Comparison of See-and-Avoid Performance in Manned and Remotely Piloted Aircraft

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This thesis titled
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ABSTRACT

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See-and-avoid is the current FAA approved method for pilots to avoid objects and other aircraft while flying in visual meteorological conditions (VMC). Although fully autonomous ‘sense-and-avoid’ or ‘detect-and-avoid’ systems are in development, none are currently certified. Thus existing unmanned aerial vehicle (UAV) operations are limited to case-by-case restricted airspace or require escort by manned aircraft [1], [2]. Many UAVs are equipped with at least a forward-looking camera. In the transition between current technology and future fully autonomous, certified sense-and-avoid systems, it seems reasonable to require a ground-based operator to perform the see-and-avoid function.

This thesis discusses the flight-testing performed to establish air traffic detection ranges for low-time pilots, and for a low-cost UAV camera system. The system was evaluated to determine if it could provide the equivalent see-and-avoid performance as the tested pilots.

Approved: _____

Michael S. Braasch

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LIST OF ACRONYMS

AC	Advisory Circular
AIAA	American Institute of Aeronautics and Astronautics
CFR	Code of Federal Regulations
DASC	Digital Avionics Systems Conference
ECEF	Earth-Centered, Earth-Fixed
ERAST	Environmental Research Aircraft and Sensor Technology
FAA	Federal Aviation Administration
GA	General Aviation
ICAO	International Civil Aviation Organization
ICAT	International Center for Air Transportation
IEEE	Institute of Electrical and Electronics Engineers
IRB	Institutional Review Board
JUP	Joint University Program for Air Transportation Research
LLH	Latitude, Longitude, Height
MAC	Mid-Air Collisions
MIT	Massachusetts Institute of Technology
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
RTCA	Radio Technical Commission for Aeronautics
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

1 INTRODUCTION

1.1 Purpose

The technology for air-transportation is improving at a rapid pace, and with this improved technology comes an inherent increase in the overall air-traffic worldwide [3]. At the same time the technology behind unmanned aerial vehicles (UAVs) is improving at an increasing rate. This brings with it even more potential applications for UAVs. Fields such as remote sensing, disaster response, surveillance, and search and rescue can all benefit greatly from these improved UAV technologies [4].

Many of these fields taking advantage of the improvements to UAV technologies are new fields for UAVs altogether. In the past UAVs were generally only operated by the military, only requiring the use of restricted airspace. With these new technologies and applications, the explicit need for operation in civil airspace is beginning to arise. As these additional UAV applications are introduced, the National Airspace System (NAS) will potentially become even more congested [4].

Currently the Federal Aviation Administration (FAA) is in charge of all regulations on any aircraft operating in the NAS. However, since UAVs have rarely operated in the NAS in the past, there are very little restrictions or regulations on both the physical airframe of the UAV and on their operational guidelines.

The FAA and the Radio Technical Commission for Aeronautics (RTCA) are in the process of creating a set of regulations for UAVs similar to that available for commercial and general aviation (GA) aircraft. One of the difficulties in doing this is the absence of quantitative requirements present on a pilot to avoid other aircraft while flying under the Visual Flight Rules (VFR).

This leads to the overall purpose of the research presented in this thesis. With very little data available on a pilot's ability to see and avoid other aircraft while flying under VFR, specifically low-time pilots, the intent is to quantify the air-traffic detection ranges for these pilots. Another purpose with this research is to evaluate a three-camera system that could potentially be used as an equivalent means for UAVs to meet the pilot's ability to see and avoid other aircraft. The result by obtaining this data will be increased safety measures for all GA, commercial, and military aircraft pilots and passengers operating in the NAS.

1.2 Proposed Solution

The goal with this research is to independently verify the air traffic detection ranges for low time pilots, as well as determining the detection ranges for a low-cost three-camera UAV system. The subject pilots used to accomplish this were all student pilots enrolled in Ohio University's Department of Aviation. The cost for the UAV camera system was intended to be less than \$200 for each camera and lens, or \$600 total.

In order to obtain these air traffic detection ranges, two aircraft were needed. The first aircraft had a low-time subject pilot onboard. There were also three cameras aimed out the windshield, and a GPS receiver and computer recording the position and time and the video feeds from the cameras. The second aircraft was simply needed as the traffic or target aircraft. The only equipment necessary to be onboard was a single GPS unit to record the position and time of the aircraft.

To capture the range between the two aircraft when the low-time pilot first identified the traffic aircraft, the position of both aircraft must be known. The time must also be known to find the correct aircraft positions, because the positions are a function of time. The range can easily be calculated after this using the equations presented in section 4.3 of this thesis.

After the flight was over, the video recorded during the flight was evaluated. When the target aircraft entered the field of view of the cameras and was identified onscreen, the time of identification was noted. With this time in hand and the above method used for the subject pilots, the range for the camera air traffic detections was easily determined.

By comparing the ranges from the subject pilot and camera system scenarios it can easily be determined if the camera system can provide an equivalent see-and-avoid capability as the subject pilots. The results of the two test scenarios, which took place between May

22, 2008 and July 8, 2008, are presented in chapter 4 of this thesis, and the conclusions regarding the efficacy of the camera system are given in chapter 6.

1.3 Contributions and Approval

Considerable segments of the research discussed in this thesis have been presented previously at the AIAA IEEE 27th Digital Avionics Systems Conference (DASC). A presentation was given outlining the research accomplished, as well as publication of the paper below.

R. J. Kephart, M. S. Braasch, “Comparison of See-And-Avoid Performance in Manned and Remotely Piloted Aircraft,” *Presented at the 27th Digital Avionics Systems Conference*, October 2008, pp. 4D2. [5]

This research has also been presented at two quarterly meetings of the FAA Joint University Program for Air Transportation Research (JUP). The first presentation developed the testing plan and everything leading up to the flight-testing. The second outlined the entire research project and presented the conclusions to the research.

R. J. Kephart, M. S. Braasch, “Comparison of See-and-Avoid Performance in Manned and Remotely-Piloted Aircraft,” *Presented at the Spring 2008 Joint University Program for Air Transportation Research Quarterly Meeting*, April 22, 2008. [6]

R. J. Kephart, M. S. Braasch, "Comparison of See-and-Avoid Performance in Manned Aircraft and Remotely Piloted Vehicles," *Presented at the Fall 2008 Joint University Program for Air Transportation Research Quarterly Meeting*, October 16, 2008. [7]

The above sources, along with all others located throughout this thesis, can be found in the references section after chapter seven near the end of the thesis. It should be noted that much of the work that appears in the 27th DASC proceedings is included in this thesis without any changes or citations to itself. All of the tables and figures included in this thesis are either property of the Avionics Engineering Center, the original work of the author, or include a reference to the original source.

The Ohio University Institutional Review Board (IRB) requires that all students or faculty, who wish to carry out any form of testing that requires the use of human subjects, must undergo specific training aimed at ensuring proper informed consent and debriefing procedures are followed. The files submitted to the IRB are attached in Appendices A and D, and the approval documents are attached in Appendices B, C, and E.

1.4 Thesis Overview

This thesis is presented in different chapters to ensure a clear communication of the material. There are seven chapters and five appendices in this thesis. The first chapter

presents the reader with the general problem to be solved, as well as the proposed research and testing method to resolve the problem. Chapter one includes a section discussing the major literature contributions to this thesis, and also the Institutional Review Board approval required in order to conduct the research using human subjects. The second chapter goes into the background and literature review performed in order to properly clarify and organize the general problem attempting to be solved. The research is further justified in this chapter, and compared to current regulations and other recent research in the field. Chapter three goes on to outline the testing and equipment that was used, as well as the procedures followed. The results of the flight-testing are presented in chapter four, starting with a broad overview of the results. The method used to calculate the traffic detection ranges is presented in this chapter, followed by the range results for the subject pilots and the UAV camera system. Chapter five expands on the results presented in chapter four in order to develop a basic model for traffic detection ranges using different camera resolutions and aircraft wingspans. The material presented in this thesis is concluded in chapter six, reiterating the overall results and their interpretation. Following the conclusion is a brief chapter outlining any further work that could be performed in a continuation study, building on the outcome and knowledge gained from the research presented throughout this thesis.

