way, there is standardization among all files. In the end of each flight, each flight file should have 7 spreadsheets, one with the flight data and 6 with approaches calculations. Save the file and move to the next flight.

APPENDIX H—DATA ORGANIZATION

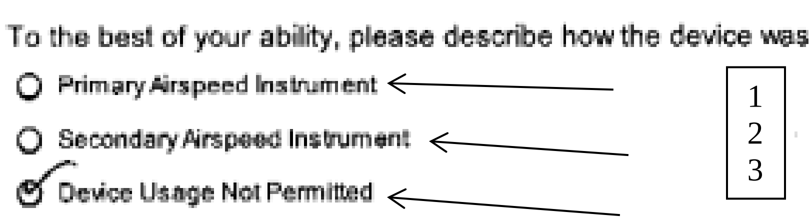
Procedure: Organizing Flight Data

<u>Adding evaluation sheet info to the flight list</u>

To add the flight information, the first thing that should be done is creating a spreadsheet to hold all of the information. It should have 8 columns, plus one column for each airport. The columns should be the date of the flight, time of the flight, aircraft ID, evaluation group number, “how device was used,” “student performance,” “frequency of use,” “total Cirrus time,” and then one column for whether visual guidance was used at each airport. The spreadsheet may look something like this:

Date	Start Time	Aircraft	Eval Group	How device was used	Student Performance	Frequency of use	Total Cirrus time	Visual Frank.	Visual Craw.	Visual Laf.
4/9/2014	0935	N586PU	2	3	1	3	140	NO	YES	YES
4/9/2014	1146	N586PU	4	3	1	1	187	NO	YES	YES
4/9/2014	1152	N591PU	3	2	1	2	120	NO	YES	YES
4/9/2014	1718	N586PU	3	2	4	2	80	NO	YES	YES
4/11/2014	0949	N591PU	4	3	1	1	60	NO	YES	YES
4/11/2014	1134	N591PU	3	2	2	2	84	NO	YES	YES
4/12/2014	0939	N586PU	3	2	3	3	65	NO	YES	YES
4/12/2014	0935	N591PU	4	3	1	1	0	NO	YES	YES
4/15/2014	1748	N586PU	3	3	2	2	60	NO	YES	YES
4/18/2014	1746	N591PU	3	3	2	2	120	NO	YES	YES
4/22/2014	1759	N591PU	1	1	2	4	86	NO	YES	YES
4/26/2014	1156	N586PU	2	2	2	2	102	NO	YES	YES
4/30/2014	0736	N586PU	1	X	1	X	185	NO	YES	YES
5/4/2014	0745	N586PU	1	2	1	4	140	NO	YES	YES
5/4/2014	0933	N586PU	2	3	4	1	80	NO	YES	YES
5/4/2014	1338	N586PU	1	2	2	2	80	NO	YES	YES
5/4/2014	1650	N586PU	4	3	4	1	50	NO	YES	YES
5/7/2014	0733	N586PU	1	2	4	2	90	NO	YES	YES
5/7/2014	1754	N586PU	1	2	1	2	39	NO	YES	YES
5/8/2014	0758	N586PU	1	2	1	2	190	NO	YES	YES
5/10/2014	1404	N586PU	1	2	2	3	180	NO	YES	YES
5/11/2014	1426	N586PU	2	3	2	1	150	NO	YES	YES
6/17/2014	0950	N586PU	4	3	4	2	4	NO	YES	YES
7/2/2014	1310	N586PU	4	3	2	1	150	NO	YES	YES
7/2/2014	1621	N586PU	2	3	2	1	100	NO	YES	YES
7/9/2014	1343	N586PU	2	3	3	1	91	NO	YES	YES
7/9/2014	1520	N586PU	2	3	2	1	80	NO	YES	YES

Each evaluation sheet contains a good amount of information, but not all of it will be entered into the spreadsheet. For total cirrus time, simply enter in the recorded amount of time. The same goes for the time, date, aircraft, and EvalGRP. The 3 other columns correspond to multiple choice questions filled out by the instructor. For these, assign a number to each answer starting with 1 for the top answer.



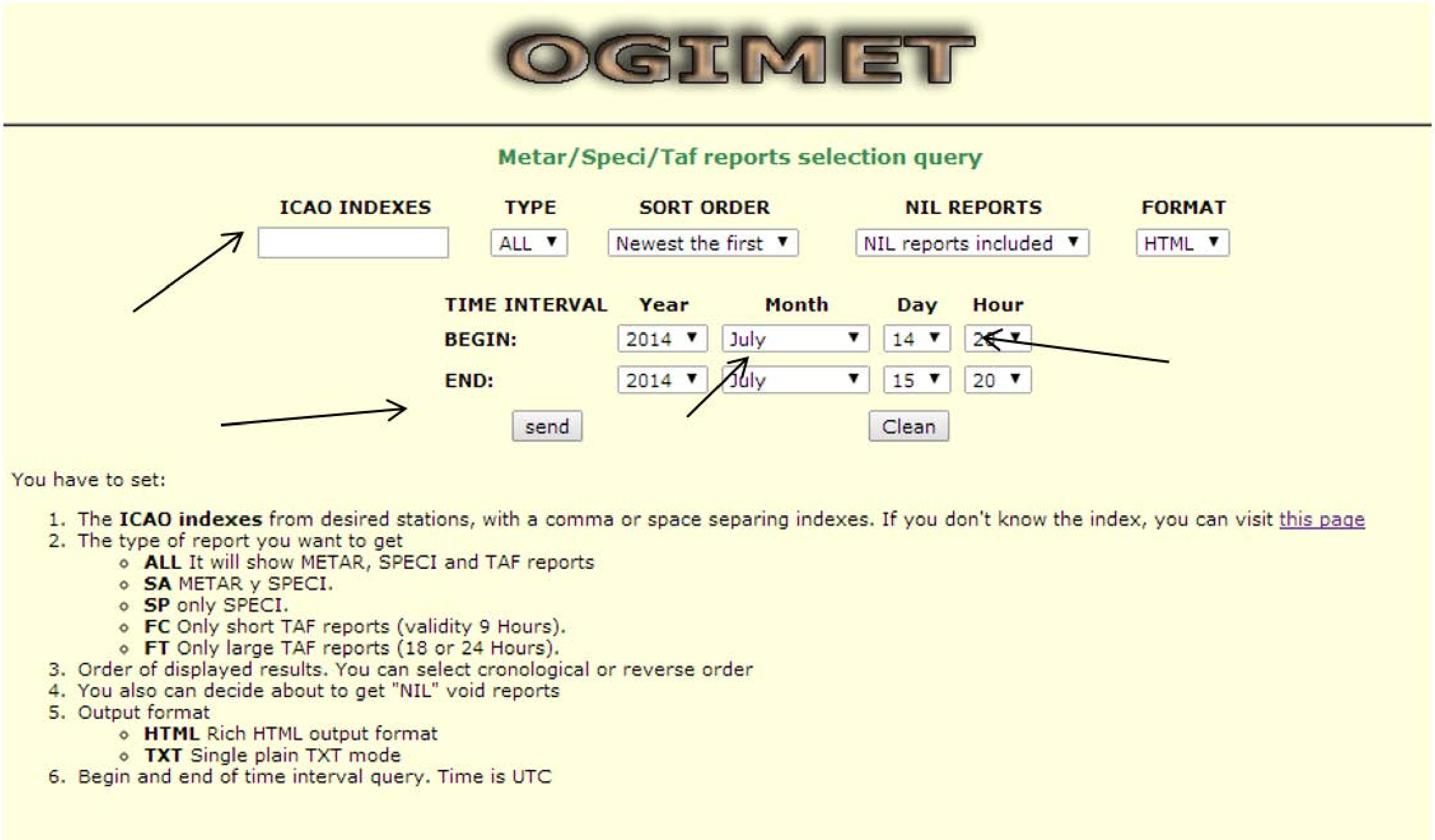
Using this method, fill in the rest of the spreadsheet. To the side, create a key that shows what number corresponds to what value.

KEY	
Device Use:	
1	Primary Instrument
2	Seconday Instrument
3	Not Used
Student Performance:	
1	0-200 ft. past the point
2	>200 ft. past the point
3	short of the point
4	add power/ go around
Frequency of use:	
1	Never
2	Rarely
3	Sometimes
4	Often
5	All of the time

Finding wind information

To gather wind information for each flight, one must know the start time of the flight, end time of the flight, and the overall location of the flight. The first thing that should be done is converting the times to Zulu time. This usually entails adding a certain amount of hours to each time (In Lafayette, adding 4 hours gets to Zulu time). Once the times are in Zulu time, open http://www.ogimet.com/metars.phtml.en in an internet browser. This will supply the wind information for each flight.

On the site, fill in the airport code under “ICAO Indexes” and fill in the date. Under “hour,” make the top drop-down menu 00 and the bottom drop-down menu 23. This will have the site display all wind records for that day. Once the date, hour, and airport code has been entered, click “send.”



OGIMET

Metar/Speci/Taf reports selection query

ICAO INDEXES	TYPE	SORT ORDER	NIL REPORTS	FORMAT
	ALL	Newest the first	NIL reports included	HTML

TIME INTERVAL	Year	Month	Day	Hour
BEGIN:	2014	July	14	20
END:	2014	July	15	20

send Clean

You have to set:

1. The **ICAO indexes** from desired stations, with a comma or space separing indexes. If you don't know the index, you can visit this page
2. The type of report you want to get
   - **ALL** It will show METAR, SPECI and TAF reports
   - **SA** METAR y SPECI.
   - **SP** only SPECI.
   - **FC** Only short TAF reports (validity 9 Hours).
   - **FT** Only large TAF reports (18 or 24 Hours).
3. Order of displayed results. You can select cronological or reverse order
4. You also can decide about to get "NIL" void reports
5. Output format
   - **HTML** Rich HTML output format
   - **TXT** Single plain TXT mode
6. Begin and end of time interval query. Time is UTC

Query made at 07/15/2014 20:26:33 UTC

Time interval: from 07/14/2014 00:00 to 07/14/2014 23:59 UTC

KLAF, Lafayette, Purdue University Airport (United States). **WMO index: -----. Latitude 40-24-45N. Longitude 086-56-51W. Altitude 184 m.**

METAR/SPECI from KLAF, Lafayette, Purdue University Airport (United States).

SA	14/07/2014 23:54->	METAR KLAF 142354Z 22005KT 10SM FEW015 BKN090 21/19 A2983 RMK AO2 RAE12 SLP099 P0000 60043 T02060189 10267 20183 53000=
SA	14/07/2014 22:54->	METAR KLAF 142254Z 17006KT 10SM -RA FEW008 BKN070 OVC120 20/18 A2983 RMK AO2 RAB53 SLP097 P0000 T02000183=
SP	14/07/2014 22:26->	*SPECI KLAF 142226Z 16005KT 10SM SCT009 BKN120 20/18 A2983 RMK AO2 T02000183=*
SA	14/07/2014 21:54->	METAR KLAF 142154Z 20006KT 10SM FEW120 21/18 A2983 RMK AO2 SLP099 T02060183=
SA	14/07/2014 20:54->	METAR KLAF 142054Z 00000KT 10SM CLR 19/18 A2983 RMK AO2 LTG DSNT E RAE20 TSE20 SLP098 P0007 60043 T01890178 50007=
SP	14/07/2014 20:26->	*SPECI KLAF 142026Z VRB03KT 10SM FEW055 FEW100 18/18 A2983 RMK AO2 LTG DSNT NE-S RAE20 TSE20 P0007 T01830178=*
SP	14/07/2014 20:14->	*SPECI KLAF 142014Z 18005KT 7SM -TSRA FEW049 SCT075 BKN100 18/17 A2983 RMK AO2 LTG DSNT NE-S P0007 T01830172=*
SP	14/07/2014 20:05->	*SPECI KLAF 142005Z 22003KT 2SM TSRA BR BKN044 BKN075 OVC100 18/17 A2985 RMK AO2 LTG DSNT ALQDS P0006 T01830172=*
SP	14/07/2014 19:59->	*SPECI KLAF 141959Z 18004KT 3/4SM +TSRA BR FEW021 BKN044 OVC080 18/17 A2986 RMK AO2 LTG DSNT ALQDS P0005 T01830167=*
SA	14/07/2014 19:54->	METAR KLAF 141954Z VRB06G15KT 2 1/2SM TSRA BR FEW021 BKN044 OVC075 19/17 A2986 RMK AO2 PK WND 26035/1932 LTG DSNT ALQDS RAB28 TSB24 SLP108 P0036 T01890167=
SP	14/07/2014 19:52->	*SPECI KLAF 141952Z 20006G15KT 1SM TSRA FEW021 BKN044 OVC080 19/16 A2986 RMK AO2 PK WND 26035/1932 LTG DSNT ALQDS RAB28 TSB24 P0034=*

A page similar to this one will then pop up.

