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Flight Training For Commercial Remote Pilots

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FLIGHT TRAINING FOR COMMERCIAL REMOTE PILOTS

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Abstract

A remote pilot training program, part of an sUAS course, were studied to determine the effectiveness and portability of the training curriculum. Students in a university unmanned aircraft systems course were the subjects, and multiple data points were collected over the 15 week program. No differences were found in student performance on the metrics used to assess the students regardless of who the students had as a flight instructor. Males scored higher than females on prior flight experience upon entering the course; however, neither gender nor prior aviation experience were significant contributing factors in student success either academically (written tests) or based on skills training (flying aircraft). Some gender bias may exist in the assessment tools used in class. A strong association was found between academic success and skill success. There was no association between flight skill and success on the FAA Part 107 remote pilot exam. There was some evidence to suggest that the course's second test, which is modeled after the remote pilot exam, may be a predictor of success on the FAA Part 107 exam. Findings from the study support offering this course to a wide range of students and that pre-requisites are not necessary for student success.

Introduction

Commercial drone pilots in the United States are legally allowed to fly a 55-pound remote aircraft with no flight training (FAA, 2020b). A score of 70 percent or higher on a 50-question multiple choice test is all that is required to obtain commercial drone license (a Part 107 remote pilot certificate). There is no regulatory action that requires flight training for remote pilots even though sUAS (Unmanned Aerial System) courses and degree programs around the United States train remote pilots. Little to no curriculum or standards exist for the consistent and safe training of remote pilots. This study will examine a training program designed to standardize flight training for remote pilots, establishing curriculum materials, maneuver description guide, and flight training syllabi for remote pilot training.

Minimum requirements to operate sUAS (0.55lbs-55lbs) in the United States as a commercial sUAS pilot (called a remote pilot certificate by the FAA) require passing of a sUAS knowledge test (FAA, 2020a). The remote pilot knowledge test asks questions from five content areas; loading and performance, operations, regulations, weather, and the national airspace system. A remote pilot knowledge test is similar in content and rigor to the private pilot knowledge test. Unlike the private pilot certificate however, there is currently no flight training requirement for remote pilots and no flight check ride as there is for private pilots.

This study examined a flight training curriculum for sUAS pilots in a State University Unmanned Aircraft Systems (UAS) course. The researcher has created a SOP Standard Operating Procedure for sUAS flight training, a flight training syllabus for fixed wind and multirotor sUAS, a maneuvers description guide for fixed wing and multirotor sUAS, and a check ride for multirotor and fixed wing sUAS. This study examined the group differences and inter-rater reliability of the developed flight training curriculum between the course developer and the student flight instructors. While training materials have been developed for both multirotor and fixed wing sUAS, for simplicity and tighter control of variables, only fixed wing sUAS were used in this study.

Problem Statement

Currently, the FAA does not require flight training for a commercial drone (Part 107 remote pilot) certificate (FAA, 2020a). Unlike manned aircraft, there is little sUAS flight training curriculum for flight schools and universities to implement to ensure they are producing pilots with both knowledge and skill required to earn a commercial certificate. FAA certification requirements for sUAS only focus on knowledge, not skill. As a sUAS commercial pilot (Part 107 certificate holder), one is authorized to operate aircraft up to 55 lbs. A 55lb aircraft presents a serious hazard to people and property on the ground in the event of a crash (FAA, 2020a). The remote pilot certificate also allows the certificate holder to fly sUAS for profit, potentially placing people on the ground in danger. While there is no regulatory action in place to require flight training for remote pilots, the purpose of this study to test and improve a training syllabus for remote pilots to improve the skills of pilots and the safety of unmanned system operations.

Review of the Literature

sUAS (Small Unmanned Aerial Systems), also known as “drones” have been flying for as longs as manned flight has been possible, even possibly even earlier. Marshall (2016) suggests that the Wright Brother’s tethered gliders and kites could be considered early examples of unmanned aircraft. Remote control airplanes have been around for almost as long as manned aircraft. The first RC airplane was flown in 1938 and the hobby of remote control aircraft has continued to grow (GUDAITIS, 1994). AMA (Academy of Model Aeronautics) 2020 membership was at about 190,000 members (EAA, 2020). However, when someone wants to charge for their services with a remote-controlled aircraft, that flight becomes a commercial, rather than a recreational flight (FAA, 2020a). The FAA first started to regulate the use of remote-controlled aircraft for commercial use under the 14 CFR Part 333 exemption program then with 14 CFR Part 107 remote pilot rules (FAA, 2016). A majority of commercial UAS pilots operate relatively small aircraft, with a majority of them less than 55 lbs. Before the current 14 CFR Part 107 remote pilot regulations, a pilot operating a UAS commercially had to apply for a 14 CFR Part 333 exemption. The Part 333 exemption required the operator to hold a pilot certificate which meant that at a minimum, all commercial UAS operators needed to hold a private pilot certificate. This chance was significant because a private pilot certificate requires at least 40 hours of flight time, passing a written and oral exam, and practical check ride with an FAA examiner (FAA, 2020b) . The cost of instruction can vary but will typically cost between $8,000 USD and $15,000 USD depending on the amount of time required before a student is ready for his/her check ride. While 40 hours is the minimum, many students will take more, with some requiring up to 80 hours before their check ride. This is a significant cost and time burden. There was a call for change in the sUAS world for new regulation changes to reduce the burden on commercial remote pilots. In 2016, the FAA passed the new changes for remote pilot certification under Title 14 CFR Part 107 (FAA, 2016). These new regulations eliminated the private pilot certificate requirement and replaced it with a remote pilot certificate which required only a knowledge exam. The knowledge test for a remote pilot certificate is very similar to the private pilot knowledge exam with some parts removed that are not applicable to unmanned aircraft, and some new additions specific to sUAS. This new process greatly reduced the burden on commercial remote pilots and brought along some changes that affected hobbyist as well.

Registration of all sUAS (those remote aircraft that weigh between 0.55 and 55lbs) commercial or hobbyist, became a requirement after the 2016 changes for SUAS (FAA, 2016). Commercial sUAS operators need to register each aircraft at a cost of $5USD each. Hobbyist, if members of AMA (Academy of Model Aeronautics), can register all their aircraft under one blanket registration number for a single $5 fee. The registration number must be mounted on the exterior of the aircraft and the operator must carry a copy of the registration certificate on his/her person while operating the aircraft (FAA, 2020c). Safety of the public is a priority concern for the FAA and the regulations reflect such concerns.

The safe operation of sUAS currently is enforced through a few basic rules (FAA, 2020). No sUAS aircraft may be operated beyond visual line of sight (BVLOS) without prior permission from the FAA in the form of a waiver. No sUAS maybe operated above 400 feet above ground level (AGL), and no sUAS may be operated with the bounds of class B,C,D, or class E airspace that is used as an airport (without prior air traffic control (ATC) authorization). Knowledge of safe operation practices, rules, and regulation is important. Pilots that have ignored Part 107 regulations have caused incidences of sUAS and manned aircraft collisions and near hits (NTSB, 2018).

On September 21st, 2017 a small unmanned aircraft systems (sUAS) Phantom 4 quad copter crashed into a United States Army UH-60 Blackhawk helicopter in New York City (NTSB, 2018). The sUAS was destroyed in the crash and the helicopter received minor damage to the rotor blades. The sUAS pilot was operating beyond visual line of site (BVLOS) and operating inside a TFR (temporary flight restriction). The NTSB (2018) stated that "the sUAS pilot's incomplete knowledge of the regulations and safe operating practices" (p.1) was a contributing factor in the accident. While this collision did not cause substantial damage and no one was injured, what potential damage do sUAS actually pose to manned aircraft?

The University of Dayton Research Institute recently conducted impact tests (Gregg, 2018) that show the damage even a small UAS can cause. Video of their test shows a small commercial quad copter smashing a hole in the leading edge of a General Aviation aircraft (University of Dayton, 2018). The University of Dayton Research Institute has been conducting several trials to determine the damage a sUAS actually poses to an aircraft. Their findings show that UAS strikes can be much worse than bird strikes as the mass of the UAS mostly remains solid during the impact leading to greater damage. A bird acts more like a fluid after contact causing far less damage than an sUAS. If an sUAS can damage an aircraft, what type of risk do sUAS pose to people?

Campolettano et al. (2017) conducted tests to determine the actual damage an sUAS could cause to a person. The researchers crashed three small commercial UAS into crash test dummies, finding that the current limits for speed and mass of sUAS (which are at least twice that of the speed and mass used in their tests) was significant enough to cause serious bodily harm. The researchers suggested that better materials or design considerations for sUAS should be developed before the operation over people. Specifically, materials or components designed to absorb impact forces and break away help to reduce the injury caused by the UAS. Limiting the chances of such impacts may very well need to come from advanced technology.

Lui & Foina (2016) conducted experiments with a small UAS quadcopter and collision avoidance algorithms. While these where conducted in a lab and do not represent real-world tests, their experiments show the possibility of collision avoidance systems for autonomous aircraft. These UAS would (theoretically) fly from one destination to another without colliding with any manned or unmanned aircraft. While this is promising technology, much of it is still in the laboratory and has not made it to mainstream UAS manufacturers. Also, these tests were on fully autonomous systems and not remotely piloted systems. While adoption of standards such as those currently being developed by the FAA (FAA, 2019), other tools might be needed to help predict the risk of an sUAS operation.