2 BACKGROUND

2.1 Chapter Overview

This chapter of the thesis begins with an introduction in section 2.2 regarding the current dilemma UAV operators are encountering. This chapter then goes into some detail about the see-and-avoid requirement for UAVs that is holding up much of the regulation process. This leads into the purpose of the project, to compare the obstacle and traffic detection capability of a UAV operator to that of an actual pilot flying a manned aircraft. After this discussion, section 2.3 covers the search area guidelines for manned aircraft, as well as some related research to determine traffic detection ranges.

2.2 Transition into the National Airspace System

In the past UAV operations have been used almost strictly by the military in restricted airspace. However, as UAV technology has matured many civilian uses have begun to develop. With this subdivision of civil UAVs comes the inherent use of the National Airspace System (NAS) in which to operate them. Heavy restrictions (equivalent to a general aviation aircraft) currently exist on UAV operation outside of restricted airspace [2].

The term see-and-avoid appears in the FAA Right-of-Way Rules (Title 14 CFR 91.113).

“When weather conditions permit, regardless of whether an operation is conducted under

instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft” [9]. Based on this rule UAVs must provide “an equivalent level of safety, comparable to see-and-avoid requirements for manned aircraft” [1], [8]. See-and-avoid is often considered the most difficult unmanned aviation requirement to meet because there are no quantifying numbers included in the equivalent manned aircraft requirement they must meet (Title 14 CFR 91.113). FAA Order 7610.4K goes on to mention several possible methods to achieve this see-and-avoid function. Among those mentioned is “forward or side looking cameras” [1], which was chosen for the premise of this research.

When flying in visual meteorological conditions (VMC), aircraft separation or the see-and-avoid function is primarily the pilot’s responsibility [9]. One important objective is to determine if a UAV operator can provide an equivalent level of traffic detection remotely. If this can be proven possible, a ground based operator or monitor could be an important intermediary step while future autonomous sense-and-avoid systems are being developed and certified.

The purpose of this project is to compare the obstacle and traffic detection capability of a UAV operator to that of an actual pilot flying a manned aircraft. It may seem obvious that the majority of midair collisions (MACs) and near midair collisions occur with low-time pilots [8]; however, it is surprising to learn of the 152 MACs and 2,241 near MACs from 1978 through 1982, “that the majority of these midair collisions and near midair

collisions, occurred in good weather and during the hours of daylight” [10]. Given this information, it was chosen to examine low-time pilots flying under the Visual Flight Rules (VFR) and determine their traffic detection ranges.

While the UAV community and RTCA Special Committee 203 are drafting regulations with precious little data available to assist in the decision making process, this is an extremely important area of research. It is anticipated that the data provided in this experiment could benefit the community as UAVs make the transition from restricted-only airspace into the broader NAS.

2.3 Current UAV Regulations and Related Research

RTCA SC-203 is one of the teams designated with the task of quantifying Unmanned Aerial Systems (UAS) performance requirements, which include both the air vehicle and the ground station. Of the already existing rules, Title 14 CFR Part 91 – General Operating and Flight Rules has specifications for unmanned aircraft but the community is having trouble complying with them. One of the most difficult rules to comply with is providing an equivalent level of safety to the see-and-avoid requirement.

Detection range and search area are both key components in the overall representation of see-and-avoid. Search area and range are not directly addressed in the FAA regulations, although AC 25.773-1 goes into some detail regarding cockpit visibility guidelines.

Search area azimuth guidelines range from $\pm 60^\circ$ up to $\pm 120^\circ$, and elevation guidelines range from no guidelines up to $+37^\circ$ and -25° [8].

To avoid a near midair collision, a 500-foot altitude separation needs to be maintained between aircraft at all times [9]. In 2005 a study was conducted to determine the minimum detection range needed for a passive sense-and-avoid system to detect a threat and maneuver in order to still maintain the 500-foot altitude separation required [11]. Since this was for a passive system, lag time introduced by a system using a ground station would require additional range to still maintain this separation. It is also assumed that each aircraft is below 10,000 feet and going no more than 250 kts, with the presumption that a system based off of aircraft transponders could be incorporated for higher altitudes. The minimum detection range was determined to be 1.17 miles for the system [11].

Traffic detection ranges have also been the topic of several other studies. The Air Force Research Labs Operational Encounter model calculated the expected pilot detection range to be between 1.7 and 2.3 miles for an alerted pilot. This model “has been used to quantify human detection capabilities against various aircraft as a function of their paint schemes, sky background, range, sun angles, and other parameters” [8]. Research at the MIT Lincoln Laboratory in the 1980’s found recognition ranges of 1.14 miles for un-alerted pilots and 1.61 miles for alerted pilots trying to detect a Cessna 421 aircraft in the open sky [12]. Several other see-and-avoid options exist, such as the AmphitechOASys

radar used in the NASA ERAST project in 2003, which was able to detect most intruder aircraft an average of 5.18 miles away [13]. Evasive action time related to see-and-avoid for a manned aircraft is discussed in Advisory Circular 90-48C Appendix I, where it shows a total time of 12.5 seconds between obstacle detection and a subsequent course change [10].

3 TESTING

3.1 Chapter Overview

This chapter of the thesis starts off in section 3.2 by identifying the different aircraft used in the testing. The rest of the equipment is then identified in section 3.3, such as the cameras, GPS units, and PCI card to capture the video. Section 3.4 goes on to describe the overall testing procedure, and how the ranges were calculated for both the subject pilots and the camera system.

3.2 Test Aircraft

With all of the above information from chapter 2 in hand, the goal became to independently verify the traffic detection ranges for low-time pilots as well as determining the detection ranges for a low-cost three camera UAV system. In our case each camera cost less than \$200; this is not a significant number, but would allow the cameras to be used on nearly any class of UAV. To accomplish this detection task, one of the flying laboratories at Ohio University was used to house most of the test equipment. A Piper Saratoga (Figure 3.1 below) was used as the test aircraft and the Ohio University Department of Aviation's Piper Warrior III (Figure 3.2 below) was used as the traffic aircraft.

Figure 3.1 - Ohio University's Piper Saratoga

Figure 3.2 - Ohio University's Piper Warrior III

3.3 Equipment and Installation

The three cameras used were Arm Electronics C600 cameras (Figure 3.3 below), each having a resolution of 600 TV lines. All of the cameras were installed behind the test aircraft windshield, on pan-tilt mounting brackets. This setup allowed adjustment to the positioning of the cameras if initial testing revealed any overlap or other errors associated with the camera positions.

Figure 3.3 - Three-Camera Installation

The three cameras installed on the Saratoga each provide a 40° horizontal by 30° vertical field of view, totaling a 120° horizontal field of view from the three cameras together. The field of view provided by these cameras meets the $\pm 60^\circ$ horizontal and $\pm 10^\circ$ vertical scanning guidance set forth by the FAA with regard to a pilot avoiding a midair collision

[14]. This field of view does not meet the $\pm 110^\circ$ azimuth guidance from the ICAO Rules of the Air Section 3.2; however, more cameras could be added to increase the horizontal field. Since this is a controlled experiment, it was ensured that all of the target aircraft fell within the horizontal field in order to maintain accuracy in the data. The horizontal field of view captured by the cameras is demonstrated in Figure 3.4 on the next page.

In order to calculate the range between the test and traffic aircraft, the location of both aircraft must be known at the time of detection. To do this, a Novatel OEM4 GPS unit was installed onboard the test aircraft. This unit is WAAS enabled and provides position and UTC data at 20 Hz. Onboard the traffic aircraft an Eagle Tree eLogger v3 with GPS expander module was installed behind the windshield. This unit is also WAAS enabled, and provides position and UTC data at 5 Hz.