The left column shows the date and time of each record. This column will be used to find the specific wind data for the flight. Now find the first record with a time before the start time. Example: if the Zulu start time was 21:20, then the data to be looked at would be 20:54 because it is the closest data point before the start time. Do the same for the stop time (the reason for also using the stop time is so that if the wind was variable, then the angle of the stop time could be used).

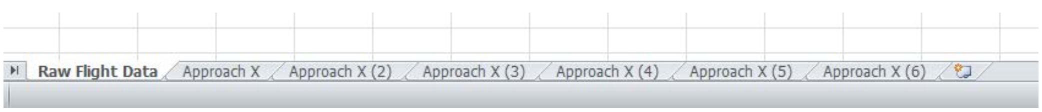
Now that the data sets have been identified, the information that should be copied is the second set of numbers/letters. In the above example, the wind data would be 00000KT.

These two strings of numbers/letters can then be placed in the flight list.

Date	Start Time	Zulu Start	Stop Time	Zulu Stop	Aircraft	Eval Group	Wind (Start)	Wind (Stop)
4/9/2014	0935	1335	1047	1447	N586PU	2	00000KT	00000KT
4/9/2014	1146	1546	1309	1709	N586PU	4	25003KT	25009KT
4/9/2014	1152	1552	1315	1715	N591PU	3	25003KT	25009KT
4/9/2014	1718	2118	1836	2236	N586PU	3	26011KT	27011KT
4/11/2014	0949	1349	1104	1504	N591PU	4	27003KT	00000KT
4/11/2014	1134	1534	1252	1652	N591PU	3	00000KT	00000KT
4/12/2014	0939	1339	1105	1505	N586PU	3	14008KT	16011KT
4/12/2014	0935	1335	1055	1455	N591PU	4	14008KT	16011KT
4/15/2014	1748	2148	1907	2307	N586PU	3	33010KT	VRB06KT
4/18/2014	1746	2146	1854	2254	N591PU	3	01004KT	36010G18KT
4/22/2014	1759	2159	1926	2326	N591PU	1	31009G15KT	33011G18KT
4/26/2014	1156	1556	1325	1725	N586PU	2	02008KT	02009KT
4/30/2014	0736	1136	0853	1253	N586PU	1	00000KT	23004KT
5/4/2014	0745	1145	0905	1305	N586PU	1	25004KT	27004KT
5/4/2014	0933	1333	1049	1449	N586PU	2	27004KT	35009KT
5/4/2014	1338	1738	1457	1857	N586PU	1	36009G16KT	03012KT
5/4/2014	1650	2050	1807	2207	N586PU	4	02009KT	03008KT
5/7/2014	0733	1133	0848	1248	N586PU	1	08003KT	07006KT
5/7/2014	1754	2154	1906	2306	N586PU	1	18013G21KT	19008G16
5/8/2014	0758	1158	0923	1323	N586PU	1	19006KT	23009KT
5/10/2014	1404	1804	1520	1920	N586PU	1	VRB03KT	27010G17KT
5/11/2014	1426	1826	1548	1948	N586PU	2	20008G15KT	21010KT
6/17/2014	950	1350	1111	1511	N586PU	4	22011G18KT	23013G23KT
7/2/2014	1310	1710	1438	1838	N586PU	4	25008KT	22007KT
7/2/2014	1621	2021	1737	2137	N586PU	2	29011KT	29010KT
7/9/2014	1343	1743	1449	1849	N586PU	2	31012G18KT	29015G20KT
7/9/2014	1520	1920	1635	2035	N586PU	2	30010G18KT	27008KT

Organizing the Data

The first thing that should be done is pulling up all necessary data. This includes the list that contains flight dates and times, the template used for organizing the data, and the online flight data itself. The template should contain 7 different tabs, 1 for raw data and then 6 more for each approach. If the template does not include these, they should be created.



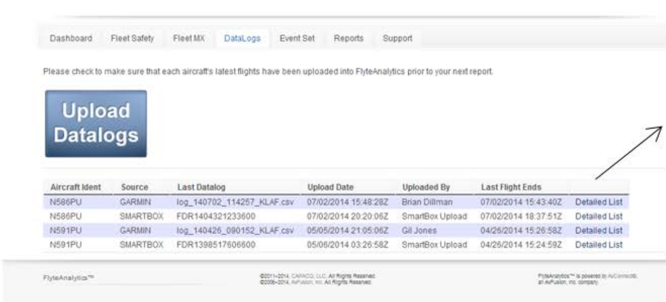
The online data will be found on a server similar to this one:

Date	Start Time	Zulu Start	Stop Time	Zulu Stop	Aircraft	Eval Group	Wind (Start)	Wind (Stop)	KLAF	KFKR	KCFJ	KLAF(DEG)	KFKR(DEG)	KCFJ(DEG)	KLAF Check	KFKR Check	KCFJ Check
4/9/2014	0935	1335	1047	1447	N586PU	2	00000KT	00000KT	L23	L4.	L4.	230	40	40	CHECK	X	X
4/9/2014	1146	1546	1309	1709	N586PU	4	25003KT	25009KT	L23	L22	L4.	20	30	210	X	X	X
4/9/2014	1152	1552	1315	1715	N591PU	3	25003KT	25009KT	L23	L22	L22	20	30	30	X	X	X
4/9/2014	1718	2118	1836	2236	N586PU	3	26011KT	27011KT	L23	R/L22	L22	30	40	40	X	X	X
4/11/2014	0949	1349	1104	1504	N591PU	4	27003KT	00000KT	L23	L4.	L22	40	230	50	X	CHECK	X
4/11/2014	1134	1534	1252	1652	N591PU	3	00000KT	00000KT	L23	L4.	L22	230	40	220	CHECK	X	X
4/12/2014	0939	1339	1105	1505	N586PU	3	14008KT	16011KT	L23	L22	L22	90	80	80	X	X	X
4/12/2014	0935	1335	1055	1455	N591PU	4	14008KT	16011KT	L23	L22	L22	90	80	80	X	X	X
4/15/2014	1748	2148	1907	2307	N586PU	3	33010KT	VRB06KT	L5/L28	R/L4.	L4.	50	290	290	X	X	CHECK
4/18/2014	1746	2146	1854	2254	N591PU	3	01004KT	36010G18KT	R5.	L4.	L4.	40	30	30	X	X	X
4/22/2014	1759	2159	1926	2326	N591PU	1	31009G15KT	33011G18KT	R5.	L4.	L4.	260	270	270	X	CHECK	CHECK
4/26/2014	1156	1556	1325	1725	N586PU	2	02008KT	02009KT	R5.	L4.	L4.	30	20	20	X	X	X
4/30/2014	0736	1136	0853	1253	N586PU	1	00000KT	23004KT	L23	L4.	L4.	230	40	40	CHECK	X	X
5/4/2014	0745	1145	0905	1305	N586PU	1	25004KT	27004KT	L23	L22	L22	20	30	30	X	X	X
5/4/2014	0933	1333	1049	1449	N586PU	2	27004KT	35009KT	L28	L4.	L4.	10	230	230	X	CHECK	CHECK
5/4/2014	1338	1738	1457	1857	N586PU	1	36009G16KT	03012KT	R5.	L4.	L4.	310	320	320	X	X	X
5/4/2014	1650	2050	1807	2207	N586PU	4	02009KT	03008KT	R5.	L4.	L4.	30	20	20	X	X	X
5/7/2014	0733	1133	0848	1248	N586PU	1	08003KT	07006KT	R5.	R9.	L22	30	10	140	X	X	X
5/7/2014	1754	2154	1906	2306	N586PU	1	18013G21KT	19008G16	L23	L22	L22	50	40	40	X	X	X
5/8/2014	0758	1158	0923	1323	N586PU	1	19006KT	23009KT	L23	L22	L22	40	30	30	X	X	X
5/10/2014	1404	1804	1520	1920	N586PU	1	VRB03KT	27010G17KT	L28	L22	L4.	10	50	230	X	X	CHECK
5/11/2014	1426	1826	1548	1948	N586PU	2	20008G15KT	21010KT	L23	L22	L22	30	20	20	X	X	X
6/17/2014	0950	1350	1111	1511	N586PU	4	22011G18KT	23013G23KT	L23	L22	L22	10	0	0	X	X	X

The flight list will look like this:

Now that all of the necessary items are there, the first step is to identify which flight is to be analysed. All of the flights are on the flight list, so one of them should be selected (it may help to do them in order, beginning with the first one).

One must now go into the server, select "detailed list" on one of the SMARTBOX rows that corresponds to the correct airplane, find the corresponding date and time for the selected flight, and click "analyze."



This will open up the data for the individual flight. Once there, one should click "download CSV," which will download all of the raw data from that flight. This file should then be opened, looking similar to this:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	# Flyte Analytics datalog 87166 exported Mon Jul 07 10:56:55 CDT 2014 - Format Copyright (c) 2012-2014 AvFusion Inc. and CAPACG LLC																			
2	Timestam	LAT	LON	GS	TRK	VSI	ALT	SOL	HPL	VPL	HDOP	HDG	PITCH	ROLL	LAT_G	MIN_LAT_	MAX_LAT_	LON_G	MIN_LON_	MAX_L(
3	2014-04-1:	40.41573	-86.9337	0.1	92	2	650.9	OTHER	20.69	20.69	2.2									
4	2014-04-1:	40.41573	-86.9337	0.1	92	-0.7	635.5	GPS3D	13.5	13.5	1.2									
5	2014-04-1:	40.41573	-86.9337	0.1	92	4.3	635.2	GPS3D	8.75	8.75	1.2									
6	2014-04-1:	40.41573	-86.9337	0.1	92	-1.2	634.1	GPS3D	4.05	4.05	1.2									
7	2014-04-1:	40.41573	-86.9337	0.1	92	2	635.9	GPS3D	5.36	5.36	1.2									
8	2014-04-1:	40.41573	-86.9337	0.1	92	9.1	644.4	GPS3D	4.25	4.25	0.8	12.5	3.1	0.2	0	0	0	0	0	(
9	2014-04-1:	40.41574	-86.9337	0.1	92	5.1	655.4	GPS3D	3.67	3.67	0.8	12.8	3.1	0.2	0	0	0	0	0	(
10	2014-04-1:	40.41575	-86.9338	0.1	92	1.6	665.9	GPS3D	3.29	3.29	0.8	13.7	3.2	0.2	0	-0.1	0	0	0	(
11	2014-04-1:	40.41575	-86.9338	0.1	92	1.6	675.1	GPS3D	3.01	3.01	0.8	14.2	3.2	0.2	0	-0.1	0	0	0	(
12	2014-04-1:	40.41576	-86.9338	0.1	92	2	682	GPS3D	2.81	2.81	0.8	14.3	3.2	0.2	0	-0.1	0	0	0	(
13	2014-04-1:	40.41576	-86.9338	0.1	92	0.4	685.9	GPS3D	2.38	2.38	0.8	14.2	3.2	0.2	0	0	0	0	0	(
14	2014-04-1:	40.41575	-86.9338	0.1	92	2.4	687.5	GPS3D	2.54	2.54	0.8	14.5	3.2	0.2	0	0	0	0	0	(
15	2014-04-1:	40.41575	-86.9338	0.1	92	0.4	688.7	GPS3D	2.07	2.07	0.8	14.3	3.2	0.2	0	0	0	0	0	(
16	2014-04-1:	40.41575	-86.9338	0	92	-0.8	690.4	GPS3D	2.02	2.02	0.8	14	3.2	0.2	0	0	0	0	0	(
17	2014-04-1:	40.41575	-86.9338	0.1	92	-1.2	692.1	GPS3D	2.01	2.01	0.8	14.6	3.2	0.3	0	-0.1	0	0	0	(
18	2014-04-1:	40.41575	-86.9338	0.1	92	0	692.6	GPS3D	2.17	2.17	0.8	15.6	3.1	0.2	0	-0.1	0	0	0	(
19	2014-04-1:	40.41575	-86.9338	0.1	92	-0.4	692.1	GPS3D	2.11	2.11	0.8	15.2	2.5	-0.1	0	-0.1	0	0	0	(
20	2014-04-1:	40.41575	-86.9338	0.1	92	1.2	690.9	GPS3D	2.06	2.06	0.8	15	1.9	-0.3	0	0	0	0	0	(
21	2014-04-1:	40.41575	-86.9338	0.1	92	5.9	689.3	GPS3D	2.01	2.01	0.8	15.5	1.8	-0.3	0	0	0	0	0	(
22	2014-04-1:	40.41575	-86.9338	0.2	92	3.2	687.5	GPS3D	2.18	2.18	0.8	15.3	1.8	-0.3	0	0	0.1	0	0	(
23	2014-04-1:	40.41574	-86.9338	0.1	92	2	685.7	GPS3D	2.04	2.04	0.8	15	1.8	-0.3	0	0	0	0	0	(
24	2014-04-1:	40.41574	-86.9338	0.1	92	-1.2	683.5	GPS3D	1.99	1.99	0.8	14.6	1.8	-0.3	0	-0.1	0	0	0	(
25	2014-04-1:	40.41574	-86.9338	0.1	92	2.4	681.2	GPS3D	1.97	1.97	0.8	14.6	1.8	-0.3	0	-0.1	0	0	0	(
26	2014-04-1:	40.41574	-86.9338	0.1	92	0	678.9	GPS3D	1.95	1.95	0.8	14.1	1.8	-0.3	0	-0.1	0	0	0	(
27	2014-04-1:	40.41575	-86.9338	0.1	92	-2.4	676.4	GPS3D	1.92	1.92	0.8	13.9	1.8	-0.3	0	0	0	0	0	(

DL87166 (1)

Ready

100%

Now open the template and save it as a new file with a name that follows this pattern:

[enough numbers to identify each plane]_[month of flight]-[day of flight]-[year]_[time (in Zulu)]

Example: 86_4-15-14_2148

Once that is finished, copy the raw data into the sheet labeled "Raw Flight Data." Then highlight the columns for the information on GPSGS, VSI, ALT, Pitch, Roll, and Vert G. Information will later be taken from these 6 columns and pasted into the other sheets, with one sheet for each approach.