The rise of small UAS continues to grow. However, currently there are no standards for the manufactures of sUAS systems (Hirling, 2017). Such a lack of standards brings the safety of sUAS systems and their associated operations into question. While a crash of a UAS will not by itself result in death or injury (as it is unmanned), it could however pose a risk to people on the ground or in other manned aircraft. Hirling (2017) researched the use of O.R.C.U.S. (Operational Risk Considerations for Unmanned Aircraft Systems) tool in Germany. The tool is designed to determine the risk posed by sUAS operations over populated areas on a given date and time. O.R.C.U.S. considers not just where the aircraft is flying, but the size and weight of the craft, the safety systems on-board the aircraft, and the ground control station. Furthermore, the model considers how long the aircraft will be over a populated area, and the amount of people estimated to be below the aircraft. While this is just a theoretical model, it could help provide useful data as to the risk posed by UAS to people on the ground. Hirling notes however, that there is still not enough accident data on UAS to develop an accurate model as is possible with car accident or manned aircraft data.

Researchers at Embry-Riddle University conducted a 13-day experiment where they collected data from a remote sensor that recorded the activity of DJI drones operating near controlled airspace (Wallace, R.J., 2018). DJI, a major manufacturer of sUAS, has technology aboard that will broadcast the drone's position and other telemetry data to the pilot. This data can be "listed to" by anyone. The researchers used AeroScope™ to map the location of drones to determine how often they were flown illegally into controlled airspace. Wallace (2018) states that "The AeroScope is a passive radio-frequency sensor designed to detect, identify, and track DJI-manufactured small unmanned aircraft" (p. 3). In the short 13-day window the researchers recorded 177 occurrences, two of which involved a near hit with a commercial aircraft. Using aircraft position data and the telemetry data from the DJI drones they were able to map both the sUAS and manned aircraft's positions. It should be noted that many sUAS are homebuilt, and many commercially built sUAS do not have the same broadcast technology employed by DJI. The findings however, suggest that close encounters between manned and unmanned aircraft may be very high.

The damage risk posed to manned aircraft by UAS has been clearly established (Gregg, 2018), and injury to humans potential (Campolettano et al., 2017). Technology to limit risks of collisions is being developed (Lui & Foina, 2016) but much of this new technology is not mainstream in sUAS. Hirling (2017), demonstrated a possible risk analysis tool, however, there is limited analysis of where the biggest threats from UAS comes from. Wallace (2018) demonstrated in a small sample that UAS and manned encounters are very frequent; however, is this frequency the norm in other parts of the country? Do the rule following certificated pilots under Part 107 pose a risk or are most of the risks coming from people who do not know about, or care about following the already established guidelines for UAS operations?

An analysis of data from sUAS and manned aircraft encounters suggests that most encounters are the result of remote pilots not following the FAA Part 107 regulations. This would tend to suggest that the regulations work when followed, and that remote pilots obeying the law, pose minimal risk to manned aircraft. The risk posed to people and property on the ground, however, remain a cause for concern if the remote pilot were to lose control of an aircraft. While one could assume that someone who earns a Part 107 certificate would already be a competent pilot, there is no gate keeper to make sure that this is the case. One potential problem with pilot competency is that the technology for sUAS has progressed so rapidly, that many aircraft are extremely easy to fly. Multirotor drones have GPS and gyroscopes that allow hands-free flying. The aircraft can hover and self-balance with no operator input. Airplanes, while more difficult to fly because they can't stop and hover, also can be equipped with self-level, altitude hold, and even auto take-off and landing. The problem with pilots only capable of flying aircraft with high levels of automation, is what do such pilots do when the automation fails, or, is turned off. Some sUAS can disable all automation with the flick of a switch on the transmitter controller. Loss of automation can make a sUAS difficult for a novice pilot to control. Therefore, a need exists to train pilots to become better remote pilots. Some research has been done to determine what prior skills lend themselves to making better remote pilots (Wheatcroft et al., 2017; Johnson & Ii, 2002; Hammond, 2004).

Wheatcroft et al., (2017) found no significant difference between people who play video games and commercial pilots, on decision-making tasks when flying a sUAS simulator. Video gamers' decision making is similar to those who are professional pilots when high risk choices need to be made. Video gamers also performed better than those who were private pilots or those from a control group who had no prior flying experience. During an initial offering of a UAS course in which students learned to fly a fixed wing sUAS, the researcher of this study, noticed that students who quickly acquired the skills required to solo the airplane also played video games. While anecdotal and from a small sample of students, it further supports the finding from Wheatcroft (2017) that video game play and sUAS piloting skills may have some beneficial correlations. While Wheatcroft (2017) did not tease out the psychological factors that might connect video game playing to good decision making, it does suggest that simulation may help train sUAS pilots in ways that are not as effective with manned pilots during primary flight training.

The use of simulators in flight training gets mixed reviews depending on when and how the simulators are utilized (Johnson & Ii, 2002). Simulators for manned flight training are most effective for instrument training or practicing maneuvers that would be too dangerous in an actual aircraft. Simulators can have the negative effect of unintentional incorrect response behaviors if the simulations do not feel like the real airplane. The probable cause of the crash of American flight 587 in November of 2001 was partly the incorrect use of rudder inputs by the co-pilot because of training he had received in a simulator (NTSB, 2004). The main problem with simulators for manned flight training is the lack of response on the control inputs (yoke, rudder pedals) in addition to the incorrect feel of motion in the cockpit. In UAS training however, simulations are much closer to what the pilot will feel, as he/she will have no motion response from the UAS in flight, and the controls do not (typically) provide any feedback. Most modern transmitters used to control UAS can be linked to the flight simulation software making the training experience very close to the actual flight in real-world conditions. Johnson & Ii, (2002) conducted a study of a computer flight simulator for helicopter flight training. They found that the simulator worked well for instrument flying tasks as well as communication tasks. The simulator did not simulate the actual flight environment of a manned aircraft because it lacked visual cues such as peripheral vision and other sensory cues found inside a manned aircraft. In sUAS however, sensory cues found in manned aviation would not be present. Therefore, while manned aviation best benefits from simulators for instrument flight or dangerous procedures, unmanned flight training can benefit from a flight environment much closer to actual the flight environment, and practice procedures that are not necessarily dangerous, but costly such as hard landings. A crash of a sUAS can cause hundreds or even thousands of dollars of damage. While simulation can prepare students for their first remote flight, actual real-world conditions will present the largest challenge to their learning. A new remote pilot must deal with wind, sun glare, distractions, disorientation, etc. Students new to flying sUAS have many of the same struggles as a new student pilot in a manned aircraft. Both manned and unmanned pilots must learn to fly straight and level, make coordinated turns, and manage pitch and power during climbs and descents. The sUAS pilot however has the added challenge of flying an aircraft that they are not physically on-board. The controls for an aircraft flying away from a remote pilot are reversed, as seen from the remote pilot, as the aircraft is flying toward, he or she. Detecting that the aircraft is descending in an uncoordinated turn might not be immediately obvious to a remote pilot standing several hundred feet away from the aircraft. A flight simulator helps the student build confidence and experience in flight controls as well as managing the disorientation of flying toward and away from oneself. Flight simulators for UAS are appropriate for primary flight training unlike manned aircraft where flight simulators are better suited for advanced flight training. Maintaining situational awareness and utilizing all the resources they have available can help to make them much more effective pilots and increase their chances of success. Taking some elements from commercial manned aviation crew resource management (CRM), might be a way to reduce the workload on both student and instructor.

Hammond (2004) examined the case for team training in health care, citing the use of CRM (Crew Resource Management) in aviation. Title 14 CFR Part 121 (commercial avialtion) in the United States, has demonstrated a high level of safety. There has not been a hull-loss since the crash of Colgan Air flight 3407 on February 12, 2009 in Buffalo, New York (NTSB, 2010). Hammond found that training as a team (or crew) made health care, as well as aviation, far safer. One key component used in curriculum development for successful team training is task analysis (Lee & Nelson, 2010). Task analysis is the process of studying all the tasks each member of a team needs to perform and documenting the tasks step by step. Curriculum developed from a task analysis provides not only a clear description of the tasks that need to be performed by the individual, but the tasks that need to be performed by supporting team members. Communication is another key element of successful CRM. During the task analysis it is important to clearly define all communication protocols including verbiage, phraseology, and methods of communication. During primary flight training for sUAS a typical flight crew may consist of one or more visual observers, a pilot in command (flight instructor), pilot operating the controls (student pilot), and possibly a retrieval team that can fetch the aircraft after landing. The crew helps reduce workload on the student by keeping eyes on the aircraft and can help reorient a student that becomes disoriented, they can help judge distance from objects or the ground, freeing the student up to focus on learning the controls, and working with his/her instructor to answer questions and provide feedback. Workload or task saturation can be common when learning a new task. A culture that promotes and provides help can greatly reduce the risk of task saturation.

Standards for flight training of UAS pilots were established by ASTM (2018). While the total document is only 9 pages, it outlines basic standards of proficiency that should be included in UAS flight training. Standards cover basic airmanship skills and knowledge for all types of remotely piloted air vehicles including multirotor, fixed wing, and vertical takeoff and landing (VTOL) aircraft. The flight training rubrics developed for this study used the ASTM standards as the framework for basic airmanship.

The damage risk posed to manned aircraft by UAS has been clearly established (Gregg, 2018), intentional threat (Leslie et. Al, 2017) and injury to humans potential (Campolettano et al., 2017). Technology to limit risks of collisions is being developed (Lui & Foina, 2016) but much of this new technology is not mainstream in sUAS. Hirling (2017) demonstrated a possible risk analysis tool however, there seems to be limited analysis of where the biggest threats from UAS comes from. Wallace (2018) demonstrated in a small sample that UAS and manned encounters are very frequent. The risk posed by sUAS is well established, therefore, a need exists for competent and well trained sUAS pilots. The AMA and ASTM have both provided frameworks for what sUAS training should look like. This study will attempt to show the effectiveness of a training model that could be replicated in other flight training programs providing a clear and detailed path for flight training of commercial sUAS pilots.