To record the video feeds coming from the three cameras, a computer PCI card with BNC video input connections was selected. This card is typically used for security or surveillance applications, but the features also worked well for our project. The card was a Netpromax NDRx204 DVR card, recording at 30 FPS total between the three cameras. The video was recorded at 704 x 480 pixel resolution per camera. Onboard the test aircraft was a rack-mounted computer, which had the PCI card installed, as well as serial connections to record the GPS output from the Novatel unit. The complete rack installation can be seen in Figure 3.5 below.

Figure 3.4 - Horizontal Field of View of the Three-Camera Setup

Figure 3.5 - Rack Unit Installation

3.4 Testing Procedure

The crew onboard the test aircraft consisted of three members: a subject pilot performed the traffic detection; a safety pilot assisted the subject with navigation and observation guidelines; and a data collector recorded the crucial information. Before the flight the safety pilot provided the necessary flight path details to the subject pilot, and described what the subject believed to be the focus of the research and their part in the experiment. Along the flight the subject searched for and identified landmarks such as bodies of water and electrical towers which the safety pilot had marked on a flight map, as well as identified any air traffic that entered his or her field of view. The purpose of identifying landmarks was to provide a sufficient distraction to the pilot as to not skew the data with an unrealistic amount of traffic scanning.

The subject pilot notified the safety pilot and data recorder as he or she identified the different landmarks and air traffic along the flight, although only information that pertained to the target aircraft was recorded. When the target aircraft was identified the data collector marked the exact time. Along the entire flight the test aircraft and traffic aircraft recorded time and position using the GPS units mentioned above. This allowed the data recorder (after the flight) to look up the positions of both aircraft at the identification time, and compute the range between the two aircraft. Figure 3.6 below demonstrates the two conflict scenarios present between the test aircraft and the target traffic aircraft during the flight.

Figure 3.6 – Traffic Aircraft Conflict Scenarios

While the flight took place, there were also three cameras behind the test aircraft windshield, which captured approximately what the pilot was able to see. The cables from the cameras fed to the onboard computer which recorded the 120° by 30° field of view. When the flight was complete the recorded video was replayed and the various detection ranges for the cameras were determined, given the limited resolution and field of view. Time was overlaid on the video, which allowed the same method to determine position and range as mentioned above for the subject pilots.

When the flight-testing was complete, the ranges from both the subject pilot and camera methods were evaluated. The result of this determined if the cameras could provide an

equivalent level of detection capability as the human eyes used by the subject pilots. If the cameras could provide superior detection capability, then an approximate lag time could be added to account for the latency that would be present between the video transmission and a ground-based operator performing the see-and-avoid function. This would allow a theoretical active see-and-avoid system to be compared to the currently approved pilot see-and-avoid used in all manned aircraft today.

4 RESULTS

4.1 Chapter Overview

This chapter of the thesis summarizes the outcome of the research conducted at Ohio University between May 22, 2008 and July 8, 2008. First an overview of the results is given in section 4.2 explaining various modifications made to the test plan. Next, section 4.3 presents the required equations necessary to perform the range calculations. The actual air traffic detection ranges for the subject pilots are shown in section 4.4 and the results are compared to the detection ranges calculated in other related research. Finally, section 4.5 shows the calculated ranges for the UAV camera system, and compares them to the results obtained from the subject pilot testing.

4.2 Modifications to Test Plan

In total, seven subject pilots have gone through the experiment and provided very useful data regarding their ability to detect air traffic during daylight VMC. Originally, the test was designed to record both pilot detection ranges and camera ranges on the same flight, so both could be compared on a single detection with the same sun angle and cloud conditions et cetera. However, after initial testing revealed a noticeably lower detection range for the cameras, not all of the traffic passes were at a close enough proximity to capture the target on camera. Thus, a later test was conducted without a subject pilot, and was designed specifically to ensure the target aircraft would be captured on camera. This

secondary test allowed the necessary range calculations to be performed. In this experiment the same Saratoga test aircraft was used, and a Cessna 210 Centurion was used as the traffic aircraft.

Each subject pilot was presented with two aircraft conflicts. The first pass was set up with the target aircraft crossing the flight path of the test aircraft at a 90° angle. The second involved the traffic aircraft approaching the test aircraft from straight ahead. This is said by pilots to be the most difficult position to detect traffic because of the illusion that the traffic aircraft is not moving, paired with the empty field myopia occurrence when attempting to focus in an empty visual field [15]. In both cases the test aircraft was kept at approximately 3000 feet altitude, and the traffic aircraft 500 feet above or below.

4.3 Range Calculations

The Novatel and Eagle Tree GPS units both output position in the geodetic Latitude, Longitude, and Height (LLH) format. While the height is in meters, both the latitude and longitude are in degrees. The range calculations that are presented in most textbooks, and are the easiest to use, generally require all the values to be the same units as one would want for the output, which in this case is meters. The Earth-Centered, Earth-Fixed (ECEF) coordinate frame is a Cartesian coordinate system, and will allow all the values to be in meters. A coordinate transformation is needed to go from LLH to ECEF, in order to calculate the range in the ECEF coordinate system. Equations 4.1 to 4.3 below will

allow a transformation from LLH (ϕ, λ, h) to ECEF (X,Y,Z) [16], where the semi-major axis $a = 6378137$ meters and the eccentricity of the ellipsoid $e = .0818191908426$.

$$X = \left(\frac{a}{\sqrt{1 - e^2 \sin^2 \phi}} + h \right) \cos \phi \cos \lambda \quad (4.1)$$

$$Y = \left(\frac{a}{\sqrt{1 - e^2 \sin^2 \phi}} + h \right) \cos \phi \sin \lambda \quad (4.2)$$

$$Z = \left(\frac{a(1 - e^2)}{\sqrt{1 - e^2 \sin^2 \phi}} + h \right) \sin \phi \quad (4.3)$$

Substituting the LLH data values into the variables in equation 4.1 to 4.3 above for each identification time, the equivalent ECEF values can be determined. If this is done for the locations of both the test and traffic aircraft, the range between the two can be found easily using equation 4.4 below [17]. The indices $_1$ and $_2$ represent either the traffic or test aircraft values. Since the quantity is squared, the term loses any negative sign that may be associated with it. Thus, the equation yields the same result regardless of which aircraft is used for which indices.

$$Range = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2} \quad (4.4)$$

4.4 Subject Pilot Results

The subject pilots were able to detect the traffic aircraft somewhat faster than the camera setup, with an average detection range of 1.275 miles. In all but one case, the 90° intersect detection was noticeably better than the oncoming detection. In one of the tests, the oncoming traffic aircraft passed within 500 feet of the subject pilot without any detection. Table 4.1 on the next page shows the ranges for the seven subject pilots, as well as the mean detection ranges. The average intersect detection range was 1.511 miles, while the average oncoming range was just over a mile at 1.038 miles. When comparing both the average ranges, the mean 90° intersect detection range is almost half a mile greater (0.473 miles) than the mean oncoming detection range.

All of these ranges fall right around the detection ranges from the other research mentioned above. Between the Air Force Research Labs Operational Encounter model and MIT's Lincoln Laboratory research a nominal detection range of 1.14 to 2.3 miles was to be expected, depending on whether the pilot was anticipating seeing any air traffic.