C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
; 87166 exported Mon Jul 07 10:56:55 CDT 2014 - Format Copyright (c) 2012-2014 AvFusion Inc. and CAPACG LLC																			
N	GS	TRK	VSI	ALT	SOL	HPL	VPL	HDOP	HDG	PITCH	ROLL	LAT_G	MIN_LAT_(	MAX_LAT_	LON_G	MIN_LON_	MAX_LON	VERT_G	MIN_VERT !
6.9337	0.1	92	2	650.9	OTHER	20.69	20.69	2.2											
6.9337	0.1	92	-0.7	635.5	GPS3D	13.5	13.5	1.2											
6.9337	0.1	92	4.3	635.2	GPS3D	8.75	8.75	1.2											
6.9337	0.1	92	-1.2	634.1	GPS3D	4.05	4.05	1.2											
6.9337	0.1	92	2	635.9	GPS3D	5.36	5.36	1.2											
6.9337	0.1	92	9.1	644.4	GPS3D	4.25	4.25	0.8	12.5	3.1	0.2	0	0	0	0	0	0.1	1	0.8
6.9337	0.1	92	5.1	655.4	GPS3D	3.67	3.67	0.8	12.8	3.1	0.2	0	0	0	0	0	0.1	1	0.9
6.9338	0.1	92	1.6	665.9	GPS3D	3.29	3.29	0.8	13.7	3.2	0.2	0	-0.1	0	0	0	0.1	1	0.8
6.9338	0.1	92	1.6	675.1	GPS3D	3.01	3.01	0.8	14.2	3.2	0.2	0	-0.1	0	0	0	0.1	1	0.9
6.9338	0.1	92	2	682	GPS3D	2.81	2.81	0.8	14.3	3.2	0.2	0	-0.1	0	0	0	0.1	1	0.8
6.9338	0.1	92	0.4	685.9	GPS3D	2.38	2.38	0.8	14.2	3.2	0.2	0	0	0	0	0	0.1	1	0.9
6.9338	0.1	92	2.4	687.5	GPS3D	2.54	2.54	0.8	14.5	3.2	0.2	0	0	0	0	0	0.1	1	0.8
6.9338	0.1	92	0.4	688.7	GPS3D	2.07	2.07	0.8	14.3	3.2	0.2	0	0	0	0	0	0.1	1	0.9
6.9338	0	92	-0.8	690.4	GPS3D	2.02	2.02	0.8	14	3.2	0.2	0	0	0	0	0	0.1	1	0.9
6.9338	0.1	92	-1.2	692.1	GPS3D	2.01	2.01	0.8	14.6	3.2	0.3	0	-0.1	0	0	0	0.1	1	0.8
6.9338	0.1	92	0	692.6	GPS3D	2.17	2.17	0.8	15.6	3.1	0.2	0	-0.1	0	0	0	0.1	1	0.9

Next, go back to the server data and identify where the landings were made. Identify which at airports the landings were made, and in what order. This can be done by moving the mouse over the data on the left, which will, on the right side, show where the plane was at that point (This method can also be used to determine what direction the plane turned before the approach, which should also be added to the flight list).

Then rename the sheets so that they correspond to the airport (if there are multiple at one airport, put a number after each one: KLAF 1, KLAF 2, …).

Next, decide what altitudes will be the cutoff points for each airport and each runway. This is normally from 15 ft above the ground to 600 ft above that (615 ft above ground). Using the altitude column as a guide, go through the raw data and identify what parts fall inside these limits. Highlight the first value below the max and min altitude values. For example, in the picture below, the altitude range was 1411 ft to 811 ft, so each altitude after that was highlighted (1407 and 806). Do this for every approach.

365	2014-04-	39.9618	-86.943	86.1	120.4	-515.9	1432.7	GPSDIFF	3.15	3.15	0.8	107.1	-1.9	2.3	0	0	0.1	0	-0.1	0	1.1	0.9	1.3	35.24
366	2014-04-	39.9616	-86.943	86.1	115.4	-537.5	1424.3	GPSDIFF	3.22	3.22	0.8	105.3	-1.9	0.4	0	-0.1	0.1	0	-0.1	0.1	1.1	0.7	1.3	35.24
367	2014-04-	39.9615	-86.942	86.5	111.1	-558.8	1415.6	GPSDIFF	3.05	3.05	0.8	102.6	0	-1	0	-0.1	0.1	0	0	0.1	1.1	0.8	1.4	35.24
368	2014-04-	39.9614	-86.942	87.1	105.5	-553.7	1407.4	GPSDIFF	2.49	2.49	0.8	98.4	-1.1	0.9	0	0	0.1	0	-0.1	0	1	0.8	1.3	35.24
369	2014-04-	39.9613	-86.941	87.6	100.5	-538.7	1402.6	GPSDIFF	2.82	2.82	0.8	97.5	-2.1	-0.7	0	-0.1	0	-0.1	-0.1	0	1	0.6	1.2	35.29
370	2014-04-	39.9612	-86.941	87.9	96.4	-541.1	1397	GPSDIFF	2.48	2.48	0.8	94.1	-0.9	-2.1	0	-0.1	0.1	0	-0.1	0.1	1.2	0.6	1.5	35.29
371	2014-04-	39.9612	-86.94	88.2	91.7	-563.1	1389.2	GPSDIFF	2.18	2.18	0.8	89.6	-0.9	0.8	0	-0.1	0.1	-0.1	-0.1	0.1	1	0.5	1.4	35.29
372	2014-04-	39.9612	-86.94	88.2	87.8	-606.1	1380.6	GPSDIFF	2.13	2.13	0.8	86.4	-0.9	2.6	0	0	0.1	0	-0.2	0	1.2	0.9	1.5	35.29
373	2014-04-	39.9612	-86.939	87.9	84	-656.9	1370.3	GPSDIFF	1.87	1.87	0.8	85.6	-1.9	1	0	-0.1	0	0	-0.1	0	1	0.6	1.4	35.29
374	2014-04-	39.9613	-86.939	88.5	80.1	-682.8	1359.9	GPSDIFF	1.84	1.84	0.8	84.3	-2.1	-2	0	-0.1	0	-0.1	-0.2	0	1.1	0.9	1.4	35.29
375	2014-04-	39.9614	-86.938	88.5	76.2	-693.9	1349.1	GPSDIFF	1.8	1.8	0.8	81.6	-2.8	-2.3	0	-0.1	0	-0.1	-0.1		1.1	0.8	1.3	35.29
376	2014-04-	39.9615	-86.938	87.9	71.9	-697.4	1337.5	GPSDIFF	1.96	1.96	0.8	79.6	-3.4	-2.1	0	-0.1	0	-0.1	-0.2		1.1	0.9	1.4	35.29
377	2014-04-	39.9616	-86.937	87.2	67.7	-716.3	1325.3	GPSDIFF	1.8	1.8	0.8	76.7	-3	-3.6	0	-0.1	0	-0.1	-0.1		1.1	0.8	1.3	35.29
378	2014-04-	39.9618	-86.937	86.3	62.7	-745.1	1311.9	GPSDIFF	1.77	1.77	0.8	72.1	-2.7	-1.6	0	0	0.1	-0.1	-0.2		1.2	1	1.5	35.29
379	2014-04-	39.962	-86.936	85.6	57	-757.3	1298.5	GPSDIFF	1.75	1.75	0.8	70	-3.6	-0.4	0	0	0.1	-0.1	-0.1		1.1	0.9	1.2	35.31
380	2014-04-	39.9622	-86.936	84.3	52	-780.5	1284.7	GPSDIFF	1.73	1.73	0.8	69.1	-4.7	2.4	0	0	0	-0.1	-0.1		1	0.9	1.2	35.31
381	2014-04-	39.9625	-86.935	83.4	47.7	-832.9	1269.6	GPSDIFF	1.71	1.71	0.8	68.7	-6.1	1.8	0	-0.1	0	-0.1	-0.1		1	0.9	1.2	35.31
382	2014-04-	39.9628	-86.935	82.7	44.2	-890.4	1253	GPSDIFF	1.51	1.51	0.8	67.9	-6	3.3	0	-0.1	0.1	-0.1	-0.1		1.1	0.9	1.3	35.31
383	2014-04-	39.963	-86.935	82.6	41.5	-893.5	1236.7	GPSDIFF	1.65	1.65	0.8	64.5	-5.4	7	0	-0.1	0.1	-0.1	-0.1		1.1	1	1.3	35.31
384	2014-04-	39.9633	-86.934	82.9	40	-830.5	1222.5	GPSDIFF	1.8	1.8	0.8	64.1	-6.3	3.7	0	-0.1	0.1	-0.1	-0.1		1	0.9	1.2	35.31
385	2014-04-	39.9636	-86.934	83.1	39	-756.5	1210.4	GPSDIFF	1.77	1.77	0.8	61.7	-6.4	1.9	-0.1	-0.2	0	-0.1	-0.2		1	0.7	1.2	35.31
386	2014-04-	39.9639	-86.934	83.2	39	-711.2	1199.2	GPSDIFF	1.75	1.75	0.8	58.1	-6.6	1.5	0	-0.1	0.1	-0.1	-0.1		1	0.9	1.2	35.31
387	2014-04-	39.9642	-86.934	83	39.1	-691.1	1187.8	GPSDIFF	1.72	1.72	0.8	53	-7.2	3.5	0	-0.1	0.1	-0.1	-0.1		1	0.8	1.2	35.31
388	2014-04-	39.9645	-86.933	83	39.1	-669.5	1176.5	GPSDIFF	1.53	1.53	0.8	54	-7.7	-0.2	0	-0.1	0	-0.1	-0.1		1	0.9	1.2	35.31
389	2014-04-	39.9648	-86.933	83.3	40.3	-664.7	1164.9	GPSDIFF	1.51	1.51	0.8	50.3	-7.4	-0.2	0	-0.1	0.1	-0.1	-0.2		1	0.7	1.3	35.29
390	2014-04-	39.9651	-86.933	83.4	41.5	-670.6	1152.8	GPSDIFF	1.49	1.49	0.8	46.1	-7.6	-0.1	0	0	0.1	-0.1	-0.2		1	0.8	1.2	35.29
391	2014-04-	39.9654	-86.932	83.1	42.2	-629.7	1141.5	GPSDIFF	1.44	1.44	0.8	44.6	-8	-0.5	0	-0.1	0.1	-0.1	-0.2		1	0.8	1.2	35.29
392	2014-04-	39.9657	-86.932	82.7	43.4	-617.5	1130.8	GPSDIFF	1.6	1.6	0.8	44.5	-8.3	-2.5	0	-0.1	0	-0.1	-0.2		1	0.8	1.2	35.29
393	2014-04-	39.966	-86.932	82.1	44.2	-626.5	1119.8	GPSDIFF	1.44	1.44	0.8	43.6	-8.9	-4.1	0	-0.1	0	-0.1	-0.2		0.9	0.8	1.1	35.29
394	2014-04-	39.9662	-86.931	81.5	44.7	-662.8	1107.3	GPSDIFF	1.57	1.57	0.8	43.9	-8.4	-2.8	0	-0.1	0	-0.1	-0.2		1	0.8	1.1	35.29
395	2014-04-	39.9665	-86.931	81	45	-716.3	1093.8	GPSDIFF	1.41	1.41	0.8	44.6	-8	-3.2	0	0	0	-0.1	-0.1		1	0.8	1.2	35.29
396	2014-04-	39.9668	-86.931	81	44.7	-764.8	1079.1	GPSDIFF	1.56	1.56	0.8	46.4	-7.2	-3.3	0	-0.1	0	-0.1	-0.1		1.1	0.9	1.3	35.29
397	2014-04-	39.967	-86.93	80.7	43.6	-811.6	1063.7	GPSDIFF	1.56	1.56	0.8	49.1	-6.6	-1.7	0	-0.1	0	-0.1	-0.1		1	0.9	1.1	35.29
398	2014-04-	39.9673	-86.93	80.3	43.1	-830.9	1048.8	GPSDIFF	1.56	1.56	0.8	51.4	-6.1	-2.2	0	0	0	-0.1	-0.1		1.1	0.9	1.3	35.29
399	2014-04-	39.9676	-86.93	80.4	42.4	-832.1	1033.9	GPSDIFF	1.56	1.56	0.8	51.5	-6.1	-0.5	0	-0.1	0.1	-0.1	-0.1		1.1	0.9	1.3	35.29
400	2014-04-	39.9679	-86.929	80.7	41.6	-783.7	1020	GPSDIFF	1.57	1.57	0.8	53.7	-6.4	-0.2	0	-0.1	0.1	-0.1	-0.1		1	0.8	1.2	35.29
401	2014-04-	39.9681	-86.929	80.8	41.4	-735.6	1007.2	GPSDIFF	1.59	1.59	0.8	52.4	-6.6	1.8	0	-0.1	0.1	-0.1	-0.2		0.9	0.6	1.2	35.29
402	2014-04-	39.9684	-86.929	80.3	41.5	-769.9	993	GPSDIFF	1.59	1.59	0.8	50.7	-6.7	-0.1	0	-0.1	0.1	-0.1	-0.1		1	0.8	1.2	35.29
403	2014-04-	39.9687	-86.928	79.8	41.6	-767.1	979.7	GPSDIFF	1.58	1.58	0.8	51.1	-7.9	-1.2	0	-0.1	0	-0.1	-0.1		1	0.8	1.1	35.29
404	2014-04-	39.969	-86.928	79.1	42	-787.2	966.3	GPSDIFF	1.57	1.57	0.8	50.7	-6.8	-0.8	0	-0.1	0	-0.1	-0.1		1.1	0.9	1.2	35.29
405	2014-04-	39.9692	-86.928	79	42.3	-799.4	952.5	GPSDIFF	1.59	1.59	0.8	49.9	-6.5	-2.1	0	-0.1	0	-0.1	-0.1		1	0.9	1.1	35.29
406	2014-04-	39.9695	-86.927	78.8	43	-793.5	938.8	GPSDIFF	1.59	1.59	0.8	47	-5.9	-1.8	0	0	0.1	-0.1	-0.1		1.1	0.9	1.2	35.29
407	2014-04-	39.9698	-86.927	78.8	42.3	-760	925.8	GPSDIFF	1.57	1.57	0.8	49	-6.2	-0.2	0	-0.1	0	-0.1	-0.1		1	0.8	1.3	35.29
408	2014-04-	39.97	-86.927	79	42.2	-721.4	913.3	GPSDIFF	1.57	1.57	0.8	53.4	-6.9	-0.7	0	-0.1	0	-0.1	-0.1		0.9	0.7	1.1	35.29
409	2014-04-	39.9703	-86.926	79.3	42.8	-732.5	900.4	GPSDIFF	1.56	1.56	0.8	51.3	-6.4	-3.1	0	-0.1	0	-0.1	-0.1		1	0.7	1.3	35.29
410	2014-04-	39.9706	-86.926	79.4	42.9	-784.4	886.9	GPS3D	1.57	1.57	0.8	49.5	-5.7	-1.6	0	-0.1	0.1	-0.1	-0.1		1.1	0.9	1.3	35.31
411	2014-04-	39.9709	-86.926	79.5	42.8	-791.5	872.8	GPS3D	1.43	1.43	0.8	48.8	-6.6	-1	0	-0.1	0.1	-0.1	-0.2		0.9	0.6	1.3	35.31
412	2014-04-	39.9711	-86.925	79.2	43.2	-773	858.7	GPS3D	1.43	1.43	0.8	48.6	-6	-1.7	0	0	0.1	-0.1	-0.1		1.1	0.8	1.4	35.31
413	2014-04-	39.9714	-86.925	78.5	43.1	-778.1	844.6	GPS3D	1.44	1.44	0.8	47.7	-4.8	-2.9	0	-0.1	0.1	-0.1	-0.1		1.1	0.9	1.3	35.31
414	2014-04-	39.9717	-86.925	77.6	42.8	-738	831	GPS3D	1.29	1.29	0.8	51.3	-3.7	-2.3	0	-0.1	0	-0.1	-0.1		1.1	0.9	1.3	35.31
415	2014-04-	39.9719	-86.924	76.4	42.4	-693.9	818.5	GPS3D	1.29	1.29	0.8	54.2	-2.9	-0.6	0	-0.1		-0.1	-0.1		1.2	0.9	1.5	35.31
416	2014-04-	39.9722	-86.924	76	42.5	-657.3	806.8	GPS3D	1.47	1.47	0.8	57.6	-4.6	-1.1	0	-0.1	0	-0.1	-0.1		1	0.8	1.2	35.31
417	2014-04-	39.9724	-86.924	73.7	43.5	-618.3	796	GPS3D	1.52	1.52	0.8	57.6	-4.6	-3	0	-0.1	0.1	-0.1	-0.1		1	0.8	1.3	35.31
418	2014-04-	39.9727	-86.923	71.7	43.3	-554.1	786.5	GPS3D	1.39	1.39	0.8	58.2	-2.8	-3.6	0	-0.1	0	0	-0.1		1.1	0.8	1.3	35.31