There are currently no requirements from the FAA on skill assessment for remote pilots; however, there are several agencies that have developed best practices for remote pilots such as the AMA (Academy of model aeronautics) and ASTM. These two groups provide a set of basic safety, knowledge, and skills that all sUAS pilots should possess. The standards set forth by the AMA and ASTM have provided the foundation for this study and are the core elements used in the flight training syllabi and rubrics used for flight training remote pilots.

Methodology

Research Questions

Q1: Do students trained to fly remote aircraft by different flight instructors using the same training syllabus, achieve similar rates of skill proficiency?

Q2: Is gender a factor in student performance in a UAS course?

Q3: Is prior experience in aviation associated with student success in learning to fly sUAS?

Q4: Is there a relationship between skill in sUAS operations and success on the FAA remote pilot exam?

Pilot Study

A new course was piloted in the spring of 2020 at Montana State University titled 'Unmanned Aircraft Systems'. The training program for remote pilots used in this study was developed and tested during the spring 2020 pilot program. A total of 20 students were trained to fly both multirotor and fixed wing aircraft. The researcher found that most students were able to solo after about 5 flights of a fixed wing aircraft, provided they built basic proficiency on flight simulation software before flying an actual aircraft. Protocols for training were developed during the pilot study such a flight training progression, minimum altitude and attitudes that would require instructor intervention, and checkoff skills required for solo flight. All 20 students showed basic proficiency after 5 training flights with most students flying their first solo around lesson five or six. The researcher further trained other students in the summer of 2020 utilizing the protocols developed in the pilot program.

The sUAS flight training curriculum developed by this researcher was used as the instructional tool to train all the pilots in this study. All flight instructors were trained by the researcher on the use of the training syllabus, flight lesson format, standard operating procedures, and maneuver description guides. In addition, each flight instructor was provided copies of all the training materials.

Population

Students were assigned flight instructors based on the student roster for the Unmanned Aerial Systems course at Montana State University in the western United States. The researcher placed students into four groups of five students each and tried to keep the groups balances based on gender and prior flight experience in an attempt to limit the variability between the groups. The researcher instructed a group of five students that became the control group. Three other flight instructors worked with the rest of the students. A total of 16 students were trained over the course of a 15-week semester. Due to the popularity of the course, and university enrollment policy, most of the students were seniors in their respective majors.

Training Procedure

Students completed seven ground school labs prior to their first flight lab. Ground school labs covered technical topics such as transmitter operation, aircraft electronics, and basic flight controls. Students completed several flight simulator labs to practice the basic flight controls and maneuvers before progressing to actual flight labs with a real airplane. Students need to pass a stage check on a remote aircraft flight simulator to demonstrate positive control of the airplane and minimal proficiency before attempting a first flight in a real-world environment.

All students, regardless of group, received the same ground instruction from the researcher. Each instructor, including the researcher, trained 5 students to fly a fixed wing trainer RC aircraft per the sUAS flight training syllabus. Students received at a minimum of 4 flight labs per the training curriculum. Students are permitted to repeat flight lab 4 as required to improve proficiency. The number of times a student repeats the lab is recorded through the scoring of a syllabus rubric for each successive flight. Each flight lasts approximately 5-7 minutes, the life of one battery charge.

Flight Instructors

Flight instructors were selected from a pool of University students who had some prior flight experience with remote aircraft. The researcher trained each instructor how to fly each lesson in the four flight training syllabi. Flight instructors were each trained on the safety protocols and operational protocols for remote pilot flight instructors. Each instructor was trained in the completion of post flight syllabus rubric scoring. A standard for when an instructor takes over control of a student aircraft was defined as: Anytime an aircraft banks more than 45 degrees, pitches more than 60 degrees, breaks a hard deck of 50 feet AGL, or at any time the instructor feels the student has become disoriented or lost positive control of the aircraft.

Scoring of Students

Every flight instructor scores at least one student from another instructor. The two instructors must each score the same student on the same day. These rubric scores (Appendix C) were used to determine inter-rater reliability. At the completion of flight training, students are given a "check-ride" by the researcher and scored on the check-ride rubric.

Validation of flight lab rubrics

Flight lab rubrics were constructed with the guidance of the ASTM Standard Guide for Training for Remote Pilot in Command of Unmanned Aircraft Systems (UAS) Endorsement (2019). The ASTM standards define all elements that should be included in an sUAS flight training program, both grounds school content knowledge, technical knowledge, and flight skills. The focus of this study is only on flight skills for fixed wing sUAS, therefore only the skills for fixed wing sUAS are included. The flight rubrics were reviewed by two content experts and two education assessment experts. Changes to the instruments were made based on the feedback from the reviewers. A final draft of the rubrics was sent to all reviewers for a final read and approval.

Prior knowledge assessment

All 20 participant answered a short questionnaire about their prior flight, RC, drone, and video game experience. This data was used as a way of keeping group differences to a minimum. Each group of five students was selected to maintain as balanced a group of skill levels as possible. A five-point Likert scale was used to assess each question with 1=no experience and 5= mastery. The survey questions consisted of the following:

Table 1: First Day of class survey

For each of the following questions, rate your level of experience/skill on a scale of 1 to 5.
1 = no experience or skill 2 = minimal experience or skill 3 = some experience or skill but a beginner

4 = intermediate experience or skill 5 = expert level experience or skill
How much flight experience do you have flying a manned aircraft?
How much flight experience do you have with remote controlled airplanes?
How much flight experience do you have with remote control helicopters (excluding quad/multirotor copters)?
How much multirotor/quadcopter experience do you have?
How much FPV (first person view) flight experience do you have?
How much computer flight simulator (RC or manned aircraft) experience do you have?
How much experience playing video games do you have?

Data Collection

All flight training was conducted during the spring 2021 semester. Flight training syllabi were collected on each flight day at the end of class. The class met three times a week, twice in a lecture class, and once in a lab. In the lab, students had the opportunity to practice on a flight simulator, fly small toy indoor quad copters, review the technical systems, and fly with their instructor on a fixed wing RC airplane. On a typical fair-weather flight day each instructor was able to fly all of their students at least one time. A scored rubric was collected for each student flight. The researcher administered the assessment for all 20 students when they were ready for their check-ride and scored each student with the check-ride rubric. All check-ride flights were conducted on a simulator due to weather and time constraints. Aircraft damaged during training flights took considerable time to repair, therefore it was not practical to conduct check-rides using actual aircraft. All flight labs and rubrics are located in Appendix A and a Flight Maneuvers Description Guide is located in Appendix B.

Data and Analysis

Research Questions

Q1: Do students trained to fly remote aircraft by different flight instructors using the same training syllabus, achieve similar rates of skill proficiency?

Q2: Is gender a factor in student performance in a UAS course?

Q3: Is prior experience in aviation associated with student success in learning to fly sUAS?

Q4: Is there a relationship between skill in sUAS operations and success on the FAA remote pilot exam?

Data collection began on the first day of class during the spring 2021 semester. Students took a "Prior flight experience" survey. A statistically significant difference was found between the male mean score of 13.5 and female mean score of 9.2 (t=2.518 p=.025). This prior flight experience score was compared to the students' final test average in the course, their final exam score, their check-ride score, and their FAA remote pilot exam (taking the FAA exam was optional. Nine of the sixteen students took and passed this exam). Gender was used as a grouping variable for several statistical tests because the females scored statistically lower on the entrance survey. No gender differences were found anywhere in the analyzed data. Complete gender comparison data will be presented later in this section.

Q1: Do students trained to fly remote aircraft by different flight instructors using the same training syllabus, achieve similar rates of skill proficiency?

Student scores on all assessments were compared with a one-way ANOVA using "flight instructor" as a grouping variable. Scores were compared for the students' test averages, individual tests, final exam, lab average*, check ride, and if available, their FAA remote pilot exam score. No statistical differences were found between any of the groups.

**Lab average is an average score of all flight rubric scores recorded by the flight instructors. Some students completed more flights than other students due to weather, aircraft damage, and other uncontrollable variables.*

Table 2: One-way ANOVA Student scores grouped by flight instructor

Assessment	df between/within	*F*	*p*
Test 1	3/12	.853	.491
Test 2	3/12	1.612	.238
Test 3	3/12	1.053	.405
Test Average	3/12	1.352	.304
Final Exam	3/12	.679	.581
Lab Average	3/12	2.844	.082
Check ride	3/12	1.113	.382
FAA Exam	3/12	.237	.798

Q2: Is gender a factor in student performance in a UAS course?

Statistical differences in prior aviation experience were found based on gender. Therefore, in order to determine if gender might be a factor that influenced scores in the course, independent t-tests were used to compare all assessment scores collected in the class.

The cognitive (written tests) tasks were examined first. An independent samples t-test was conducted on student test averages (average of three unit tests). While the males' mean score was higher (male=83.94 vs female=79.2) there was no statistically significant difference (t=.651 p=.525).

Table 3: Independent sample t-test of test average by gender

Test Average	*n*	*mean*	*SD*	*df*	*t*	*p*
Male	6	83.94	10.75	14	.651	.525
Female	10	79.2	15.67			

To test if averaging hid any individual test differences, the unit tests scores were also compared separately. Test 1, test 2 and test 3 were compared separately using gender as a grouping variable. No statistically significant difference was found between any individual tests. Males scored higher on test 1 (foundational knowledge and application of UAS) but not statistically significant (t=.375 p=.714).

Table 4: Independent sample t-test of test one by gender

Test 1	*n*	mean	SD	df	*t*	p
Male	6	90	13.52	14	.375	.714
Female	10	87.6	11.74			

On test 2, the females had a marginally higher mean score (females 76.2 males 72) but not significantly significant (*t=-.102 p=.921*). Test 2 is modeled after the FAA remote pilot exam and uses actual test questions from the 2018 remote pilot exam. Some additional questions were added by the researcher.