Table 4.1 - Subject Pilot Detection Ranges

Subject Pilot	Intersect	Oncoming
Pilot 1	1.294	No Detection
Pilot 2	1.178	0.309
Pilot 3	1.898	1.127
Pilot 4	1.710	1.202
Pilot 5	1.167	2.336
Pilot 6	1.773	1.258
Pilot 7	1.559	1.034
Mean	1.511	1.038

(statute miles)

When comparing the mean values of the intersect and oncoming detections, there appears to be a significance difference between the two sets of data. There is a tool called Student's t -test to determine any statistical significance between these two datasets [18]. In this case, the two datasets are dependent on the other because the same pilot performed both observations. Below in equation 4.5 this statistical tool is presented and the calculated t value was found to be 1.61. In equation 4.5, d_i is the difference between the two datasets for a specific pilot, and n is the number of points in the dataset. The higher the t value calculated, the more significant the difference between the two datasets.

$$t = \frac{\sum d_i / n}{\sqrt{\frac{n \sum d_i^2 - (\sum d_i)^2}{n-1}}} \quad (4.5)$$

The t value in this experiment was 1.61, which is less than the t value for $n-1$ degrees of freedom and 95% certainty, or 1.943 (many tables exist with significant t values tabulated). Since this t value is less than the threshold for 95% certainty, the two datasets cannot be considered to differ significantly. However, in the future if more data points were added to the set, the average variation in the data points might decrease and the t value could potentially decrease below the threshold and prove a significance difference between the two datasets.

4.5 UAV Camera System Results

In the testing involving the UAV three-camera system, the subject pilot was searching for a Cessna 210 Centurion somewhere in the sky. The Centurion is a single engine aircraft with a 39-foot wingspan. After the flight the recorded video was replayed using three displays. Though not real-time, this served as a simulation of a UAV operator designated with the task of obstacle and traffic detection. Circled below in Figure 4.1 is a screenshot of one of the traffic aircraft identifications from the right camera on an intersect detection, followed by a screenshot of an oncoming detection from the center camera circled in Figure 4.2 below. The target aircraft is approximately 0.4 miles away in Figure 4.1, and 0.49 miles in Figure 4.2. This gives an idea of how much earlier or later an actual remote pilot in the loop system may provide detection of the air traffic.

Figure 4.1 - Intersect Detection on Camera

Figure 4.2 - Oncoming Detection on Camera

The following UAV camera detection ranges found in Table 4.2 and 4.3 below are what was determined to be the fastest detection times possible with the limited camera resolution and field of view. These camera results are for a single alerted user, informed of the aircraft direction. The detection ranges could be even smaller for an un-alerted user, or if latency was introduced for the video feeds to transmit to the ground and allow a ground operator to identify the intruder aircraft. The average range for the overall camera system is just over half a mile at 0.521 miles. The mean camera intersect detection range of 0.651 miles is approximately 2.3 times worse than the mean intersect detection range established for the subject pilots. The mean camera oncoming detection

range of 0.417 miles is approximately 2.49 times worse than the mean oncoming detection range for the subject pilots. It should be noted that these detection ranges are based off of the capability of the human eye. An automatic detection algorithm could also be used that would be independent of the lumen and other camera characteristics, and may be much better at detecting objects in the imagery.

Table 4.2 - Intersect Camera Detection Ranges

Detection	Intersect
1	0.717
2	0.582
3	0.638
4	0.665
Mean	0.651

(statute miles)

Table 4.3 - Oncoming Camera Detection Ranges

Detection	Oncoming
1	0.372
2	0.424
3	0.494
4	0.319
5	0.475
Mean	0.417

(statute miles)

When comparing the mean values of the intersect and oncoming detections for the camera test, we can use the same Student's t -test used for the subject pilots [18]. Above in equation 4.5 this statistical tool was presented for dependent datasets and the calculated t value is found to be 4.42, which is more than the t value for $n-1$ degrees of freedom and 95% certainty, or 2.353 (many tables exist with significant t values tabulated). Since this t value is more than the threshold for 95% certainty, the two datasets can be considered to differ significantly. So the oncoming detection dataset can be considered significantly closer or smaller than the intersect detection dataset.

5 RESOLUTION AND DETECTION RANGES

5.1 Chapter Overview

This chapter of the thesis uses the ranges found in chapter four in order to determine estimate ranges for different wingspan aircraft, and also to determine the potential ranges for other resolution cameras. The main results of this study are presented in the form of a graph in figure 5.2. These results suggest that an HD camera can provide detection ranges greater than one mile for traffic aircraft with wingspans greater than 34 feet.

5.2 Connecting Range, Resolution, and Wingspan

With the above camera ranges in hand and a known recording resolution (704 x 480 pixels), basic approximations regarding the applicability of a camera system at higher resolutions were made, as well as detection capabilities for larger or smaller aircraft.

Using the equations below with the 704 pixel horizontal resolution and 40° horizontal field of view (FOV) at the mean detection range of 2201.76 feet (0.417 miles), a ratio of 2.2766 feet per pixel for the cameras was found. This value implies the 39 foot wingspan for the target aircraft would occupy approximately 17 pixels in an oncoming detection.

To verify this value an oncoming detection screenshot was digitally zoomed in to 3200% in order to see the individual pixels of the image. Counting the approximate number of pixels the target aircraft occupied, revealed values near 17 pixels as well. This 17 pixel

value became the threshold for the occupied pixels variable in the equations below.

Figure 8 below shows where the different variables used in the equations originate, such as width in feet (W) and half screen width in pixels (HSW).

$$W = HSW = Range \times \tan\left(\frac{FOV}{2}\right) \quad (5.1)$$

Rearranging the above equation and setting it equal to the ratio of occupied pixels to the aircraft wingspan yields the equation below.

$$\frac{OccupiedPixels}{Wingspan} = \frac{HSW}{Range \times \tan\left(\frac{FOV}{2}\right)} \quad (5.2)$$

Rearranging the equation above, one can easily find the detection range. The range equation below is a function of half screen width, wingspan, occupied pixels required for detection, and the field of view of the camera.

$$Range = \frac{HSW \times Wingspan}{OccupiedPixels \times \tan\left(\frac{FOV}{2}\right)} \quad (5.3)$$

Figure 5.1 - Camera Range Diagram

This idea can be applied to other resolutions or aircraft with different wingspan lengths.

The results of this analysis are shown in Figure 9 below for the listed aircraft types at other typical resolutions (640x480, 800x600, 1024x768, 1600x1200, and 1920x1080).

From this graph it shows that 1920x1080 high definition video (HD) or above is required to accurately identify a Cessna 210 traffic aircraft at ranges greater than 1 mile.

However, even with HD video, aircraft with wingspans smaller than 34 feet will be difficult to detect at this range with a 17-pixel threshold. A smaller pixel threshold could

be used with more advanced methods to increase the camera detection range, such as implementing an automatic detection algorithm or taking into account multiple frames to increase the sensitivity.

Figure 5.2 - Range vs. Resolution (Assuming 17 Pixel Minimum Detection Threshold)

6 CONCLUSIONS

After several subject pilots had gone through the experiment, it became evident that the pilots were consistently identifying the traffic aircraft before the camera system. Many of the traffic aircraft were not visible on the cameras during the initial subject pilot testing. This required a secondary set of test scenarios to be created with the sole purpose of capturing the traffic aircraft on the camera system. This flight configuration involved much more communication between the safety pilot and the traffic aircraft pilot, in order to pass each other at a closer proximity than in the previous testing. An important theme noticed throughout the subject pilot testing is the pilots' earlier detection of the intersecting traffic over the oncoming traffic. The average subject pilots' oncoming traffic detection range was nearly half a mile shorter than the average intersect detection. The preliminary results of this study give a good indication of the ability of a pilot flying VFR to identify general aviation air traffic.

The results of the UAV camera system study indicate that the cameras used in this testing (recorded at 704x480 pixels) were not of sufficient resolution to capture enough of the detail in the sky that the pilots were seeing. The greatest range that the 39-foot wingspan of the centurion was visible was just over seven-tenths of a mile away. This was not a sufficient distance to consider the see-and-avoid capability of the camera system equivalent to the see-and-avoid capability of the low-time subject pilots.

Using the camera range data to determine a minimum pixel threshold required to detect a traffic aircraft, approximate detection ranges for different length wingspan aircraft as well as for various camera resolutions were made. The result of this analysis led to the hypothesis that an HD resolution camera would be the minimum resolution usable to detect most air traffic at ranges similar to a pilot's detection ability. While an HD camera would be able to detect the 39-foot wingspan of the centurion at distances greater than one mile, aircraft with 34-foot wingspans or smaller would still be undetectable at this distance.