Once this is complete, copy the data from each approach into its designated sheet. The sheet should then automatically calculate the rest of the data. It should look like this:

						FPA	
GPSGS	VSI	ALT	Pitch	Roll	Vert G	n Radiann	Degrees
87.1	-553.7	1407.4	-1.1	0.9	1	-0.06	3.59
87.6	-538.7	1402.6	-2.1	-0.7	1	-0.06	3.48
87.9	-541.1	1397	-0.9	-2.1	1.2	-0.06	3.48
88.2	-563.1	1389.2	-0.9	0.8	1	-0.06	3.61
88.2	-606.1	1380.6	-0.9	2.6	1.2	-0.07	3.88
87.9	-656.9	1370.3	-1.9	1	1	-0.07	4.22
88.5	-682.8	1359.9	-2.1	-2	1.1	-0.08	4.36
88.5	-693.9	1349.1	-2.8	-2.3	1.1	-0.08	4.43
87.9	-697.4	1337.5	-3.4	-2.1	1.1	-0.08	4.48
87.2	-716.3	1325.3	-3	-3.6	1.1	-0.08	4.64
86.3	-745.1	1311.9	-2.7	-1.6	1.2	-0.09	4.87
85.6	-757.3	1298.5	-3.6	-0.4	1.1	-0.09	4.99
84.3	-780.5	1284.7	-4.7	2.4	1	-0.09	5.22
83.4	-832.9	1269.6	-6.1	1.8	1	-0.10	5.63
82.7	-890.4	1253	-6	3.3	1.1	-0.11	6.07
82.6	-893.5	1236.7	-5.4	7	1.1	-0.11	6.10
82.9	-830.5	1222.5	-6.3	3.7	1	-0.10	5.65
83.1	-756.5	1210.4	-6.4	1.9	1	-0.09	5.14
83.2	-711.2	1199.2	-6.6	1.5	1	-0.08	4.83
83	-691.1	1187.8	-7.2	3.5	1	-0.08	4.70
83	-669.5	1176.5	-7.7	-0.2	1	-0.08	4.55
83.3	-664.7	1164.9	-7.4	-0.2	1	-0.08	4.51
83.4	-670.6	1152.8	-7.6	-0.1	1	-0.08	4.54
83.1	-629.7	1141.5	-8	-0.5	1	-0.07	4.28
82.7	-617.5	1130.8	-8.3	-2.5	1	-0.07	4.22
82.1	-626.5	1119.8	-8.9	-4.1	0.9	-0.08	4.31
81.5	-662.8	1107.3	-8.4	-2.8	1	-0.08	4.59
81	-716.3	1093.8	-8	-3.2	1	-0.09	4.99
81	-764.8	1079.1	-7.2	-3.3	1.1	-0.09	5.33
80.7	-811.6	1063.7	-6.6	-1.7	1	-0.10	5.67
80.3	-830.9	1048.8	-6.1	-2.2	1.1	-0.10	5.84
80.4	-832.1	1033.9	-6.1	-0.5	1.1	-0.10	5.84
80.7	-783.7	1020	-6.4	-0.2	1	-0.10	5.48
80.8	-735.6	1007.2	-6.6	1.8	0.9	-0.09	5.14
80.3	-769.9	993	-6.7	-0.1	1	-0.09	5.41
79.8	-767.1	979.7	-7.9	-1.2	1	-0.09	5.42
79.1	-787.2	966.3	-6.8	-0.8	1.1	-0.10	5.61
79	-799.4	952.5	-6.5	-2.1	1	-0.10	5.71
78.8	-793.5	938.8	-5.9	-1.8	1.1	-0.10	5.68
78.8	-760	925.8	-6.2	-0.2	1	-0.09	5.44
79	-721.4	913.3	-6.9	-0.7	0.9	-0.09	5.15
79.3	-732.5	900.4	-6.4	-3.1	1	-0.09	5.21
79.4	-784.4	886.9	-5.7	-1.6	1.1	-0.10	5.57
79.5	-791.5	872.8	-6.6	-1	0.9	-0.10	5.62
79.2	-773	858.7	-6	-1.7	1.1	-0.10	5.51
78.5	-778.1	844.6	-4.8	-2.9	1.1	-0.10	5.59
77.6	-738	831	-3.7	-2.3	1.1	-0.09	5.37
76.4	-693.9	818.5	-2.9	-0.6	1.2	-0.09	5.13
76	-657.3	806.8	-4.6	-1.1	1	-0.09	4.88

	MIN	MAX	Range
GPSGS	76.00	88.50	12.50

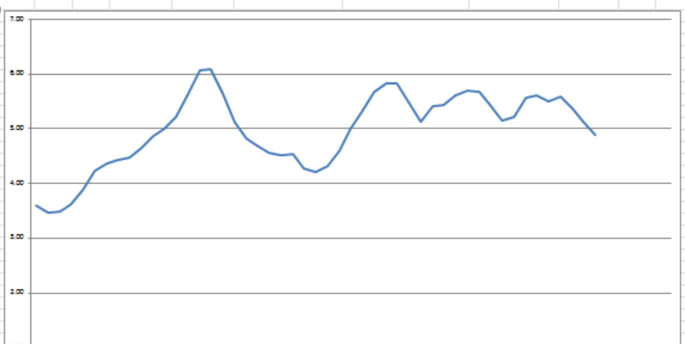
	MIN	MAX	STD Dev	Mean	Range	Time between 0 and -500	Time between -500 and -1000	Time less than -1000	Time above 0
VSI	-893.50	-538.70	84.40	-724.54	354.80	0	49	0	0