Table 5: Independent sample t-test of test two by gender

Test 2	*n*	*mean*	*SD*	*df*	*t*	*p*
Male	6	76	10.41	14	-.102	.921
Female	10	76.2	11.98			

Finally, on test 3 (hardware) males had a higher mean score (83.83) than the females (73.4) but the difference was not statistically significant (*t=.990 p=.339*).

Table 6: Independent sample t-test of test three by gender

Test 3	*n*	*mean*	*SD*	*df*	*t*	*p*
Male	6	85.83	12.53	14	.990	.339
Female	10	73.4	28.85			

Next, the practical portion (flight training) of the class was examined. Students were given an average lab score based on the rubric scores assigned by their respective flight instructors. The lab scores were compared using an independent sample t-test. No significant difference was found. While males had a higher mean score (*m*=14.167) than their female counterparts (*m*=9.09) the difference was not statistically significant (*t*=1.906 *p=.077*).

Table 7: Independent sample t-test of flight labs by gender

Flight Labs	n	mean	df	*t*	*p*
Male	6	14.167	14	1.906	.077
Female	10	9.09			

Next, the student check-ride scores were compared using gender as a grouping variable. The male mean score was higher (*m*=21.67) than the females mean score (*m*=15.875) but no statistically significant difference was found (*t=1.703 p=.111*).

Table 8: Independent sample t-test of check ride by gender

Check ride	n	mean	df	*t*	*p*
Male	6	21.67	14	1.703	.111
Female	10	15.875			

The FAA remote pilot exam was not a requirement of the course. As an incentive, students who elected to take the FAA exam and pass (score >70 percent) were exempted from the final exam in the course, and given a score of 100% for a final exam grade in the class regardless of the passing grade on the FAA exam. Nine of the sixteen students enrolled in the class took the exam and all nine students passed. While this is a small sample, an independent samples t-test was run to determine if any gender differences were found. The female mean score (*m*=82.6) was higher than the male mean score (*m*=80.25) however not statistically significant differences were found (*t*=-.523 *p=.380*).

Table 9: Independent sample t-test of FAA exam by gender

FAA Exam	*n*	mean	*df*	*t*	*p*
Male	4	80.25	7	-.523	.617
Female	5	82.60			

Q3: Is prior experience in aviation associated with student success in learning to fly sUAS?

A Pearson's correlation was performed on the prior flight experience scores and the student check-ride scores. No statistically significant association was found (*R=.376 p=.152*).

Table 10: Pearson's correlation between prior flight experience and check ride score

Measure	*R*	*p*
Prior flight experience & check ride	.376	*.152*

Other associations were tested using a Pearson's correlation. Significant correlations were found between mean test-average and check-ride score, lab average and check-ride score, and simulator lab score, and check-ride score. The simulator lab was the first assessment of students' flight skill conducted before outdoor flight training with actual aircraft.

Table 11: Pearson's correlation between check ride and other assessments

Measure	*R*	*p*
Test Average & Check Ride	.751	*.001*
Lab Average & Check Ride	.624	*.010*

Simulator Lab & Check Ride	.572	*.021*

Q4: Is there a relationship between skill in sUAS operations and success on the FAA remote pilot exam?

A Pearson's correlation was performed on FAA exam score and student check-ride score. No statistically significant differences were found (*R=.202 p=.632*).

Associations between other assessments were run but no statistically significant differences were found. The table below summarizes those tests.

Table 12: Pearson's correlation between key course assessments

Measure	*R*	*p*
FAA exam and check ride	.202	*p=.632*
Prior flight experience & test average	.011	*p=.967*
Test 2 & FAA exam	.690	*p=.058*
Test avg. & FAA exam	.129	*p=.762*

Analysis and Discussion

The analysis of the data from this study shows that there was no statistically significant difference between student scores on the metrics used to assess students based on the flight instructors assigned to them. This outcome supports the use of student flight instructors to help deliver the course curriculum. The ANOVA that was performed on all assessments showed no statistical significance in any area, meaning student performance was not significantly helped or hindered by any particular instructor.

Table 13: *ANOVA-Groupings by flight instructor*

Assessment	df between/within	*F*	*p*
Test 1	3/12	.853	.491
Test 2	3/12	1.612	.238
Test 3	3/12	1.053	.405

Test Average	3/12	1.352	.304
Final Exam	3/12	.679	.581
Lab Average	3/12	2.844	.082
Check ride	3/12	1.113	.382
FAA Exam	3/12	.237	.798

It is difficult for a single instructor to train an entire class of students to fly while still maintaining a consistent and meaningful instructional experience for all students. In future offerings of the course, only the student flight instructors should flight-instruct. This would free the professor up to move among the groups and provide focused attention where needed. The professor could still flight instruct as needed but would only do so as a demonstration for an instructor, a whole class demonstration, or to help with a student that was having specific difficulty. By removing the burden of flight instruction, the professor can better maintain consistency between all of the instructors, and more closely monitor the progress of the students and intervening early to address problems.

A large amount of time was spend each lab repairing crash damage. Some student flight instructors crashed planes at a much higher rate than others. A crashed plane took on average 30 minutes to repair and make flyable again. In the future, it would be beneficial to have a team (half the class) of students working on airplane repair while half the class is outside flying. The professor could lead the students in repair, using the crashes as “teachable moments”. In this way, a constant fleet of flyable aircraft is always at the ready so that flying can continue as close to uninterrupted as possible.

In an attempt to rule out other factors that may have contributed to a student’s success or failure in the course gender was examined. Gender was selected because it was statistically significant in the amount of prior experience that students had coming into the course as determined by their entry survey. Gender however, was not found to be a statistically significant factor in any of the assessments used in the course. It was noted however, that male scores were higher on almost all assessments even if not statistically significant. It is possible that there is some gender bias that is just not represented in this small (n=16) sample size. All flight instructors in this course were males, and all assessments were scored by males. In order to determine if there could be male bias in scoring, all female instructors have been selected for the fall offering of this course. The researcher is aware of the potential for bias not just in the people scoring the assessments, but also in the assessment tools. It was interesting to note that the only scores which favored females, were those not created by the instructor (the FAA exam and test 2 which uses questions from the FAA exam question bank). The researcher recognizes the potential for gender bias and will work students and faculty to update the assessment tools for future use. It is recommended that future assessments be analyzed to see if gender bias continues to be an issue.

While not statistically significant, the correlation between test 2 and the FAA remote-pilot exam scores is of interest. Test 2 is modeled after the FAA exam and is meant to prepare students for the FAA exam. While the association not statistically significant (R= .690 p=.058), it was close enough that with some adjustment this association could be improved in the future. Furthermore, if the association can be improved, regression analysis would allow for the creation of a predictor formula to advice students when they are ready to sit for the FAA Part 107 remote pilot exam. Upon speaking with all of the students who took the FAA exam this semester, they found that the FAA exam contained material not taught in the course or represented on test 2.

This finding suggests that the course materials are becoming dated, and need to be updated with the current FAA rules and regulations, particularly remote ID, and flight over people. The FAA portions of the course required the most time to teach, and represented the largest learning curve for students. Future offerings of the course will allocate more time to FAA material. It was also suggested by many students to move the FAA Part 107 unit to the beginning of the course so more time can be dedicated to its study.

Prior aviation experience did not translate to higher levels of skill among the students. It should be noted however that there was very little prior aviation experience among any of the students. Prior flight experience also was not associated with written test performance.

Table 14: Pearson's correlation between check ride score and other assessments

Measure	*R*	*p*
Prior flight experience & check ride	.376	*.152*
Prior flight experience & test average	.011	*p=.967*

This course resides as a technical course in the College of Agriculture and therefore pulls from a non-technical, non-aviation population. This course is still new (introduced in spring 2020 as Unmanned Aircraft Systems) and is not well known across campus (had a name change in 2021 to remote and autonomous aircraft). In future years, as the diversity in majors of the students enrolled in the course increases, it will be interesting to see how much prior experience may impact student success. Negotiations are underway between this course instructor and the

College of Engineering to allow the class to be used as a technical elective in their aerospace minor, which is part of the mechanical engineering degree. Also, the aviation program on campus, will now allow their professional flight majors to take the course as a technical elective. It is expected that this course will gain popularity across the colleges within the university and therefore change the dynamics and increase the diversity of the student population. Continued monitoring of the course assessments is recommended, as it record keeping on the majors of the students.

The largest challenge faced by the researcher was getting highly skilled flight instructors to teach the flying portion of the course. Three university students were selected. The first flight instructor was a former UAS student who took the class in the spring of 2020. The university shut down in March of 2020 due to the Covid-19 pandemic and instruction was moved on-line. While some flight instruction occurred before the shut-down, only a fraction of the training was completed. This student passed his FAA Part 107 remote pilot exam two days before the Covid-19 lockdown. This particular instructor needed to spend many hours (estimated at 30+) to reach a level of proficiency required to effectively flight instruct. While he was proficient by the end of the course, it would have been more beneficial if he was at that level at the start of the semester. Had he not been affected by the Covid-19 shut-down, his level of flying proficiency would have been much higher. Flight instructor number two, already held a remote pilot certificate and had quadcopter experience but no fixed-wing time. He spent several days learning to fly before the start of the semester. He never reached a level of proficiency adequate to train students effectively. The other flight instructors had to fly his students in order to get them to a basic level of proficiency. The third flight instructor was a mechanical engineering major. He had built and flown remote control airplanes for many years prior. He was the most successful pilot of the three students, and his students spent the most time flying airplanes. It is anticipated that in future semester's, flight instructor proficiency will be less of an issue as the top students from past classes can move up as instructors in future years. Three students were identified early this semester and are already being groomed as next fall's flight instructors. An instructor training program needs to be developed so that instructors are ready and proficient before the start of the semester. The logistics of such a program is difficult however, as student flight instructors can earn college credit in an independent study during the semester they instruct, but no other forms of compensation are available to the students outside the academic semester in which they instruct.