7 FUTURE WORK

Seven subject pilots took part in the experiment and provided very useful information regarding their ability to detect oncoming and 90° intersect air traffic. It would be beneficial to run several more subjects through the testing in order to reduce any anomalies or errors introduced into the data. For example, the oncoming detection for subject 5 being over twice the range of the subject's intersect detection may turn out to be an irregularity, and could be one of the things smoothed out in the mean values by accumulating more numbers into the average. In the end it would be beneficial to have performed the test with a sufficient number of subject pilots to achieve statistical significance within the data. This could mean having air traffic detection data for anywhere from 12 to 20 or more subject pilots.

This test should be performed at various hours of the day with different sun angles, to determine the effects of the sun on the detection ranges. The effects of the weather could also be included in the study. Cloud cover and UV index would both be valuable information to have for all of the data in the study, allowing someone to rank or compare the ranges based on the UV index for each flight. These variables could have a large impact on the variation of detection ranges found with the different subject pilots. They could also impact the camera system to a large extent. Glare from the sun on the cameras was noted at different stages throughout the testing. If the intensity of this could be

determined, the overall effect it has on the camera system could be established. Some of these effects could be lessened or removed by the use of multi-spectral cameras, such as infrared imaging.

Running the camera test using a 1920x1080 pixel HD camera to detect oncoming traffic could also prove extremely valuable. This would enable someone to test the hypothesis regarding an HD camera as a minimum detection resolution usable for ranges greater than one mile. The model presented in section 5.2 of this thesis was based entirely off the data received with the 704 x 480 pixel camera. Some deviation from this model is to be expected from a higher resolution HD camera; however, the extent of this difference is uncertain until it can be revealed through further testing. One important barrier to note with HD video is that the bandwidth required to telemeter the video feeds across the wireless data link from the aircraft to the ground station would simply be too large to transmit using current encoding algorithms and communications technology.

Since this project already has multiple cameras implemented, another path for this research could be investigating the technology behind a 3-dimensional camera system. This system could work similar to current stereoscopic vision systems; using two or more images of the same frame at slightly different angles and combining them to form an almost 3-D image to help the user better perceive the air traffic ranges at the monitoring ground station. Another potential research area could be to use an automated detection

algorithm to detect all the potential conflicts, and then use an additional camera to send one or more zoomed in frames of each potential conflict to the remote operator.

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APPENDIX A – PROJECT OUTLINE

The project described in detail in this thesis was outlined in the document on the following page. This outline was sent to the Ohio University Institutional Review Board in January 2008, and approved on February 12, 2008 for the use of human subjects in the research. Each subject signed a consent form before the flight test could take place, and afterwards they were each given a copy of the debriefing form found at the end of this appendix.

IRB Number 08F007

Committee: B S

OHIO UNIVERSITY
INSTITUTIONAL REVIEW BOARD (IRB)
PROJECT OUTLINE FORM

Title of Research Proposal Human Factors Study Comparing General Aviation Pilots and UAV Pilots Using Displays for Traffic Detection

Investigator(s) Information

Primary Investigator

Name Dr Michael Braasch
Department Electrical Engineering and Computer Science (Avionics Engineering Center)

Address 239 Stocker Center, Ohio University, Athens OH 45701
(If off-campus, include city, state and zip code)

Email braaschm@ohio.edu Phone 740-593-0105

Training Module Completed? ☐ Yes ☐ No

Co-investigators

Name Ryan Kephart
Department Electrical Engineering and Computer Science (Avionics Engineering Center)

Address 234A Stocker Center, Ohio University, Athens, OH 45701
(If off-campus, include city, state and zip code)

Email rk158903@ohio.edu Phone 937-205-7356

Training Module Completed? ☐ Yes ☐ No

Advisor Information (if applicable)

Name Dr Michael Braasch
Department Electrical Engineering and Computer Science (Avionics Engineering Center)

Address 239 Stocker Center, Ohio University, Athens OH 45701

(If off-campus, include city, state and zip code)

Email braaschm@ohio.edu Phone 740-593-0105

Training Module Completed? ☐ Yes ☐ No

Anticipated Starting Date 3/1/2008 Duration 12 mos 0
yrs

(Work, including recruitment, **cannot** begin prior to IRB approval. This date should **never** precede the submission date)

Funding Status

Is the researcher receiving or applying for external funding? ☐ Yes ☐ No

If yes, list source FAA Joint University Program For Air Transportation Research

If yes, describe any consulting or other relationships with this sponsor.

None

Is there a payment of any kind connected with enrollment of participants on this study that will be paid to persons other than the research

participants? ☐ Yes ☐ No
(If yes, describe.)

Review Level

Based on the definition in the guidelines, do you believe your research qualifies for:

 X Exempt Review Category _____
 Expedited Review Category _____
 Full Committee Review

Recruitment/Selection of Subjects

Maximum Number of Human Participants 20

Characteristics of subjects (check as many boxes as appropriate).

___Minors ___Physically or Mentally Disabled ___Elementary School
Students

☒ Adults ☐ Legal Incompetency ☐ Secondary School Students

___ Prisoners ___ Pregnant Females ___ University Students

____Others (Specify)_____

Briefly describe the criteria for selection of subjects (inclusion/exclusion). Include such information as age range, health status, etc. Attach additional pages if necessary.

Subjects will be current Aviation students at Ohio University. Each subject will have approximately 50+ hours of flight time and will hold a private pilot's license. [Sentence Removed]

How will you identify and recruit prospective participants? If subjects are chosen from records, indicate who gave approval for the use of the records. If records are "private" medical or student records, provide the protocol, consent forms, letters, etc., for securing consent of the subjects for the records. Written documentation for cooperation/permission from the holder or custodian of the records should be attached. (Initial contact of subjects identified through a records search must be made by the official holder of the record, i.e. primary physician, therapist, public school official.)

Participants will be recruited at the Ohio University Airport. Students will have the research explained to them as well as the benefits to society and asked if they would like to participate (given they have a pilot's license and 50+ hours of flight time).

Please describe your relationship to the potential participants, i.e. instructor of class, co-worker, etc. If no relationship, state no relationship.

No relationship

Attach copies of all recruitment tools (advertisements, posters, etc.) and label as APPENDIX B

Performance Sites

List all collaborating and performance sites, and provide copy of IRB approval from that site and/or letters of cooperation or support.

Ohio University Airport, Albany, OH

Project Description

Please provide a brief summary of this project, using non-technical terms that would be understood by a non-scientific reader. Please limit this description to no more than one typewritten page.

Many unmanned aerial vehicles (UAVs) are piloted exclusively with cameras attached to the UAV while the pilot uses displays to view the camera output and determine the location and orientation of the vehicle, and maneuver it using remote control (no line-of-sight is present between the pilot and the UAV). The purpose of this project is to compare the ability of a UAV pilot (to detect traffic) to that of an actual pilot flying a manned aircraft (the traffic may consist of: other airplanes, hot air balloons, hang gliders etc). For this experiment, we will use an American Champion Citabria as the traffic (flying at a safe altitude lower or higher than the plane with the subject pilot).

This comparison will be conducted by attaching 3 cameras (one forward looking and 2 peripheral) around the windshield of a Piper Saratoga, one of the Avionics Engineering Center's flying research laboratories. These cameras will be attached to a computer in the back of the plane that will record the video feeds.

The pilot flying the Saratoga will be the subject and will be accompanied by a safety pilot and a data collector. The data collector's job will be to record the time that the subject identifies the aircraft traffic each time it passes into the pilot's field of view. After the flight is over the subject will watch the video from a previous pilot's flight. When the subject identifies the intruder aircraft he will notify the data collector who will record the time. We would like to run at least 12 subject pilots through the test (but can use up to 20 or more depending on the turnout).