	MIN	MAX	Range
Pitch	-8.90	-0.90	8.00

	MIN	MAX	Range
Roll	-4.10	7.00	2.20

	MIN	MAX	Range
NORMG	0.90	1.20	0.30

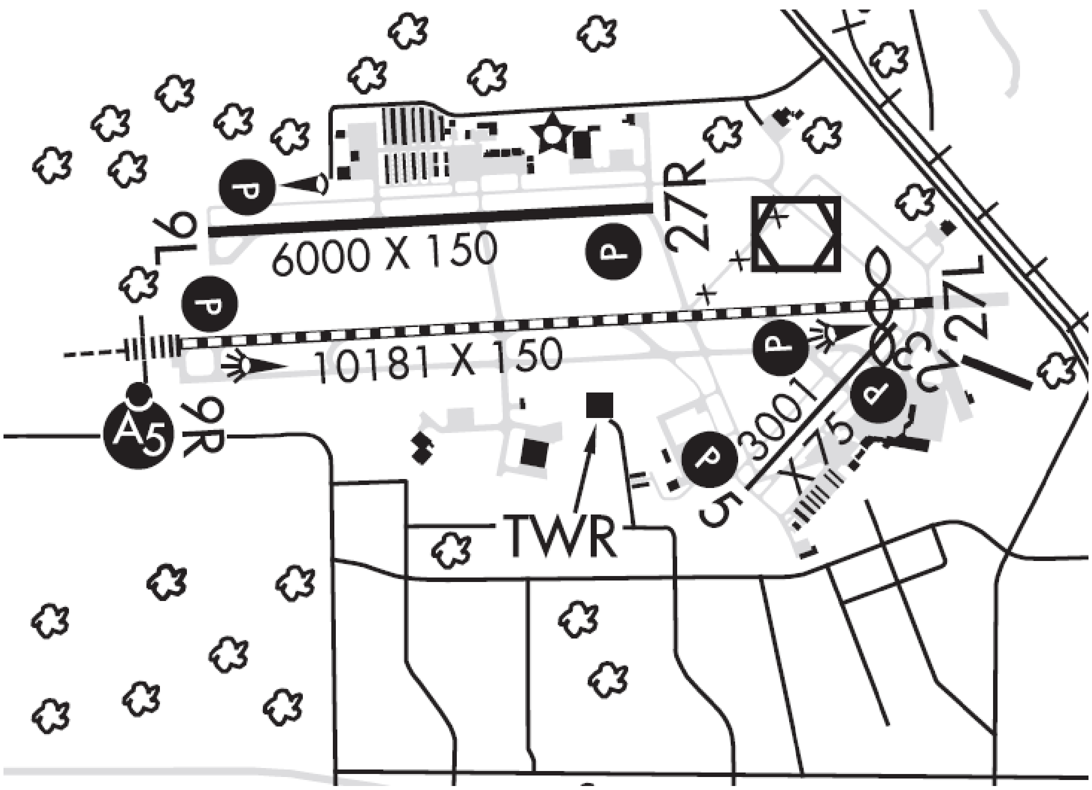
	MIN	MAX	STD Dev	Mean	Range	Time above 3.5 degrees	Time below 2.5 degrees	Time within range
FPA	3.48	6.10	0.68	4.98	2.62	47	0	2



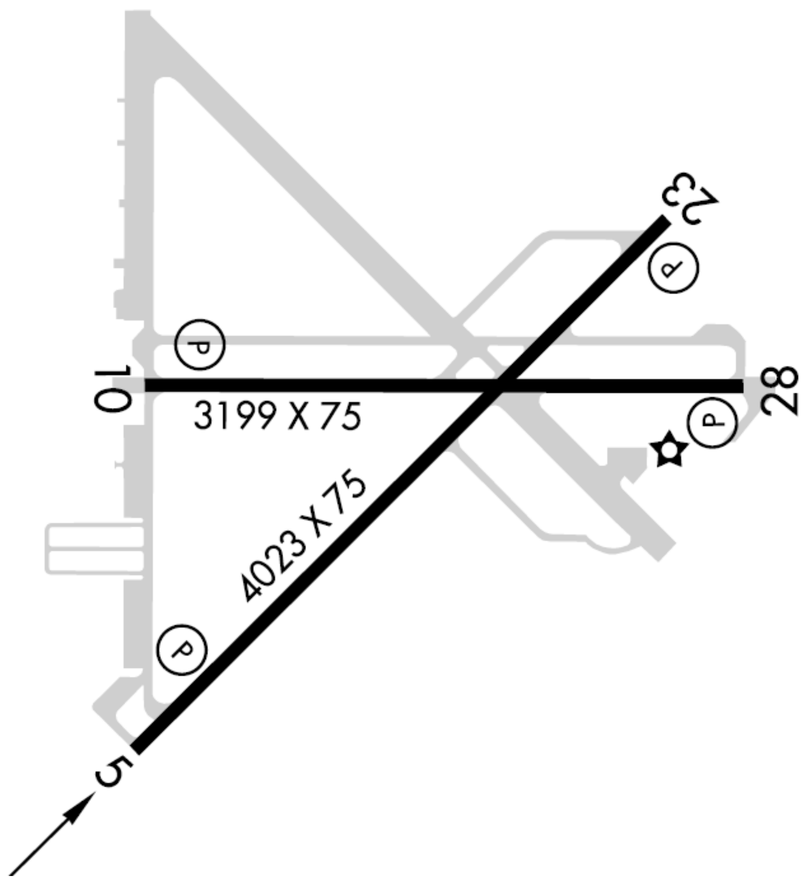
Raw Flight Data | KCFJ 1 | KCFJ 2 | KFKR 1 | KFKR 2 | KLAF 1 | KLAF 2

APPENDIX I—AIRPORT ELEVATIONS AND LAYOUTS

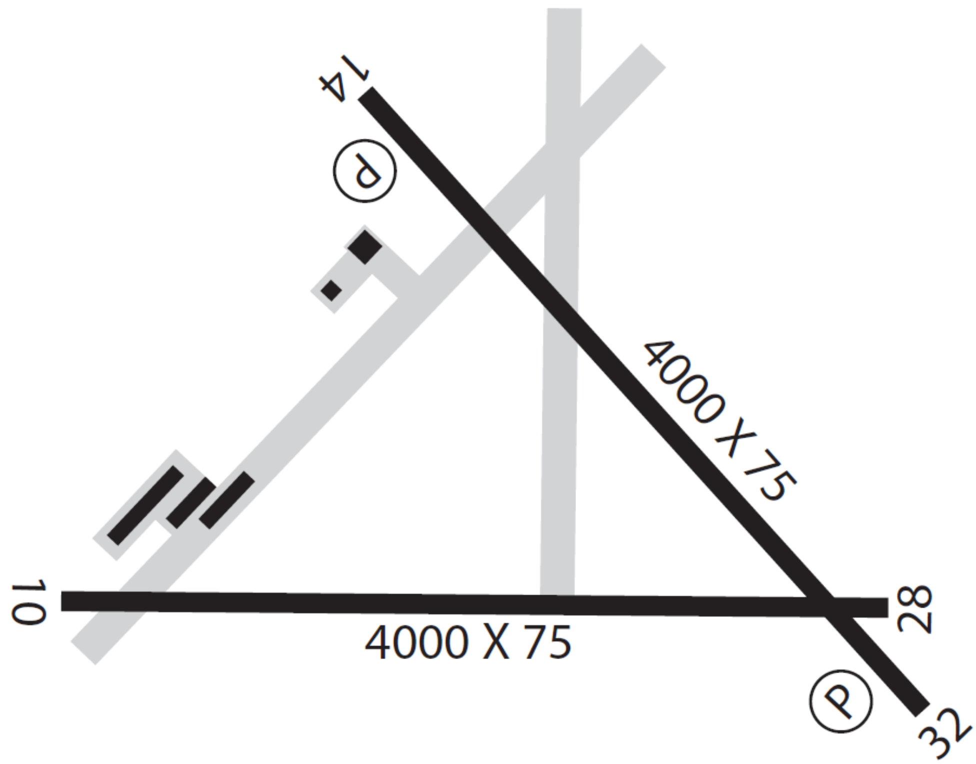
Airport	Runway	Altitude	Range	
			Low	Up
KMLB	9L	31	46	646
	9R	32	47	647
	27L	22	37	637
	27R	26	41	641
	5	25	40	640
	23	21	36	636
	Airport	33	48	648



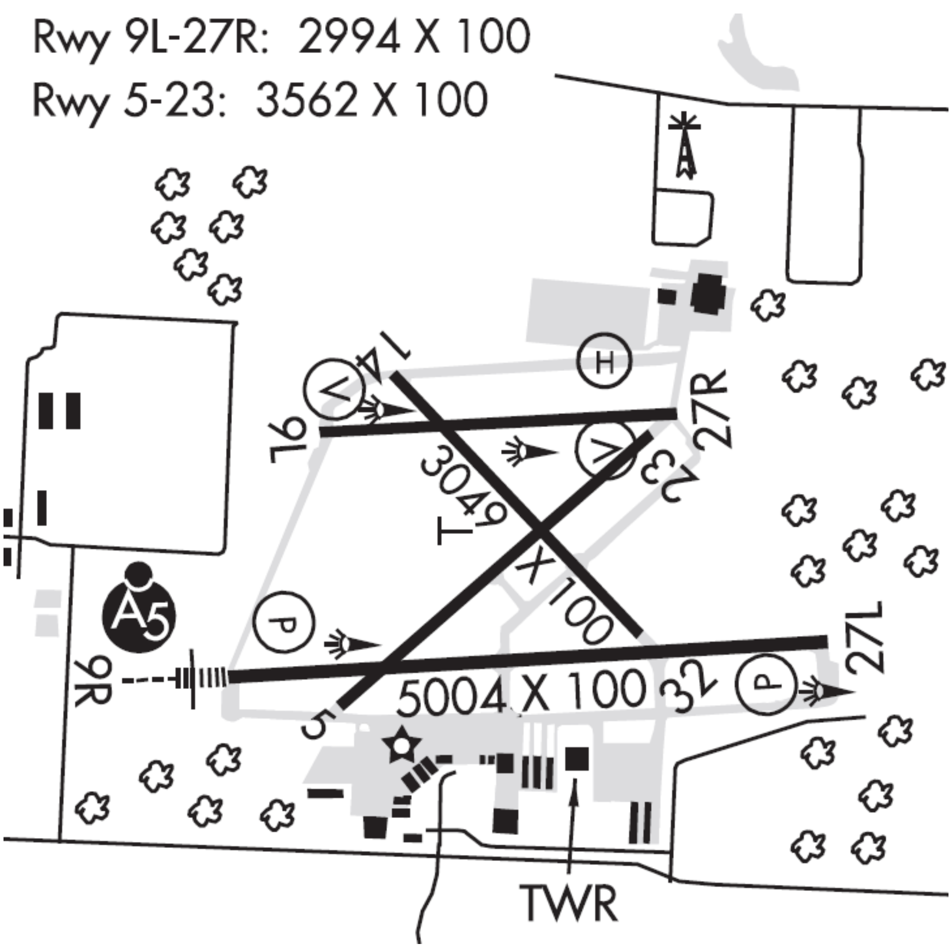
Airport	Runway	Altitude	Range	
			Low	Up
X26	5	18	33	633
	23	21	36	636
	10	18	33	633
	28	21	36	636
	Airport	21	36	636



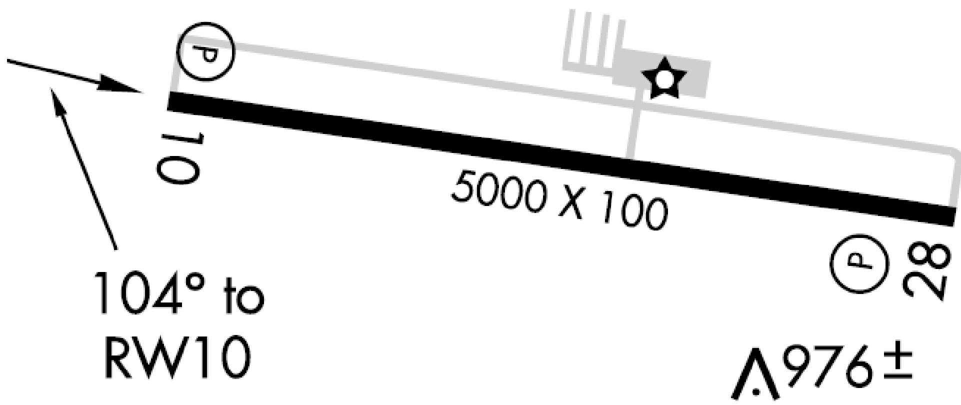
Airport	Runway	Altitude	Range	
			Low	Up
X59	10	22	37	637
	28	23	38	638
	14	24	39	639
	32	23	38	638
	Airport	26	41	641