While not a primary research objective, as a new course, the answer to questions about the appropriateness of the course for different students, prerequisite requirements, and the overall rigor needed to be assessed. The results from this analysis suggests that the class is appropriate for all majors regardless of their prior experience. It should be noted however, that not all majors were represented in this study sample and further research in subsequent years will be required to better answer this question. The course seems to fit the description of a high-end entry level course based on the difficulty of the material both written and practical.

Future Research

Several areas of possible future research resulted from this study. First, a training curriculum for flight instructors needs to be developed. While having the skills to fly is an important entry requirement, teaching others how to acquire this skill requires a fair amount of attention. A major problem faced by the researcher in this study was dealing with damaged aircraft because flight instructors could not always save the aircraft from a student mistake.

Flight instructors need better training on when to intervene and take control of the aircraft. Also, safe flight altitudes that allow time to intervene when students lose control or become disoriented may be much higher for less skilled flight instructors. A study that examines the training and/or the skill set required to make for an effective instructor would be beneficial. Instructors need to be able to teach, but also, they need to be able to prevent damage to the aircraft. Would aerobatic training make an instructor better equipped to deal with taking over control in unusual attitude situations? In manned aviation, flight instructors typically will not allow the aircraft to exit a safe flight envelope, but in sUAS, it is far easier for the aircraft to end up in an unusual attitude. What is the best way to train instructors for dealing with unusual attitudes?

The use of electronic auto stabilization aids may be of use for training and reducing aircraft damage. Many inexpensive, lightweight devices are available that could auto-level the airplane when the student lets go of the controls. Such devices can also restrict roll and pitch making unusual attitudes almost impossible. Possible research questions could be:

1. Do students trained on aircraft will stabilization hardware progress faster than those without?
2. What happens to students trained to fly with auto-level devices once the automation is removed?
3. Do students trained to fly aircraft with auto-level devices damage aircraft at a lesser rate than those who fly only fully manual aircraft?

Conclusions

This study allowed for a deep assessment of an sUAS flight training program. The questions answered in this research will serve to make for a much better, more effective, flight training program for future sUAS pilots. This study also set the stage for further research and improvement in this flight training curriculum. sUAS attracts interest from a wide range of people and backgrounds and presents some unique training challenges. Changes in FAA regulations along with advancements in technology will require continued adjustments and improvements to any UAS training program. As with any aviation program, continuing education, reflection, evaluation, and continuous improvement will be vital to the success of any quality training program.

References

ASTM. (2018). Specification for Aircraft Flight Manual (AFM) for a Small Unmanned Aircraft System (sUAS) (pp. 1–5). ASTM International. https://doi.org/10.1520/F2908-18

ASN Drone Database(2018) https://aviation-safety.net/database/issue/dronedb.php

Austin, R. (2010). Unmanned aircraft systems: UAVS design, development and deployment. West Sussex, United Kingdom: Wiley.

Boselli, C., Danis, J., McQueen, S., Breger, A., Jiang, T., Looze, D., & Ni, D. (2017). Geofencing to secure airport perimeter against sUAS. International Journal of Intelligent Unmanned Systems, 5(4), 102-116. doi:http://dx.doi.org.ezproxy.library.und.edu/10.1108/IJIUS-02-2017-0002

Brooker, P. (2013). Introducing unmanned aircraft systems into a high reliability ATC system. *The Journal of Navigation*, 66(5), 719-735. doi:http://dx.doi.org.ezproxy.library.und.edu/10.1017/S0373463313000337

Campolettano, E. T., Bland, M. L., Gellner, R. A., Sproule, D. W., Rowson, B., Tyson, A. M., Rowson, S. (2017). Ranges of injury risk associated with impact from unmanned aircraft systems. *Annals of Biomedical Engineering*, 45(12), 2733-2741. doi:http://dx.doi.org.ezproxy.library.und.edu/10.1007/s10439-017-1921-6

Card, B. A., U.S.A.F.R. (2018). Terror from above. *Air & Space Power Journal*, 32(1), 80-95. Retrieved from http://ezproxy.library.und.edu/login?url=https://search-proquest-com.ezproxy.library.und.edu/docview/2050581361?accountid=28267

Chapa, J. O., U.S.A.F. (2014). Remotely piloted aircraft and war in the public relations domain. *Air & Space Power Journal,* 28(5), 29-46. Retrieved from http://ezproxy.library.und.edu/login?url=https://search-proquest-com.ezproxy.library.und.edu/docview/1610986389?accountid=28267

EAA. (2020). Academy of Model Aeronautics. Retrieved October 7, 2020, from https://www.eaa.org/eaa/aviation-interests/aviation-partners/ama

Federal Aviation Administration FAA (2016) FAA Releases 2016 to 2036 Aerospace Forecast https://www.faa.gov/news/updates/?newsId=85227

Federal Aviation Administration (FAA) (2018a)., Title 14 CFR, Chapter I, Subchapter F, Part

107. (2018, October 2). Retrieved from https://www.ecfr.gov/cgi-bin/text idx?SID=e331c2fe611df1717386d29eee38b000&mc=true&node=pt14.2.107&rgn=div5

Federal Aviation Administration (FAA) (2018b)., Unmanned Aircraft Systems (uas) Frequently Asked Questions. (2018, August 28). Retrieved from https://www.faa.gov/uas/faqs/#ffr

Federal Aviation Administration (FAA) (2018c)., Title 14 CFR, Chapter I, Subchapter F, Part 91. (2018, October 23). Retrieved from https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=3efaad1b0a259d4e48f1150a34d1aa77&rgn=div5&view=text&node=14:2.0.1.3.10&idno=14

FAA. (2019). Operations of sUAS over people (p. 206). Federal Aviation Administration. https://www.faa.gov/uas/programs_partnerships/dot_initiatives/media/2120-AK85_NPRM_Operations_of_Small_UAS_Over_People.pdf

FAA. (2020a). Airman Certification Standards. https://www.faa.gov/training_testing/testing/acs/

FAA. (2020b). Certificated Remote Pilots including Commercial Operators. https://www.faa.gov/uas/commercial_operators/

FAA. (2020c). Register Your Drone [Template]. https://www.faa.gov/uas/getting_started/register_drone/

Gregg, P. (2018) Risk in the Sky? https://udayton.edu/blogs/udri/18-09-13-risk-in-the-sky.php

GUDAITIS, F. (1994). The first days of radio Control. http://jmrc.tripod.com/fa/days/days_1.htm

Johnson, D. M., & Ii, J. E. S. (2002). Utility of a Personal Computer Aviation Training Device for Flight Training. U.S. Army Research Institute for the Behavioral and Social Sciences, 1787, 45.

Hauck, Leslie F,I.I.I., U.S.A.F., & Geis, John P,I.I., U.S.A.F. (2017). Air mines: Countering the drone threat to aircraft. *Air & Space Power Journal*, 31(1), 26-40. Retrieved from http://ezproxy.library.und.edu/login?url=https://search-proquest-com.ezproxy.library.und.edu/docview/1874624751?accountid=28267

Hirling, O., & Holzapfel, F. (2017). O.R.C.U.S. risk assessment tool for operations of light UAS above Germany. International Journal of Intelligent Unmanned Systems, 5(1), 2-17. doi:http://dx.doi.org.ezproxy.library.und.edu/10.1108/IJIUS-08-2016-0006

Kochenderfer, M. J., Edwards, M. W. M., Espindle, L. P., Kuchar, J. K., & Daniel, J. (2010). Airspace encounter models for estimating collision risk. Journal of Guidance, Control and Dynamics, 33(2), 487-499. Retrieved from http://ezproxy.library.und.edu/login?url=https://search-proquest-com.ezproxy.library.und.edu/docview/743426573?accountid=28267

Laura, N. M., & Quagliotti, F. (2018). Design of inoffensive sUAS for humanitarian missions. Aircraft Engineering and Aerospace Technology, 90(3), 524-531. doi:http://dx.doi.org.ezproxy.library.und.edu/10.1108/AEAT-11-2016-0235

Lee, H. D., & Nelson, O. W. (2010). Instructional Analysis and Course Development. American Technical Publishers.

Lin et al. - 2020—Overload and automation-dependence in a multi-UAS .pdf.

Leung, T. J., & Rife, J. (2017). Refining fault trees using aviation definitions for consequence severity. *IEEE Aerospace and Electronic Systems Magazine*, 32(3), 4-14. doi:http://dx.doi.org.ezproxy.library.und.edu/10.1109/MAES.2017.150171

Liu, Z., & Aislan, G. F. (2016). An autonomous quadrotor avoiding a helicopter in low-altitude flights. *IEEE Aerospace and Electronic Systems Magazine*, 31(9), 30-39. doi:http://dx.doi.org.ezproxy.library.und.edu/10.1109/MAES.2016.150131

Mirot, A. (2013). The future of unmanned aircraft systems pilot qualification. *Journal of Aviation/Aerospace Education & Research*, 22(3), 19-30. Retrieved from http://ezproxy.library.und.edu/login?url=https://search-proquest-com.ezproxy.library.und.edu/docview/1687639335?accountid=28267

NTSB. (2004). In-Flight Separation of Vertical Stabilizer American Airlines Flight 587 (p. 212).

NTSB. (2010). Loss of Control on Approach Colgan Air, Inc.