After the flight is over (45 minutes to 1 hour flight time) we will be able to process the data and determine the time the subject identified the traffic, and the range to that object. (GPS receivers onboard the Saratoga and Citabria will be used to record the position of each aircraft over the course of the flight)

Our hypothesis is that when the subject watches the displays while on the ground they will be able to identify the traffic at the same time or faster as compared to their performance while piloting the plane (since the subject will be

piloting the plane and watching the instrumentation, as well as looking for traffic near the flight path).

Please describe the specific scientific objectives (aims) of this research and any previous relevant research.

Specific aims of this research include:

- *Verifying our hypothesis that UAV pilots can detect objects as well or better than licensed pilots in the cockpit.*
- *Present this data at the June 2007 FAA conference in Atlantic City, NJ to assist in the transition of UAVs into civil airspace.*

'See and avoid' is the current FAA approved method for actual pilots to avoid objects and other aircraft while flying in visual meteorological conditions. No data has been collected in the past comparing UAV pilot traffic detection to that of a pilot in the cockpit.

Methodology: please describe the procedures (sequentially) that will be performed/followed with human participants.

Recruitment:

Recruiting will be strictly voluntary and will take place at the Ohio University Airport. Aviation students will be asked if they are interested in helping with research at Ohio University. If interested, the background for the research and what their role would be will be explained to them. If interested, their name, email address, and phone number will be recorded for further contact regarding the consent form and flight scheduling.

Pre-Flight Procedures:

Before the flight begins, the subject will be shown the equipment and a demonstration of their role (flight path to follow, what to look for, what to tell the data collector, etc). At this point the subject will be required to sign the consent form if they wish to continue and participate in the research.

In-Flight Procedures:

The pilot will fly the aircraft and follow a flight path as specified by the safety pilot. After a certain altitude is reached the subject will be directed to identify any aircraft in their field of view for the remainder of the flight, notifying the data collector when an aircraft is spotted. The safety pilot will also ask the subject to perform tasks and maneuvers common during pilot training. After the flight is completed the pilot will land the plane.

Post-Flight Procedures:

When the flight is over one of the investigators will explain the actual purpose of the flight and why they were deceived in order to obtain more accurate data (they will also receive a copy of Appendix D). After the subject has been debriefed, they will watch a previous pilot's flight on 3 displays and identify any aircraft they see. A data collector will record the time at which the subject identifies the traffic.

The subject's participation is complete at this time, and the data will be processed to compare the observation times with previous subjects.

Describe any potential risks or discomforts of participation and the steps that will be taken to minimize them.

We see no additional risks on the subject that would not normally be present during ANY flight. In a normal flight all pilots are required to be on the lookout for any objects or other aircraft in their flight path in order to safely avoid them. The 'traffic' aircraft in our experiment will be at a much lower or higher altitude than the subject pilot, so as to still be visible while not posing any threat to the pilot. This event is common for planes to be visible to one another in congested airspace.

Describe the anticipated benefits to the individual participants. If none, state that. (Note that compensation is **not** a benefit, but should be listed in the compensation section on the next page.)

An anticipated benefit to the individual participants is the participation in research that will help ensure the safety of future transition of UAV operations into civil airspace. All subjects in this research currently train on General Aviation aircraft and free flight time will be a benefit.

Describe the anticipated benefits to society and/or the scientific community. There must be some benefit to justify the use of human subjects.

In June 2008 the results of this data will be presented to the FAA and the aerospace community. This data could help reduce the current restrictions on UAV operation in civil airspace by showing that UAV pilot traffic detection can be equal or superior to that of the FAA certified 'see and avoid' method currently used in General Aviation.

Please discuss the level of confidentiality, if any, honored for the data collected. For example, indicate whether records will be labeled with the subject's name, or whether they will be labeled with a code number, with a master key that links name and code number maintained in a separate and secure location.

Each subject pilot will be identified by a number and the collected data (times at which traffic is identified) will be identified by the subject pilot number only. No personal information will be collected other than the total number of flight hours the subject has flown. Data collection will not be used to evaluate pilot performance. This data will be presented in an anonymous form to the FAA and major journal publications for verification of the ability to detect objects with UAVs. Prior to signing the consent form, subjects will be fully informed of the proper use of the data collection and its purposes.

With whom will *identifiable* data be shared outside the immediate research team? For each, explain confidentiality measures.

The data will not be shared with anyone outside the immediate research team. The data presented to the FAA will not be identifiable and will only include the outcomes of the research.

Will participants be: Audiotaped?

- ☐ Yes
☐ No

Videotaped?

- ☐ Yes
☐ No

If so, describe how/where the tapes will be stored (i.e. locked file cabinet in investigator office), who will have access to them, and an estimate of the date they will be destroyed.

N/A

Provide details of any compensation (money, course credit, gifts) being offered to participants, **including** how the compensation will be prorated for participants who discontinue participation prior to completion.

The flight time that the subject accumulates from the experiment will be free and at no expense to the subject. If the subject discontinues participation before the test is finished, the flight time they completed as well as any other costs will still remain free of charge.

Instruments

List all questionnaires, instruments, standardized tests below, with a brief description, and provide copies of each, labeled as APPENDIX C.

N/A

How will the data be analyzed? If applicable, state the hypothesis and describe how the analysis of the data will test that hypothesis.

The times at which the traffic was detected will be used along with the aircraft position information to calculate the range at which the pilot made the detection. The pilot's detection ranges while flying the Saratoga will be compared to the detection ranges while sitting on the ground viewing the video monitors.

Our hypothesis is that the pilots on the ground watching video displays will spot the traffic at the same time or before the pilots in the cockpit and flying the plane.

Plots of identifying times and ranges to the target will be constructed. The range will show how far away the target was when it was identified on the displays versus in the cockpit.

Informed Consent Process

Are you requesting a waiver or alteration of Informed Consent? ☐ Yes ☐ No

(If yes, check one, and answer a - e)

- ☐ Waiver of signature
- ☐ Deception (incomplete disclosure)
- ☐ Complete Waiver of consent

a. Provide justification for the waiver.

The consent form will have the complete details of our research included, but will also have additional 'faux research goals' the pilot will be required to perform while flying the aircraft. The purpose of the additional tasks is to shift the focus of the pilot from constantly scanning the horizon for traffic, to a more natural scenario of checking instrumentation and navigation pertinent to the flight (while also scanning for traffic in the background).

b. Describe how the proposed research presents no more than minimal risk to participants.

Pilots are required to follow a set of visual flight rules VFR, which pertain to flying with visual reference to the environment outside the cockpit. The proposed method presents no more than minimal risk to the subject because it is designed to closer simulate the natural tendencies of a general aviation pilot.

c. Why will a waiver of informed consent not adversely affect the rights and welfare of participants?

The consent form will be altered to present the idea of additional research aims within the study. The subjects would still be required to complete the additional tasks even without our research present, so the addition will not adversely affect the participants.

d. Why is it impracticable to carry out the research without a waiver or alteration of informed consent?

If the subjects knew our research was focused on a specific area, they would have less focus on the VFR rules and spend more time scanning for traffic.

This could skew the data if the pilots identify the traffic noticeably sooner than they would under normal flying conditions.

e. How will pertinent information be provided to participants, if appropriate, at a later date?

Appendix D will be given to the pilots after the flight.

Even if waiver of written informed consent is granted, you will likely be required to obtain verbal permission that reflects the elements of informed consent (if appropriate). Please specify below information to be read/given to participants.

The consent form will be given as a modified version and will still require a signature before participation is granted.

Attach copies of all consent documents or text and label as APPENDIX A. Please use the template provided at the end of this document.

Informed consent is a process, not just a form. Potential participants/representatives **must** be given the information they need to make an informed decision to participate in this research. How will you provide information/obtain permission?

When the Ohio University Aviation students are asked if they would like to participate they will be given copy of the consent form (Appendix A), which also includes information on the research and what to expect during the experiment.

How and where will the consent process occur? How will it be structured to enhance independent and thoughtful decision-making? What steps will be taken to avoid coercion or undue influence?

After the subjects get the consent form, they will have at least one week to decide if they would like to participate. After the signed consent form is received we will schedule the flight time for the experiment.