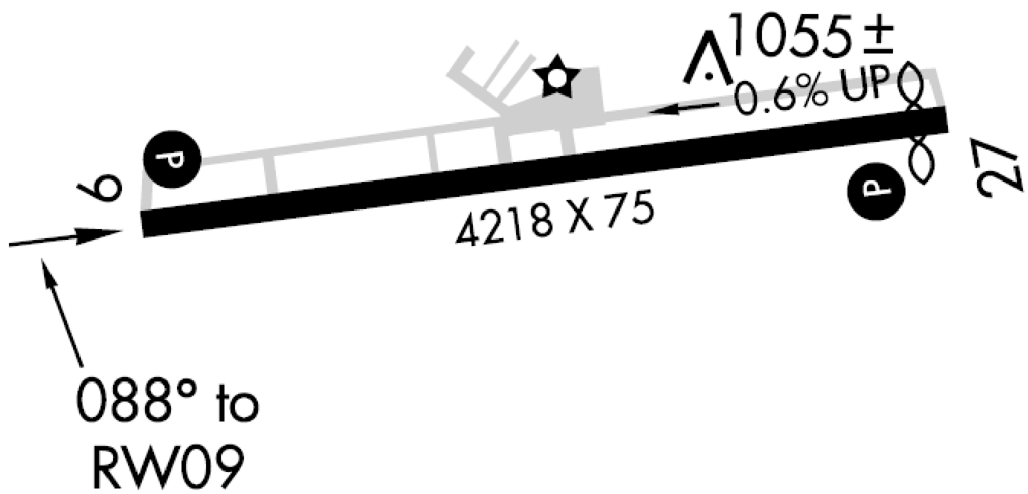
Airport	Runway	Altitude	Range	
			Low	Up
KOSU	9L	904	919	1519
	9R	901	916	1516
	27L	890	905	1505
	27R	892	907	1507
	5	903	918	1518
	23	893	908	1508
	14	900	915	1515
	32	894	909	1509
	Airport	906	921	1521



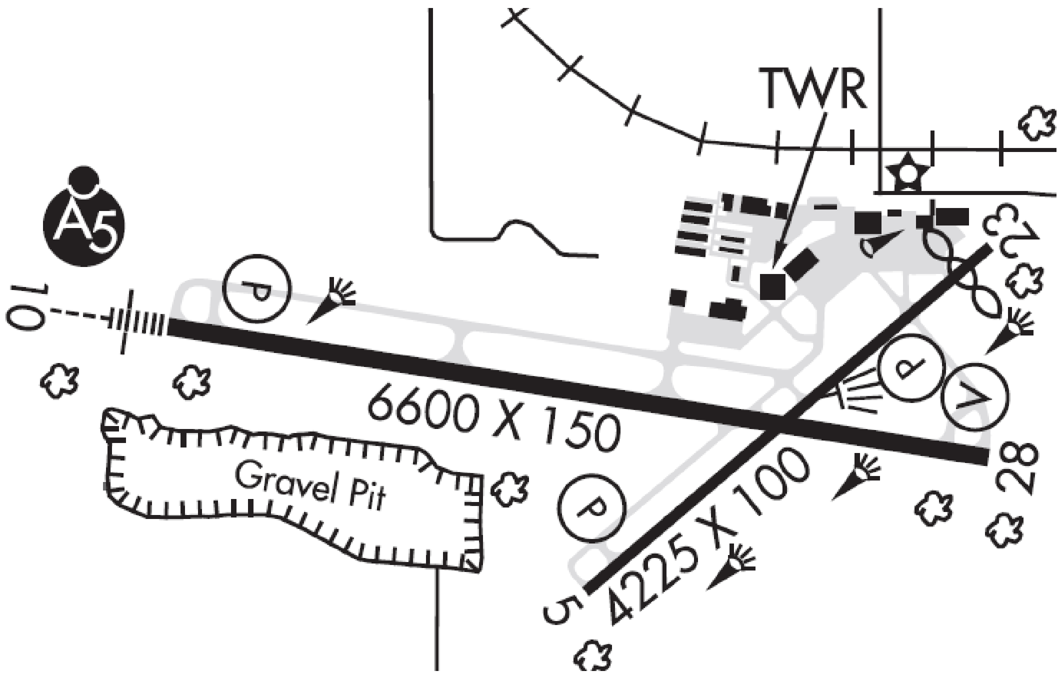
Airport	Runway	Altitude	Range	
			Low	Up
KDLZ	10	945	960	1560
	28	945	960	1560
	Airport	945	960	1560



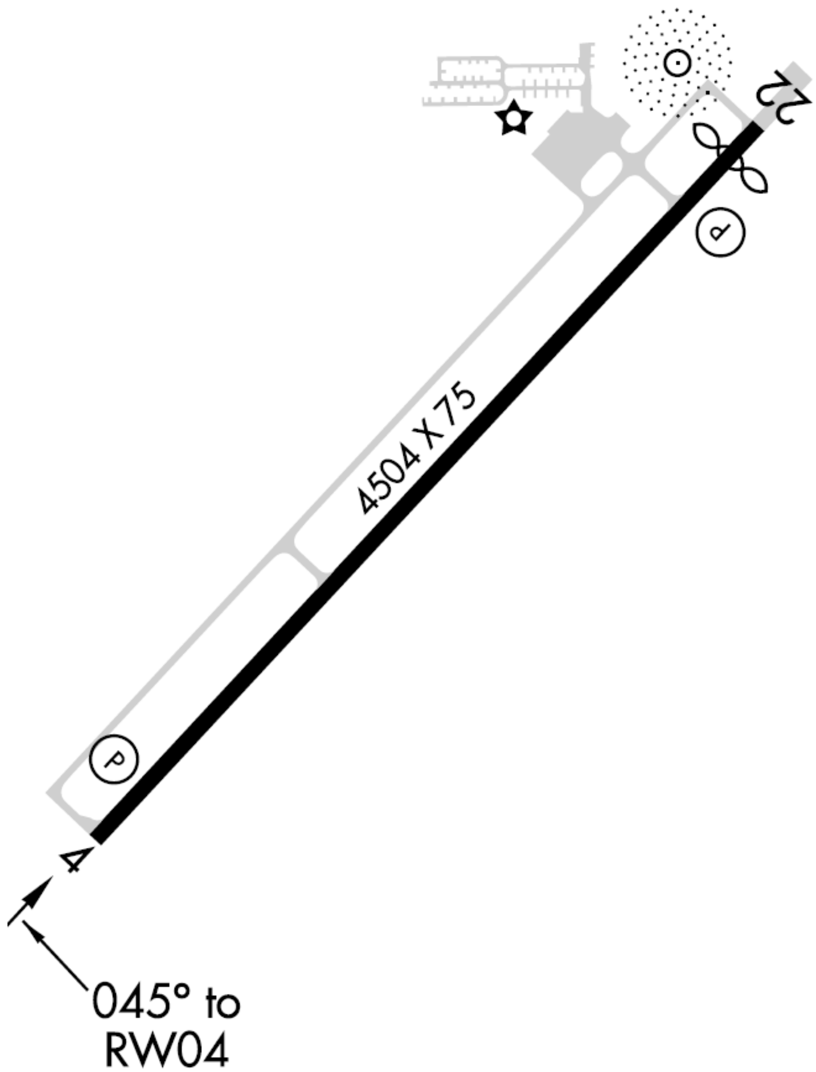
Airport	Runway	Altitude	Range	
			Low	Up
KMRT	9	1021	1036	1636
	27	997	1012	1612
	Airport	1021	1036	1636



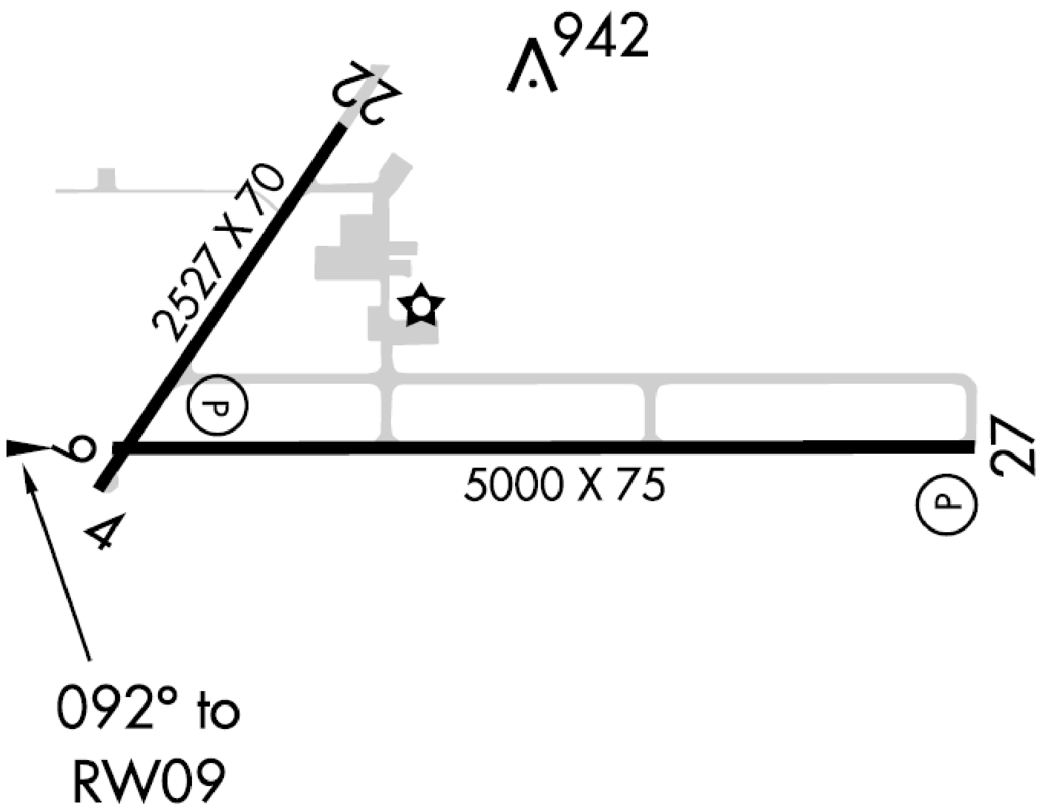
Airport	Runway	Altitude	Range	
			Low	Up
KLAF	5	593	608	1208
	10	600	615	1215
	23	606	621	1221
	28	598	613	1213
	Airport	606	621	1221



Airport	Runway	Altitude	Range	
			Low	Up
KCFJ	4	796	811	1411
	22	801	816	1416
	Airport	801	816	1416



Airport	Runway	Altitude	Range	
			Low	Up
KFKR	4	857	872	1472
	22	857	872	1472
	9	856	871	1471
	27	861	876	1476
	Airport	857	872	1472



APPENDIX J—DATA RECORDER ASSESSMENT

PEGASAS Project 3: Angle of Attack Equipment for General Aviation Operations

Background:

Prior to the initiation of this research project the knowledge concerning the available data parameters was primarily limited to Garmin equipment. It was understood that the available parameters in the Avidyne Entegra system were different in type than the Garmin G1000 but it was not readily apparent that certain parameters are recorded at different rates. This was primarily due to the limited access that the aviation industry has in working with Avidyne systems as the data from the Primary Flight Display (PFD) is encrypted. It was with this knowledge that the original proposal was developed and based upon recent findings it is necessary for us to make modifications to ensure the integrity of the research findings. During the work being completed in Subtask 2A (Determine data recording capabilities of aircraft in University Fleets) it was determined that the data recording capabilities of the various equipment with the Avidyne Entegra and the G1000 avionics platforms is different enough in the record rate of various parameters to create potential issues in the merging of the data for analysis purposes.

Of particular concern is the record rate of the Latitude and Longitude of the aircraft. These parameters will be necessary to determine the position of the aircraft along various stages of the traffic pattern to compare the flight characteristics of the various study groups. With 4 seconds of time between captures it creates too much of a difference in data to be able to potentially combine results across the three universities.

Following are the capture rates for the Avidyne Entegra with the G1000 comparison listed in the right column.