National Transportation Safety Board. (2017). NTSB aviation incident final report CA17IA202A. Retrieved from https://go.usa.gov/xnnkh

Shvetsov, A. V., & Shvetsova, S. V. (2017). Protection of high-speed trains against bomb-carrying unmanned aerial vehicles. *Journal of Transportation Security*, 10(3-4), 115-126. doi:http://dx.doi.org.ezproxy.library.und.edu/10.1007/s12198-017-0182-9

Stöcker, C., Bennett, R., Nex, F., Gerke, M., & Zevenbergen, J. (2017). Review of the current state of UAV regulations. Remote Sensing, 9(5), 459. doi:http://dx.doi.org.ezproxy.library.und.edu/10.3390/rs9050459

UAS on main street: Policy and enforcement at the local level. (2015). Homeland Security Affairs, Xi Retrieved from http://ezproxy.library.und.edu/login?url=https://search-proquest-com.ezproxy.library.und.edu/docview/1835615613?accountid=28267

University of Dayton. [Screen name]. (2018). *Risk in the sky.* youtube. https://www.youtube.com/watch?app=desktop&v=7gt8a_ETPRE&feature=youtu.be

U.S. Department of Transportation (2018) FAA Drone Registry Tops One Million https://www.transportation.gov/briefing-room/faa-drone-registry-tops-one-million

Wallace, R.J.(2018). Evaluating Small UAS Near Midair Collision Risk Using AeroScope and

ADS-B. *International Journal of Aviation, Aeronautics, and Aerospace*. 5 (4), 1-31. Retrieved from: https://commons.erau.edu/cgi/viewcontent.cgi?article=1268&context=ijaaa

Woodrow Bellamy III (2017) US Now Has 60,000 Part 107 Drone Pilots https://www.aviationtoday.com/2017/09/07/us-now-60000-part-107-drone-pilots/

Appendix A (Flight Labs)

Unmanned Aerial Systems
Flight Lab 1

Goal: Become acquainted with the operation of the transmitter and battery charging system.

Outcomes

Transmitter

By the completion of this session you should be able to:
☐Install the batteries into the radio transmitter
☐ Access all menus
☐ Create a new aircraft in the radio
☐ Change the aircraft type
☐ Set the display picture
☐ Set dual rates and expo
☐ Bind to a Rx
☐ Explain the operation of all the flight control sticks
☐ Use the radio to operate an aircraft or simulator

Battery Charger

By the completion of this session you should be able to:
☐Connect a battery to the charger
☐ Identify the charging connections and charge control connections
☐ Properly power the battery charging unit with AC or DC source
☐ Identify the battery type
☐ Determine the correct settings to safely charge the battery
☐ Locate and navigate all of the menus on the charger
☐ Enable/disable audible tones on charger
☐ Determine charge current and voltage
☐ Charge a battery
☐ Explain safe charging procedures

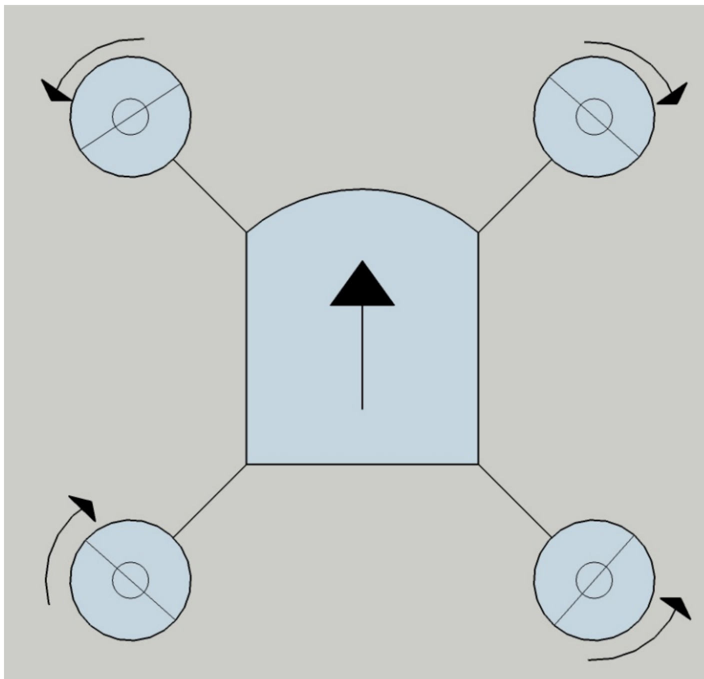
Unmanned Aerial Systems
Flight Lab 2

Goal: Complete first flights with quadcopter/multirotor

Outcomes

Flight controls

By the completion of this session you should be able to:
☐Identify and describe the function of each of the four flight controls.
☐ Describe yaw, pitch, roll, throttle as they pertain to quadcopter operation.
☐ Perform a power controlled hover in a no/light wind environment
☐ Perform a 360 yaw turn and stop at each 90 degree interval
☐ Perform a take-off, hover, land maneuver
☐ Take off-fly straight forward-land



Unmanned Aerial Systems
Flight Lab 3

Goal: Complete first flights with an airplane in the simulator

Outcomes

Flight controls

By the completion of this session you should be able to:
☐Identify and describe the function of each of the four flight controls.
☐ Describe yaw, pitch, roll, throttle as they pertain to airplane operation.
☐ Perform a take-off and maintain flight for 5 seconds or more.
☐ Practice flying around the field in a circle
☐ Attempt a landing if possible

Unmanned Aerial Systems
Flight Lab 4

Goal: Complete basic maneuvers with a quad-copter

<u>Outcomes</u>

Basic Maneuvers

By the completion of this session you should be able to:
☐Take off and land with basic control
☐ take off, move forward and land.
☐ hover, roll left, stop, hover
☐ hover, roll right, stop, hover
☐ take off, move straight forward, stop, hover, move straight back, stop, hover
☐ take off, move forward, yaw 180 degrees, fly back, stop, land

Unmanned Aerial Systems
Flight Lab 5

Goal: Complete basic maneuvers with an airplane in the simulator.

<u>Outcomes</u>

Basic Maneuvers

By the completion of this session you should be able to:
☐Take off and fly one lap of the field without crashing.
☐ Make a landing attempt and get the airplane on the runway (crashing is ok).
☐ Practice flying away from and toward yourself.
☐ Practice power off landings
☐ Practice slow flight
☐ Practice flying at different speeds

Unmanned Aerial Systems
Flight Lab 6

Stage 1 Check (airplane)

Goal: Demonstrate basic in-flight control of the airplane in the simulator. This is a pre-check requirement for first flight of actual aircraft under direct, connected, instructor control and supervision (buddy-box).

Outcomes

Basic Maneuvers

Student may not progress to real-world flight without completion of these maneuvers:
☐Take off and fly multiple laps of the field without crashing.
☐ Fly away from and toward yourself with minimal disorientation.
☐ Land on runway without crashing.
☐ Perform slow flight without loss-of-control of the aircraft.
☐ Perform a stall/recovery

Unmanned Aerial Systems
Flight Lab 7
Stage 1 Check (Quad)

Goal: Demonstrate basic in-flight control of the airplane in the simulator or with toy quad indoors. This is a pre-check requirement for first flight of actual aircraft under direct instructor supervision.

Outcomes

Student may not progress to real-world flight without completion of these maneuvers:
☐Take off and fly multiple laps of the field/course without crashing.
☐ Fly away from and toward yourself with minimal disorientation.
☐ Land on designated location without crashing.
☐ Perform hover at designated altitude.
☐ Perform turns to designated headings at designated altitude.

Unmanned Aerial Systems
Flight Lab 8
First Flight Airplane

Student:_______________________________

Instructor:______________________________

Goal: Demonstrate basic in-flight control of the airplane with assistance of an instructor using a buddy-box. Perform straight and level flight, turns to the left and right. Take off and landings demonstrated by the instructor.

Basic Maneuvers

Demonstrated Skill	Beginner	Intermediate	Mastery
Maintain straight and level flight flying away from remote pilot.	Student struggles to maintain positive control, instructor has to frequently take control.	Aircraft maintains altitude to within +/- 50 feet, some instructor input required.	Aircraft maintains altitude to within +/- 50 feet, no instructor input required.
Maintain straight and level flight flying toward remote pilot.	Student struggles to maintain positive control, instructor has to frequently take control.	Aircraft maintains altitude to within +/- 50 feet, some instructor input required, and/or some evidence of disorientation.	Aircraft maintains altitude to within +/- 50 feet, no instructor input required, and no evidence of disorientation.
Perform 30 degree banked turns to the left and right while maintaining altitude and positive control.	Some attempt at turns are made but student gets disoriented, losses control, or aircraft ends up out of operational safety limits.	Turns to the left and right are made with moderate changes in altitude (+/- 50 feet) and pitch. Turns may be uncoordinated.	Coordinated turns to the left and right are made with little to no changes in altitude (+/- 20 feet).

Skills introduced and demonstrated by instructor (May be performed in front of large group one time)

☐ Hand Launch take-off
☐ Perform slow flight without loss-of-control of the aircraft.
☐ Left-hand traffic pattern
☐ Landing

Instructor Signature:______________________________
Date:__________________

Unmanned Aerial Systems

Flight Lab 9
Second Flight Airplane

Student:_______________________________ **Instructor:**_________________________

Goal: Demonstrate basic in-flight control of the airplane with assistance of an instructor using a buddy-box. Perform straight and level flight, turns to the left and right. Slow flight and basic throttle control will be practiced. Student should attempt to make 360 circuit around flying field without instructor taking over.