Will the investigator(s) be obtaining all of the informed consents? ☐ Yes ☐ No

If not, identify by name and training who will be describing the research to subjects/representatives and inviting their participation?

N/A

Will all adult participants have the capacity to give informed consent? If not, explain procedures to be followed.

Yes

If any participants will be minors, include procedures/form for parental consent and for the assent from the minor.

N/A

Will participants be deceived or incompletely informed regarding any aspect of the study? ☐ Yes ☐ No

If yes, provide rationale for use of deception.

Deception will be used to obtain data closer to the data that would be obtained in a natural scenario. The pilot's focus will be spread across several tasks instead of allowing them to concentrate more on identifying traffic. This will affect the identification time made by the subject and will provide data closer to normal flight.

If yes, attach copies of post-study debriefing information and label as APPENDIX D. Additionally, complete the questions related to a consent form waiver or alteration on page 9.

Investigator Assurance

I certify that the information provided in this outline form is complete and correct.

I understand that as Principal Investigator, I have ultimate responsibility for the protection of the rights and welfare of human subjects, conduct of the study and the ethical performance of the project.

I agree to comply with Ohio University policies on research and investigation involving human subjects (O.U. Policy # 19.052), as well as with all applicable federal, state and local laws regarding the protection of human subjects in research, including, but not limited to the following:

- The project will be performed by qualified personnel, according to the OU approved protocol.
- No changes will be made in the protocol or consent form until approved by the OU IRB.
- Legally effective informed consent will be obtained from human subjects if applicable, and documentation of informed consent will be retained, in a secure environment, for three years after termination of the project.
- Adverse events will be reported to the OU IRB promptly, and no later than within 5 working days of the occurrence.
- All protocols are approved for a maximum period of one year. Research must stop at the end of that approval period unless the protocol is re-approved for another term.

I further certify that the proposed research is not currently underway and will not begin until approval has been obtained. A signed approval form, on Office of Research Compliance letterhead, communicates IRB approval.

Principal Investigator Signature_____ **Date**_____

(please print name) Michael Braasch

Co-Investigator Signature_____ **Date**_____

(please print name) Ryan Kephart

Faculty Advisor/Sponsor Assurance

By my signature as sponsor on this research application, I certify that the student(s) or guest investigator is knowledgeable about the regulations and policies governing research with human subjects and has sufficient training and experience to conduct this particular study in accord with the approved protocol. In addition:

- I agree to meet with the investigator(s) on a regular basis to monitor study progress.
- Should problems arise during the course of the study, I agree to be available, personally, to supervise the investigator in solving them.
- I assure that the investigator will report significant or untoward adverse events to the IRB in writing promptly, and within 5 working days of the occurrence.
- If I will be unavailable, as when on sabbatical or vacation, I will arrange for an alternate faculty sponsor to assume responsibility during my absence.

I further certify that the proposed research is not currently underway and will not begin until approval has been obtained. A signed approval form, on Office of Research Compliance letterhead, communicates IRB approval.

Advisor/Faculty Sponsor Signature _____ Date _____

(please print name) Michael Braasch

*The faculty advisor/sponsor must be a member of the OU faculty. The faculty member is considered the responsible party for legal and ethical performance of the project.

Checklist:

- ☐ Completed and Signed IRB-1 (this form)
- ☐ Appendix A - copies of all consent documents (in 12 pt. Font) including
 - ___ Informed Consent to Participate in Research (adult subjects)
 - ___ Parental Permission/Informed Consent (parents of subjects who are minors or children)
 - ___ Assent to Participate in Research (used when subjects are minors or children)
- ☐ Appendix B - copies of any recruitment tools (advertisements, posters, etc.)

☐ Appendix C – copies of all instruments (surveys, standardized tests, questionnaires, interview topics, etc.).

- ☐ Appendix D - Copies of debriefing text
- ☐ Appendix E - Approval from other IRB, School District, Corporation, etc.
- ☐ Appendix F - Any additional materials that will assist the Board in completing

its review

- ☐ Appendix G – Copies of any IRB approvals

- ☐ Appendix H – Copies of Human Subjects Research Training Certificates

(for all key personnel involved in non-exempt research)

All fields on the form must be completed, regardless of review level. If a field is not applicable, indicate by inserting n/a. Incomplete forms will result in delayed processing.

Forward this completed form and all attachments to:

Human Subjects Research
Office of Research Compliance
RTEC 117

Questions? Visit the website at www.ohio.edu/research/compliance/ or email compliance@ohio.edu

Appendix A

Deception Consent Form

Ohio University Consent Form

Title of Research: Human Factors Study on General Aviation Pilots

Researchers: Michael Braasch, Ryan Kephart

You are being asked to participate in research. For you to be able to decide whether you want to participate in this project, you should understand what the project is about, as well as the possible risks and benefits in order to make an informed decision. This process is known as informed consent. This form describes the purpose, procedures, possible benefits, and risks. It also explains how your personal information will be used and protected. Once you have read this form and your questions about the study are answered, you will be asked to sign it. This will allow your participation in the study. You should receive a copy of this document to take with you.

Explanation of Study

This study is designed to collect data on flying patterns of general aviation pilots. Data corresponding to the visual flight rules (VFR) will be recorded, as well as usage patterns on navigation instrumentation. Object and Traffic detection will be relayed from the subject to the safety pilot. The safety pilot may ask the subject to perform small maneuvers throughout the flight. After the 45-minute to 1-hour flight is over a debriefing will take place, and a small study will be conducted in the airport hanger. **The study will have you watch three displays with video from a previous pilot's flight and identify points of interest.**

Risks and Discomforts

No risks or discomforts are anticipated.

Benefits

In June 2008 the results of this data will be presented to the FAA and the aerospace community. **The results from this study could provide valuable information pertaining to pilot safety.**

Confidentiality and Records

Each subject pilot will be identified by a number and the collected data (times at which traffic is identified) will be identified by the subject pilot number only. No

personal information will be collected other than the total number of flight hours the subject has flown. Data collection will not be used to evaluate pilot performance. This data will be presented in an anonymous form to the FAA and major journal publications for verification of the ability to detect objects with UAVs.

Additionally, while every effort will be made to keep your study-related information confidential, there may be circumstances where this information must be shared with:

- * Federal agencies, for example the Office of Human Research Protections, whose responsibility is to protect human subjects in research;
- * Representatives of Ohio University (OU), including the Institutional Review Board, a committee that oversees the research at OU;

Compensation

The flight time that the subject accumulates from the experiment will be free and at no expense to the subject. If the subject discontinues participation before the test is finished, the flight time they completed as well as any other costs will still remain free of charge.

Contact Information

If you have any questions regarding this study, please contact:

Ryan Kephart - rk158903@ohio.edu or

Michael Braasch – braaschm@ohio.edu

If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

By signing below, you are agreeing that:

- you have read this consent form (or it has been read to you) and have been given the opportunity to ask questions
- known risks to you have been explained to your satisfaction.
- you understand Ohio University has no policy or plan to pay for any injuries you might receive as a result of participating in this research protocol
- you are 18 years of age or older
- your participation in this research is given voluntarily

- you may change your mind and stop participation at any time without penalty or loss of any benefits to which you may otherwise be entitled.

Signature_____ Date_____

Printed Name_____

Version Date: 01/20/08

Appendix D

Deception Debriefing

Ohio University Deception Debriefing

Title of Research: Human Factors Study Comparing General Aviation Pilots and UAV Pilots Using Displays for Traffic Detection

Researchers: Michael Braasch, Ryan Kephart

Explanation of Study

Many unmanned aerial vehicles (UAVs) are piloted exclusively with cameras attached to the UAV while the pilot uses displays to view the camera output and determine the location and orientation of the vehicle, and maneuver it using remote control (no line-of-sight is present between the pilot and the UAV). The purpose of this project is to compare the ability of a UAV pilot (to detect traffic) to that of an actual pilot flying a manned aircraft (the traffic may consist of: other airplanes, hot air balloons, hang gliders, etc). For this experiment, we **used** an American Champion Citabria as the traffic (flying at a safe altitude lower or higher than the plane with the subject pilot).