Avidyne Entegra Digital Data (FIT & OSU)

AhrsAndRateData		Recorded 5 times/second (Higher than G1000)
	magHeading	
	pitch	
	roll	
	lateralAcceleration	
	rateofTurn	
	Roll Rate [deg/sec]	
	Pitch Rate [deg/sec]	
	Yaw rate [deg/sec]	
	Long Accel [m/s^2]	
	Lat Accel [m/s^2]	
	Norm Accel [m/s^2]	
AirData timestamp		Recorded once per second (Same as G1000)
	altitude [ft]	
	baroCorrectedAlt [ft]	
	altitudeRate [ft/min]	
	trueAirspeed [kts]	
	indicatedAirspeed [kts]	
	airspeedTrend	
	densityAltitude	
FlightDirectorData		Recorded once per second (Same as G1000)
	apAnnunciators	
	fdPitch	
	fdRoll	
	logicStates	
PriNavDetails		Recorded once every 4 seconds (Lower than G1000)
	ActiveCourse [deg]	
	ActiveBearing [deg]	
	HdiDeviation [%]	
	VdiDeviation [%]	
	DesiredCourse [deg]	
	HdiSource	
	VdiSource	

PriNavDisplayBlockText	Recorded once every 4 seconds (Lower than G1000)
mGroundTrack [deg]	
DistanceToWpt [nm]	
DtkOrBrg [deg] VhfFreq	
EteInSeconds [sec]	
NeedleTextType [enum]	
NxWptID	
GpsPositionAndTimeData	Recorded once every 4 seconds (Lower than G1000)
mLongitude [deg]	
mLatitude [deg]	
UtcDate [mm:dd:yyyy]	
UtcTime [hh:mm:ss]	
GroundSpeed [kts]	
EngineData	Recorded once every 6 seconds (Lower than G1000)
manPresL [InHg]	
oilPresL [Psi]	
fuelflowL [Gph]	
tachL [RPM]	
oilTempL[DegF]	
percentPowerL	
coolTempL [DegF]	

Garmin G1000 Recorded Parameters (Garmin Perspective)—All Recorded once per second
Local Date
Local Time
Total Flight Time
Latitude
Longitude
Altimeter Setting
Altimeter Setting
Altitude Above Sea Level
Outside Air Temperature
Indicated Airspeed
Ground Speed
Vertical Speed
Pitch
Roll
Lateral Acceleration
Normal Acceleration
Heading
Track
Voltage 1
Voltage 2
Amperage Meter 1
Engine Fuel Flow
Engine Oil Temperature
Engine Oil Pressure
Engine Manifold Pressure
Engine Rotations per Minute
Cylinder 1 - Head Temperature
Cylinder 2 - Head Temperature
Cylinder 3 - Head Temperature
Cylinder 4 - Head Temperature
Cylinder 5 - Head Temperature
Cylinder 6 - Head Temperature
Cylinder 1—Exhaust Gas Temperature
Cylinder 2—Exhaust Gas Temperature
Cylinder 3—Exhaust Gas Temperature
Cylinder 4—Exhaust Gas Temperature
Cylinder 5—Exhaust Gas Temperature
Cylinder 6—Exhaust Gas Temperature
GPS Altitude
True Airspeed
Horizontal Situation Indicators
Course
Navigation Frequency 1
Navigation Frequency 1
Communications Frequency 1
Communications Frequency 2
Horizontal Course Deviation Indicator Deflection
Vertical Course Deviation Indicator Deflection
Wind Speed
Wind Direction
Distance to Waypoint
Bearing to Waypoint
Magnetic Variation
Autopilot
Rollm
Pitchm
RollC
PitchC
GPS Calculated Vertical Speed
GPS Fix
Vertical Alert Limit
Vertical Alert Limit
Horizontal Protection Level WAS
Horizontal Protection Level FD
Vertical Protection Level WAS
Vertical Protection Level FD

Another issue that has arisen is that Avidyne encrypts the data that comes from the PFD. Avidyne has provided the technical support needed to decode the data from the PFD for our use, but the software programs from past projects that have analyzed the data aren't currently equipped to handle the Avidyne PFD data. This will require software to be written which was not a subtask that was anticipated in the project and it is unknown exactly how long it will take to develop the ability to analyze the data.

Stand-Alone Data Recorder:

An option is available that would record a standardized set of data points that would serve for the main analysis capability and the data from the Garmin G1000 and Avidyne Entegra systems could be incorporated for those parameters that would provide additional analysis capability without compromising commonality and generalizability. The unit can be installed as a minor alteration and only requires a logbook signoff if the unit is not connected to aircraft power. The data below are recorded in the stand-alone unit.

AvConnect Smart Box™ DataSet
Timestamp(UTC)
LAT
LON
GS
TRK
VSI
ALT
SOL
HPL
VPL
HDOP
HDG
PITCH
ROLL
LAT_G
MIN_LAT_G
MAX_LAT_G
LON_G
MIN_LON_G
MAX_LON_G
VERT_G
MIN_VERT_G
MAX_VERT_G
RPM

<u>Summary Options</u>:

The options below (in no particular order) reflect the potential directions that could be taken and are presented to the FAA for analysis and decision making purposes.

<u>Option 1:</u> Acquire the AvConnect Smart Box™ which will allow the research team to have a commonality of data across all three aircraft platforms. This will eliminate the digital data from being a restriction to the blending of the data for analysis. The consistent parameters will be used as a standardized platform for determining the degree of stability during approach for the various participant groups.

Option 1 anticipated effects: Increase in budget, ability to maintain timeline and ability to combine data.

Option 2: Continue with the current analysis capabilities and there is a likely possibility that the data from the Avidyne units will be too granular on certain parameters to be able to conduct a robust analysis. In addition, the data from the Avidyne and the Garmin units with different parameters will not be able to be combined for assessment which would reduce the generalizability of the research findings.

Because of the inexperience of the analysis team in using the PFD data from Avidyne, it is possible that the software modifications necessary for using the PFD data would take longer than expected in the scope of the project. This could potentially result in either research findings coming only from the aircraft equipped with the G1000 avionics platform (which would reduce generalizability) or an extension in the completion date of the project.

Option 2 anticipated affect: Reduction in generalizability, reduction in data to be analyzed, potential extension in timeline for full analysis capability but with reduction in generalizability likely.

The decision was made to pursue Option 1 and the data included within this report reflects that decision.

APPENDIX K—AOA DEVICE DIAGRAMS

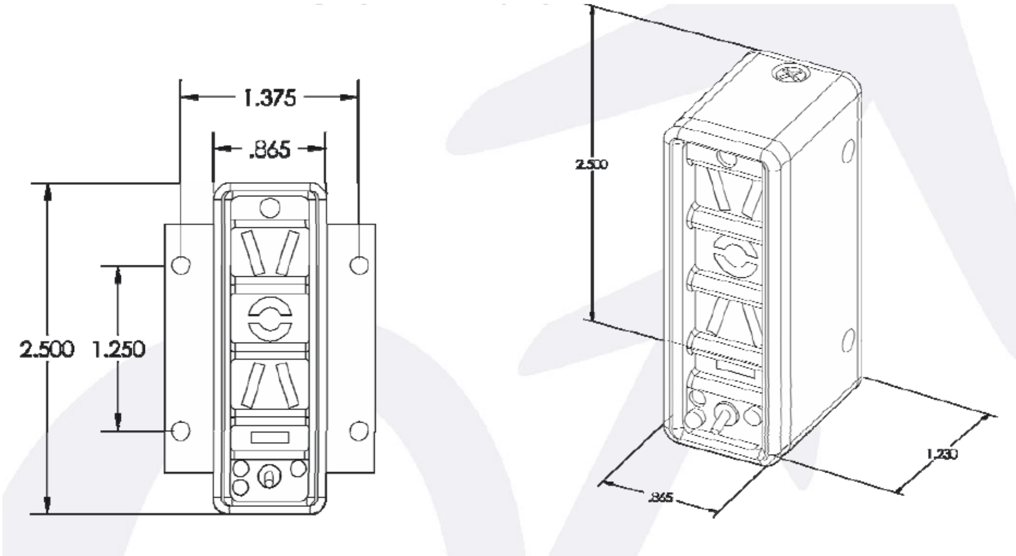


Figure K-1. Legacy Display Dimensions

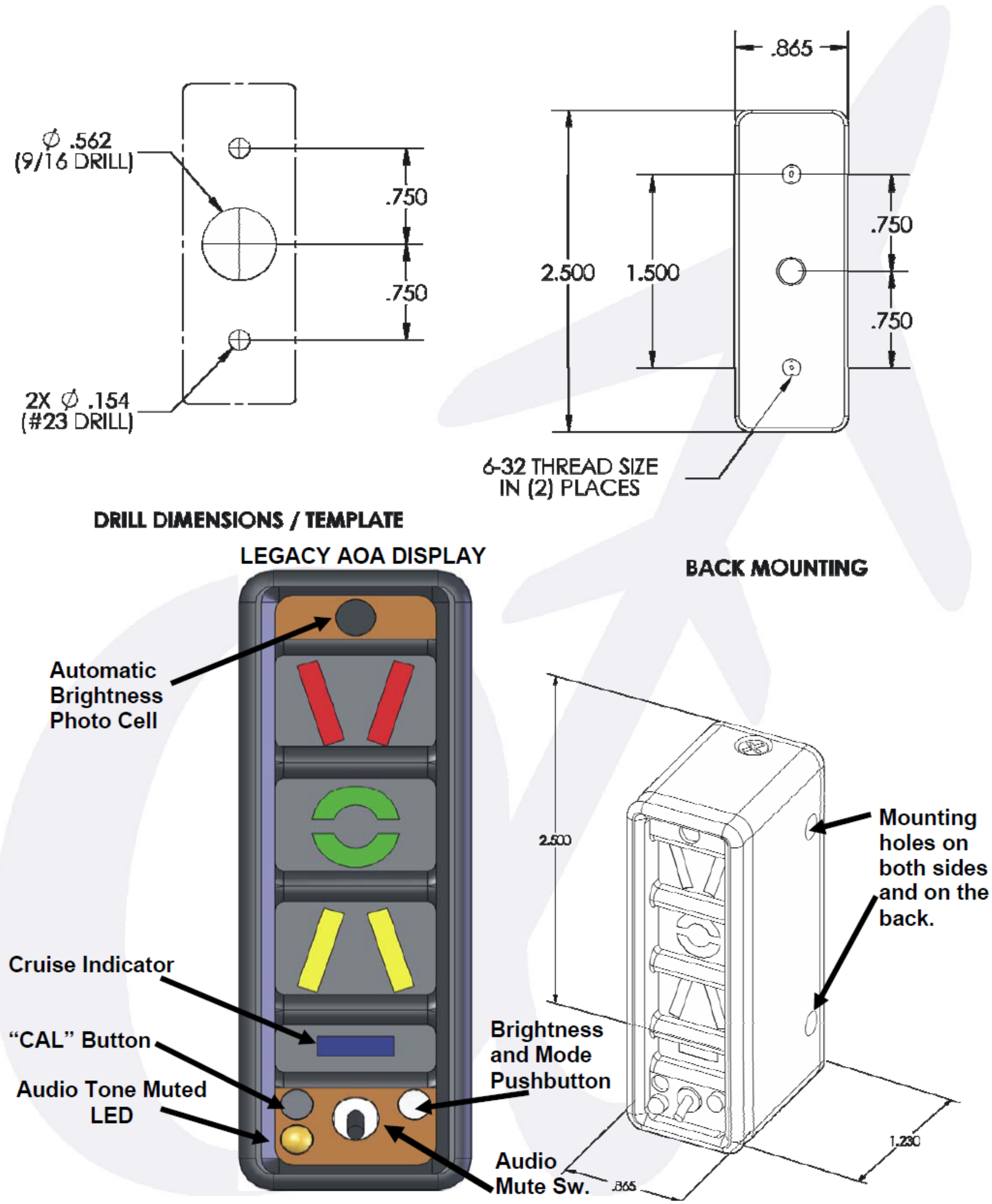


Figure K-2. Flush Panel Mounting (Purdue Cirrus Aircraft)