Basic Maneuvers

Demonstrated Skill	Beginner	Intermediate	Mastery
Maintain straight and level flight flying away from you.	Student struggles to maintain positive control, instructor has to frequently take control.	Aircraft maintains altitude to within +/- 50 feet, some instructor input required.	Aircraft maintains altitude to within +/- 50 feet, no instructor input required.
Maintain straight and level flight flying toward you.	Student struggles to maintain positive control, instructor has to frequently take control.	Aircraft maintains altitude to within +/- 50 feet, some instructor input required, and/or some evidence of disorientation.	Aircraft maintains altitude to within +/- 50 feet, no instructor input required, and no evidence of disorientation.
Perform basic turns to the left and right while maintaining positive control and maintain altitude to +/- 20 feet.	Some attempt at turns are made but student gets disoriented, losses control, or aircraft ends up out of operational safety limits.	Turns to the left and right are made with moderate changes in altitude (+/- 50 feet) and pitch. Turns may be uncoordinated.	Coordinated turns to the left and right are made with little to no changes in altitude (+/- 20 feet).
Perform slow flight while maintaining positive control of aircraft.	Student attempts slow flight but is unable to maintain positive control for more than a few seconds before control is taken. Student often stalls the aircraft or otherwise loses control.	Aircraft is slowed to just above stall speed. Positive control is mostly maintained with pitch, power, yaw, and roll control. Instructor may take over in event of a stall or loss of positive control.	Aircraft is slowed to just above stall speed. Positive control is maintained with pitch, power, yaw, and roll control. Any stalls are immediately recovered from.
Fly a left-hand traffic pattern with a go around, do not land.	Little or no legs are completed without the instructor taking over. Most of the flying is	Most of a left-hand traffic pattern consisting of downwind, base, final, upwind, and cross wind is	A complete left-hand traffic pattern consisting of downwind, base, final, upwind, and cross wind is

	uncoordinated and unstable.	performed without error or instructor control. Instructor may have to execute a go around, or some of the pattern may be unstable.	performed without error or instructor control. A go around and properly performed by student.

Skills introduced and demonstrated by instructor (May be performed in front of large group one time)

☐ Aileron roll

☐ Loop

☐ Stall/recovery

☐ Left-hand traffic pattern

☐ Power off landing

Instructor Signature:_________________________________

Date:__________________

Unmanned Aerial Systems
Flight Lab 10
Third Flight Airplane

Student:______________________________

Instructor:_________________________________

Goal: Demonstrate in flight control of airplane for one or more circuits of the field with no instructor control. Attempt first hand-launch take-off if instructor approves. Attempt first landing if instructor approves.

Demonstrated Skill	Beginner	Intermediate	Mastery
Full circuit of the flying field without instructor control.	Student can only fly some of the circuit. Student loses positive control, has trouble holding altitude, or becomes disoriented. Instructor has to take control often.	Student can fly most of the circuit of the field (all legs of the traffic pattern except altitude is maintained the entire time). Some instructor input is required. Most of the circuit is stable.	Student can fly the full circuit of the field (all legs of the traffic pattern except altitude is maintained the entire time). No instructor input is required. Entire circuit is stable.
Hand launch take off. (Someone other than the student will throw the airplane, student is ready at the controls).	Student crashes or instructor has to take over because very little positive control is demonstrated. Student is unable to recover aircraft in flight.	Instructor has to take over, but aircraft does not crash and/or Student maintains control but exceeds pitch and roll limits before regaining control.	Student applies full power, climbs to altitude determined by the instructor, and aircraft does not exceed 30 degrees of pitch, or 30 degrees of bank.
Landing attempt, instructor may take control.	Student does not demonstrate the control required for a	Student can fly most legs of the traffic pattern but instructor	Student can fly all legs of the traffic pattern and get the

	landing attempt. Instructor has to take control repeatedly. Most of the flight/approach is unstable.	takes over briefly to stabilize aircraft. Final approach is not stabilized. Student does not need to land.	aircraft to a stabilized final approach. Student does not need to land.
Perform slow flight while maintaining positive control of aircraft.	Student attempts slow flight but is unable to maintain positive control for more than a few seconds before control is taken. Student often stalls the aircraft or otherwise loses control.	Aircraft is slowed to just above stall speed. Positive control is mostly maintained with pitch, power, yaw, and roll control. Instructor may take over in event of a stall or loss of positive control.	Aircraft is slowed to just above stall speed. Positive control is maintained with pitch, power, yaw, and roll control. Any stalls are immediately recovered from.
Fly a left-hand traffic pattern.	Little or no legs are completed without the instructor taking over. Most of the flying is uncoordinated and unstable.	Most of a left-hand traffic pattern consisting of downwind, base, final, upwind, and cross wind is performed without error or instructor control. Instructor may have to execute a go around, or some of the pattern may be unstable.	All of a left-hand traffic pattern consisting of downwind, base, final, upwind, and cross wind is performed without error or instructor control.

Skills introduced and demonstrated by instructor (May be performed in front of large group one time)

☐ Full solo flight requirements

Instructor Signature:______________________________

Date:___________________

Unmanned Aerial Systems
Flight Lab 11
Fourth Flight Airplane

Student:________________________________ Instructor: ________________________________

Goal: Demonstrate all pre-solo skills and refine/practice weak skills. Student should be at or approaching the skills required for a solo flight.

Demonstrated Skill	Beginner	Intermediate	Mastery
Hand launch the airplane	Student crashes or instructor must take	Instructor must take over, but aircraft does not crash	Student applies full power, climbs

(student throws the airplane).	over because very little positive control is demonstrated. Student is unable to recover aircraft in flight.	and/or Student maintains control but exceeds pitch and roll limits before regaining control.	to altitude determined by the instructor, and aircraft does not exceed 30 degrees of pitch, or 30 degrees of bank.
Climb up to and maintain altitude of 50-100' as determined by instructor.	Aircraft fails to reach altitude, overshoots altitude, or is unable to maintain altitude to +/- 50 feet or better.	Aircraft climbs up to but might overshoot determined altitude. Student maintains altitude +/- 50 feet as determined by instructor.	Aircraft climbs up to but does not overshoot determined altitude. Student maintains altitude +/- 20 feet as determined by instructor.
Make 3 full circuits of the flying field maintaining positive control of the aircraft at all times.	Student can only fly some of the circuit. Student loses positive control, has trouble holding altitude, or becomes disoriented. Instructor must take control often.	Student can fly most of the circuit of the field (all legs of the traffic pattern except altitude is maintained the entire time). Some instructor input is required. Most of the circuit is stable.	Student can fly the full circuit of field. No instructor input is required. Entire circuit is stable.
Perform slow flight while maintaining positive control of aircraft at altitude determined by instructor.	Student attempts slow flight but is unable to maintain positive control for more than a few seconds before control is taken. Student often stalls the aircraft or otherwise loses control.	Aircraft is slowed to just above stall speed. Positive control is mostly maintained with pitch, power, yaw, and roll control. Instructor may take over in event of a stall or loss of positive control.	Aircraft is slowed to just above stall speed. Positive control is maintained with pitch, power, yaw, and roll control. Any stalls are immediately recovered.
Fly a left-hand traffic pattern.	Little or no legs are completed without the instructor taking over. Most of the flying is uncoordinated and unstable.	Most of a left-hand traffic pattern consisting of downwind, base, final, upwind, and cross wind is performed without error or instructor control. Instructor may have to execute a go around, or some of the pattern may be unstable.	All of a left-hand traffic pattern consisting of downwind, base, final, upwind, and cross wind is performed without error or instructor control.

Land inside designated touchdown zone with no damage to the aircraft.	Aircraft crashes or is damaged, lands outside the designated landing zone, or the instructor had to take over.	Aircraft is landed without damage in the designated touchdown zone with some instructor input.	Aircraft is landed without damage in the designated touchdown zone without and instructor input.

Skills introduced and demonstrated by instructor (May be performed in front of large group one time)

☐ Full solo flight requirements

Instructor Signature:______________________________

Date:__________________

Student made successfully solo? ☐ Yes ☐ No Date:__________ Instructor signature:______________

Unmanned Aerial Systems
Flight Lab 11a
5th Flight Airplane

Student:____________________________________

Instructor:______________________________

Goal: Demonstrate all pre-solo skills and refine/practice weak skills. Student should be at or approaching the skills required for a solo flight. This lab will be repeated as required until student is ready for 1st solo. Student needs to be at Mastery in all skills for solo flight. Instructor will still have the ability to take control even during student solo.

Maneuvers

Demonstrated Skill	Beginner	Intermediate	Mastery
Hand launch the airplane (student throws the airplane).	Student crashes or instructor must take over because very little positive control is demonstrated. Student is unable to recover aircraft in flight.	Instructor must take over, but aircraft does not crash and/or Student maintains control but exceeds pitch and roll limits before regaining control.	Student applies full power, climbs to altitude determined by the instructor, and aircraft does not exceed 30 degrees of pitch, or 30 degrees of bank.
Climb up to and maintain altitude of 50-100’ as determined by instructor.	Aircraft fails to reach altitude, overshoots altitude, or is unable to maintain altitude to +/- 50 feet or better.	Aircraft climbs up to but might overshoot determined altitude. Student maintains altitude +/- 50 feet as	Aircraft climbs up to but does not overshoot determined altitude. Student maintains altitude +/-

		determined by instructor.	20 feet as determined by instructor.
Make 3 full circuits of the flying field maintaining positive control of the aircraft at all times.	Student can only fly some of the circuit. Student loses positive control, has trouble holding altitude, or becomes disoriented. Instructor must take control often.	Student can fly most of the circuit of the field (all legs of the traffic pattern except altitude is maintained the entire time). Some instructor input is required. Most of the circuit is stable.	Student can fly the full circuit of the field (all legs of the traffic pattern except altitude is maintained the entire time). No instructor input is required. Entire circuit is stable.
Perform slow flight while maintaining positive control of aircraft at altitude determined by instructor.	Student attempts slow flight but is unable to maintain positive control for more than a few seconds before control is taken. Student often stalls the aircraft or otherwise loses control.	Aircraft is slowed to just above stall speed. Positive control is mostly maintained with pitch, power, yaw, and roll control. Instructor may take over in event of a stall or loss of positive control.	Aircraft is slowed to just above stall speed. Positive control is maintained with pitch, power, yaw, and roll control. Any stalls are immediately recovered from.
Fly a left-hand traffic pattern.	Little or no legs are completed without the instructor taking over. Most of the flying is uncoordinated and unstable.	Most of a left-hand traffic pattern consisting of downwind, base, final, upwind, and cross wind is performed without error or instructor control. Instructor may have to execute a go around, or some of the pattern may be unstable.	All of a left-hand traffic pattern consisting of downwind, base, final, upwind, and cross wind is performed without error or instructor control.
Land inside designated touchdown zone with no damage to the aircraft.	Aircraft crashes or is damaged, lands outside the designated landing zone, or the instructor had to take over.	Aircraft is landed without damage in the designated touchdown zone with some instructor input.	Aircraft is landed without damage in the designated touchdown zone without and instructor input.