This comparison **was setup** by attaching 3 cameras (one forward looking and 2 peripheral) around the windshield of a Piper Saratoga, one of the Avionics Engineering Center's flying research laboratories. These cameras **were** attached to a computer in the back of the plane that **recorded** the video feeds.

A safety pilot and a data collector accompanied you through the flight. The data collector's job **was** to record the time that **you identified** the aircraft traffic each time it **passed** into **your** field of view. We will now be able to process the **GPS data from your flight** and determine the time **you** identified the traffic, and the range to that object. (GPS receivers onboard the Saratoga and Citabria were used to record the position of each aircraft)

Now that the flight is over, **you are being asked** to watch the video from a previous pilot's flight. When **you** identify the intruder aircraft **you** will notify the data collector who will record the time. **This data will later be compared with your identification times during the actual flight.**

Benefits

In June 2008 the results of this data will be presented to the FAA and the aerospace community. This data could help reduce the current restrictions on UAV operation in civil airspace by showing that UAV pilot traffic detection can be equal or superior to that of the FAA certified 'see and avoid' method currently used in General Aviation.

Contact Information

If you have any questions regarding this study, please contact:

Ryan Kephart - rk158903@ohio.edu or

Michael Braasch - braaschm@ohio.edu

APPENDIX B – PROJECT APPROVAL DOCUMENT

The Institutional Review Board approved the use of human subjects for the project described in Appendix A above on February 12, 2008. A copy of the approval document is provided below. This research was approved for human subject use between the dates of February 12, 2008 and February 11, 2009.

OHIO
UNIVERSITY

Office of the Vice President
for Research

08F007

Office of Research Compliance
Research and Technology
Center 117
Athens OH 45701-2979

T: 740.593.0664
F: 740.593.9838
www.research.ohiou.edu

The following research study has been approved by the
Institutional Review Board at Ohio University for the period listed
below.

Project: Human Factors Study Comparing General Aviation Pilots
and UAV Pilots Using Displays for Traffic Detection

Researcher(s): Michael Braasch
Ryan Kephart

Advisor: Michael Braasch
(if applicable)

Department: Avionics Engineering Center

Jeff Vancouver, Ph.D., Chair
Institutional Review Board

2/12/08
Approval Date

2/11/09
Expiration Date

This approval is valid until expiration date listed above. If you wish to continue beyond expiration date, you must submit a periodic review application and obtain approval prior to continuation.

The approval remains in effect provided the study is conducted exactly as described in your application for review. Any additions or modifications to the project must be approved by the IRB (as an amendment) prior to implementation.

Adverse events must be reported to the IRB promptly, within 5 working days of the occurrence.

APPENDIX C – APPROVED CONSENT FORM

The human subject pilot consent form on the following page was read and signed by each of the subject pilots before undertaking the research experiment. Note that the subjects were never asked to partake in the second half of the study regarding the three displays, due to the outcome of the camera range calculations. This document was approved for use with human subjects on February 12, 2008. A signed copy of each consent form is kept on file in the Avionics Engineering Center, and a blank copy was given to each subject to review and keep.

APPROVED**Ohio University Consent Form**

FEB 12 2008

Title of Research: Human Factors Study on General Aviation PilotsOHIO UNIVERSITY
INSTITUTIONAL REVIEW BOARD**Researchers:** Michael Braasch, Ryan Kephart

You are being asked to participate in research. For you to be able to decide whether you want to participate in this project, you should understand what the project is about, as well as the possible risks and benefits in order to make an informed decision. This process is known as informed consent. This form describes the purpose, procedures, possible benefits, and risks. It also explains how your personal information will be used and protected. Once you have read this form and your questions about the study are answered, you will be asked to sign it. This will allow your participation in the study. You should receive a copy of this document to take with you.

Explanation of Study

This study is designed to collect data on flying patterns of general aviation pilots. Data corresponding to the visual flight rules (VFR) will be recorded, as well as usage patterns on navigation instrumentation. Object and Traffic detection will be relayed from the subject to the safety pilot. The safety pilot may ask the subject to perform small maneuvers throughout the flight. After the 45-minute to 1-hour flight is over a debriefing will take place, and a small study will be conducted in the airport hanger. **The study will have you watch three displays with video from a previous pilot's flight and identify points of interest.**

Risks and Discomforts

No risks or discomforts are anticipated.

Benefits

In June 2008 the results of this data will be presented to the FAA and the aerospace community. **The results from this study could provide valuable information pertaining to pilot safety.**

Confidentiality and Records

Each subject pilot will be identified by a number and the collected data (times at which traffic is identified) will be identified by the subject pilot number only. No personal information will be collected other than the total number of flight hours the subject has flown. Data collection will not be used to evaluate pilot performance. This data will be presented in an anonymous form to the FAA and major journal publications for verification of the ability to detect objects with UAVs.

Additionally, while every effort will be made to keep your study-related information confidential, there may be circumstances where this information must be shared with:

- * Federal agencies, for example the Office of Human Research Protections, whose responsibility is to protect human subjects in research;
- * Representatives of Ohio University (OU), including the Institutional Review Board, a committee that oversees the research at OU;

Compensation

The flight time that the subject accumulates from the experiment will be free and at no expense to the subject. If the subject discontinues participation before the test is finished, the flight time they completed as well as any other costs will still remain free of charge.

Contact Information

If you have any questions regarding this study, please contact:

Ryan Kephart - rk158903@ohio.edu or

Michael Braasch - braaschm@ohio.edu

If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

By signing below, you are agreeing that:

- you have read this consent form (or it has been read to you) and have been given the opportunity to ask questions
- known risks to you have been explained to your satisfaction.
- you understand Ohio University has no policy or plan to pay for any injuries you might receive as a result of participating in this research protocol
- you are 18 years of age or older
- your participation in this research is given voluntarily
- you may change your mind and stop participation at any time without penalty or loss of any benefits to which you may otherwise be entitled.

Signature_____ Date_____

Printed Name_____

Version Date: 01/20/08

APPENDIX D – APPROVED PROJECT FLIER

Ohio University's Institutional Review Board approved the flier on the following page on May 8, 2008. This flier was posted on several boards around Stocker Center and the Ohio University Airport. The purpose of the flier was to attract and get in contact with any potential pilots for the subject pilot testing.

Student Pilots Needed!

Fly the Piper Saratoga

Data corresponding to the visual flight rules, usage patterns on navigation instrumentation, and object and traffic detection will be recorded over the duration of the flight.

Help out the community by providing valuable information pertaining to pilot safety.

- # Testing will take place May 10 – June 7, 2008
- # Approx. 1 hour flight
- # Just need a private pilot license

Contact: Ryan Kephart (rk158903@ohio.edu)
Dr. Braasch (braaschm@ohio.edu)

Ryan Kephart
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APPENDIX E – FLIER AMENDMENT APPROVAL

Ohio University's Institutional Review Board approved the flier on the previous page on May 8, 2008. The following page is a copy of the approval document, thus allowing use of the flier in contacting human subjects.

OHIO
UNIVERSITY

Office of the Vice President
for Research

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Office of Research Compliance
Research and Technology
Center 117
Athens OH 45701-2979

T: 740.593.0664
F: 740.593.9838
www.research.ohiou.edu

The amendment, detailed below, and submitted for the following research study has been approved by the Institutional Review Board at Ohio University. Approval date of this amendment does not affect the expiration date of the original approval.

Amendment: Utilize Flier for Recruitment

Project: Human Factors Study Comparing General Aviation Pilots and UAV Pilots Using Displays for Traffic Detection

Project Director: Michael Braasch
Ryan Kephart

Advisor: Michael Braasch
(if applicable)
Department: Avionics Engineering Center

Rebecca G. Cale
Institutional Review Board

Date

Protocol Expiration Date: 2/11/2009