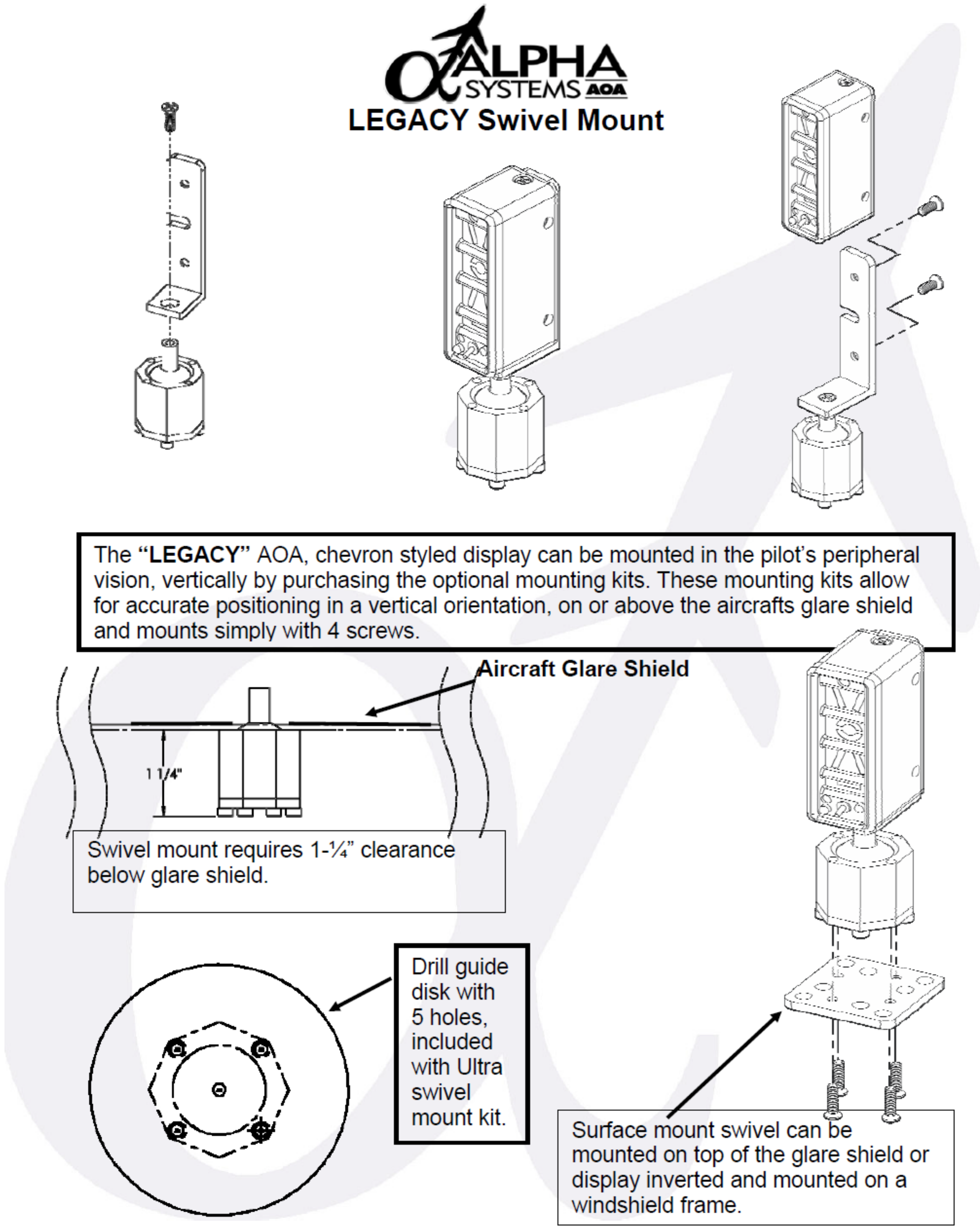


Figure K-3. Glare Shield Mounting (OSU and FIT Piper Aircraft)

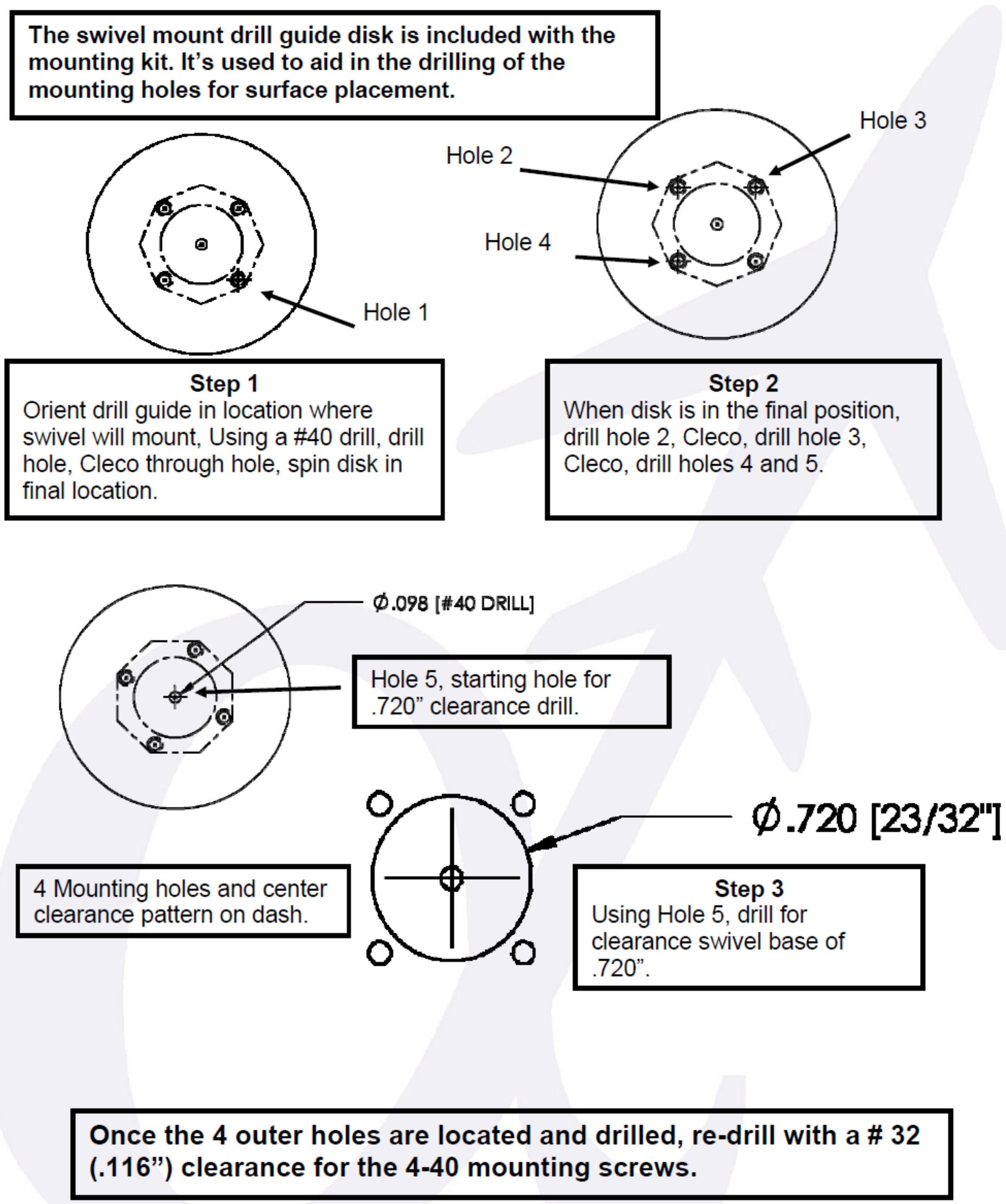


Figure K-4. Glare Shield Mounting (OSU and FIT Piper Aircraft)

Figure K-5. AOA Interface Module

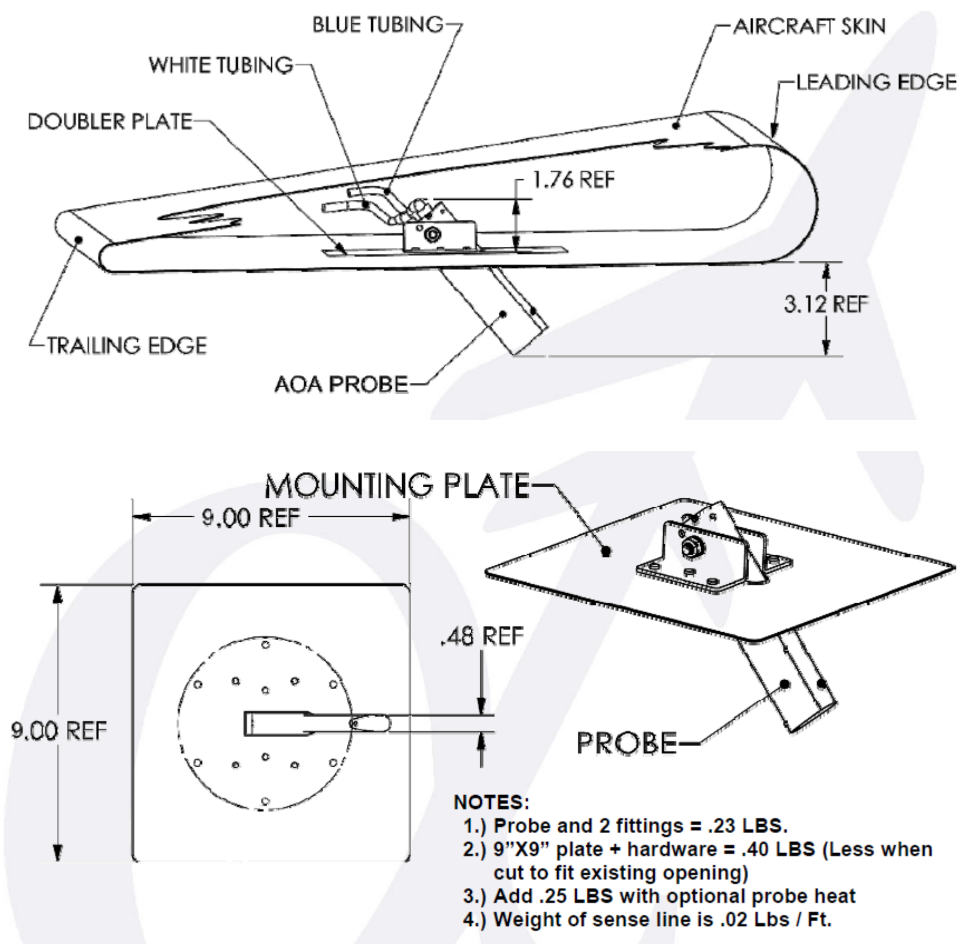


Figure K-6. AOA Probe Mounting Information

APPENDIX L—APPROACH ANALYSIS FACTORS, RESULTANTS, AND CODES

Factor/Resultant	Label	Description
SumFPA	Sum Flight Path Angle	The sum of the variation of the flight path angle for the last 30 seconds of the approach
Participant	Participant	The number of the participant in the study used to facilitate confidentiality
Date	Date	Date of the Evaluation Flight
Time	Time	Time of the Evaluation Flight
University	University	Code representing each university (1-3)
EvalGRP	Evaluation Group	Code representing the group to which the participant was randomly assigned
LdgOrder	Landing Order	The order of landing of each approach (1-6)
Pwr	Power Off or On	Code representing if the landing is a power-off or power-on landing
EduDate	Education Date	The date of the AOA education
EduInst	Education Instructor	The instructor that provided the AOA flight education to the participant
EvalPilot	Evaluation Pilot	The safety pilot that sat in the right seat during the evaluation flight
EduToEval	Education to Evaluation	The length of time (in days) between when the education flight and evaluation flight were conducted
WindDir	Wind Direction	The direction of the wind as reported in the METAR
WindSpd	Wind Speed	The speed of the wind as reported in the METAR
Gust	Gust	Code representing whether or not the winds were gusting during an approach as reported in the METAR
Aircraft	Aircraft	Code representing the type of aircraft that was flown during the approach
DispUse	Display Use	Code representing if the participant used the display as a primary or secondary reference
FreqUse	Frequency of Use	Code representing the frequency with which the participant referenced the display
FltTime	Flight Time	The amount of flight time of the participant
VASI	Visual Approach Slope Indicator	Code representing if there was any type of visual guidance present for reference on the approach
Twnd	Tailwind	Code representing if a tailwind situation was present during the base to final turn
Airport	Airport	Code representing the airport where the approach was conducted
Runway	Runway	The number of the runway for the approach
TurnDir	Direction of Turn	Code representing the direction of turn
AOALocation	AOA Location	Code representing the location of the AOA display

The legend below describes the codes that were used in the data processing

Aircraft	
1	Warrior
2	Arrow
3	SR-20

Direction of Turns	
1	Left
2	Right

Wind Gust	
0	No Gust
1	Gust

Visual Approach Guidance	
0	No Visual
1	Visual

Tailwind Condition	
0	No Tailwind
1	Tailwind

Power	
1	Power On
0	Power Off

Location of Display	
0	Below Dash
1	Above Dash

University	
1	FIT
2	OSU
3	Purdue

Education Instructor	
1	Jones
2	Bloss
3	Spence
4	France
5	Kieffer
6	Borsa
7	Dillman
8	Cardoza
9	Peden
10	White
11	Callender
12	Solomon

Kind of Device Usage	
1	Primary Instrument
2	Secondary Instrument
3	Not Used

Frequency of Use	
1	Never
2	Rarely
3	Sometimes
4	Often
5	All of the time

Airport	
1	KFKR
2	KCFJ
3	KLAF
4	KMLB
5	X26
6	X59
7	KOSU
8	KMRT
9	KDLZ

Evaluation Pilot	
1	Jones
2	Bloss
3	Spence
4	France
5	Kieffer
6	Borsa
7	Dillman
8	Brynjolfsson
9	Cardoza
10	Peden
11	White
12	Callender
13	Solomon
14	Knight
15	Rice