Skills introduced and demonstrated by instructor (May be performed in front of large group one time)

☐ Full solo flight requirements (as required)

Instructor Signature:______________________________

Date:___________________

Student made successfully solo? ☐ Yes ☐ No Date:__________ Instructor signature:______________

Appendix B (Maneuver Description Guide)

Maneuver Description Guide (MDG)
Airplane

This guide is designed to help you progress through the basic maneuvers required for 1st solo in a fixed wing UAS and to develop the proficiency for a fixed wing UAS check ride. This guide is intended for a small, single engine, propeller aircraft with a fixed wing. A trainer similar in design to the one pictured below is recommended as it has gentle flying characteristics and can typically self-recovery, or recover very quickly and easily.

Take off (hand Launch)

Take off should always be made into the wind. On a tractor style, fixed wing airplane, the pilot should hold the airplane by the fuselage belly and toss the airplane forward with a firm yet gentle toss. The flight controls should be held in the non-dominate hand and the airplane tossed with the dominate hand. Full power should be applied to the aircraft before the toss. Most single engine, propeller aircraft will have a left turning tendency and the pilot should be prepared to compensate, but not over compensate for this turn with right rudder. Slight back pressure, and if required, roll correction applied as needed until a proper altitude has been reached. Once at altitude, power can be reduced to about 75%-50% depending on the aircraft, battery, prop, etc. Always be aware of the propeller and any other moving parts of the aircraft. Be extremely cautious when handing an aircraft as the throttle could go to full at any time making a hazardous condition.

Climb Out
After a gentile hand-toss or ground launch, full power and a max 20 degree climb out angle should be established. Wings should be held level and any cross wind corrected for with aileron and rudder inputs. A safe operating minimum altitude of 30-50' AGL should be established. Depending on the size of the aircraft a max altitude of 150 feet is typically good for training. A comfortable estimated altitude should be established between the instructor and student pilot.

Straight and level flight
The first, most basic skill any new pilot will learn is straight and level flight. Aircraft power should be reduced to a manageable level to allow for easier control. Typically 75% power is a good starting point. Downwash from the propeller will push the tail of the airplane down and pull the nose up. Gently adjust the pitch until the aircraft is flying level. Use aileron control to compensate for roll. If you can't maintain level flight without adding control input, use trim to make the aircraft fly straight and level hands free, or as close to hands free as possible. It is easiest to fly away from yourself when learning straight and level flight.

Flight toward yourself
Flight toward oneself is one of the most difficult skills to learn aside from landing. The flight controls (for roll control and yaw) are reversed as viewed from the pilot when flying toward oneself. Overtime this will make little difference to a pilot but in the beginning it can cause much confusion. One of the best things to remind yourself of is that when flying toward yourself push the controls toward the low wing will fix the aircrafts attitude. In the image below pushing the aileron stick to the right will level this banked aircraft as it flies toward the pilot.

Circuit of the Airfield
In order to demonstrate controlled flight, the student should complete several laps around the airfield. A consistent altitude as viewed from the student should be maintained. Appropriate back

pressure should be applied on the elevator during turns to maintain altitude. A constant altitude as established by the instructor should be maintained as close as possible during the entire circuit.

Slow Flight
Slow flight is an essential skill to practice before landing can be accomplished. Control surfaces become "sluggish" as the amount of airflow over the control surfaces is reduced. Slow flight should be initiated at a safe altitude from which a stall/spin situation can be safely recovered. 100 feet AGL is recommended. To enter slow flight, gradually reduce engine power while maintaining altitude with pitch. Once the airplane can no longer maintain altitude increase power as required but use pitch to maintain as slow a speed as possible without entering a stall. If the airplane does stall relax the back pressure on the control stick and apply full power to recover.

Stall-Spin recovery
Stalls and spins should be practiced at a minimum safe altitude to allow for recovery time. 100 feet AGL or higher is generally recommended for spin recovery.

Stalls will be practiced in both power on and power off configurations.

Power on Stall - At 100 feet AGL slow the aircraft to approximately half throttle and achieve straight and level flight. Increase power to full takeoff power and execute a steep climb in excess of 20 degrees. Maintain the climb until the stall then relax back pressure on the stick and recover. Apply rudder input if necessary, to prevent a spin. **DO NOT USE AIELRONS IN A STALL!** Recovery should be immediate and smooth.

Power off stall - At 100 feet, reduce power to approximately 50% and achieve straight and level flight. Slowly reduce power while maintain altitude with pitch control. Once the aircraft is behind the power curve (further reduction in power results in loss of altitude regardless of pitch input), throttle may have to be added back in to maintain altitude while holding minimum airspeed. Once the airplane stalls, smoothly add full power, relax back pressure on the stick and recover the stall. Add rudder input as required to prevent a spin. **DO NOT USE AIELRONS IN A STALL!** Recovery should be immediate and smooth.

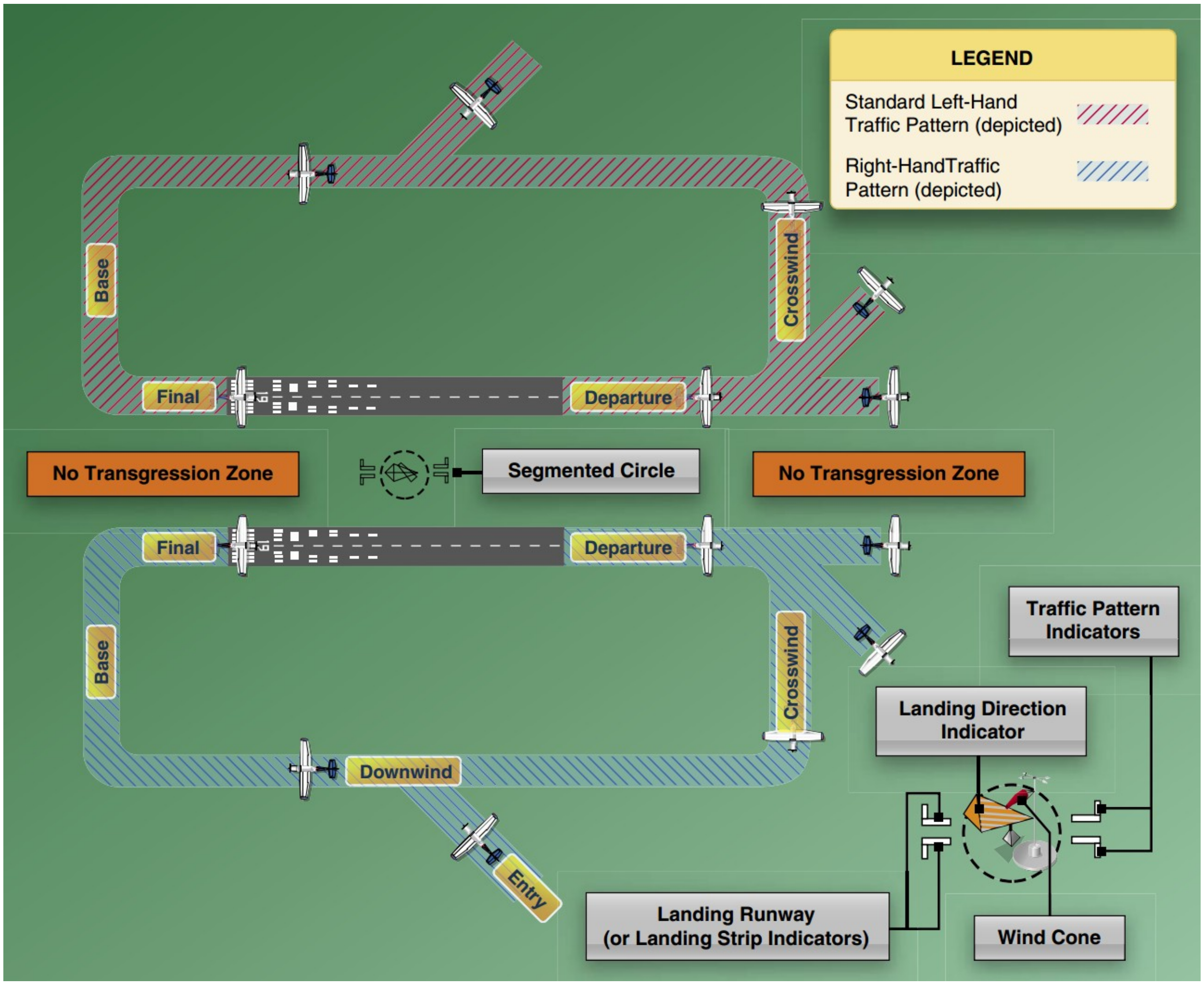
Spin Recovery – Spins should only be practiced in aircraft rated for spins. Special care should be taken to assure that all components are properly attached and secured before a spin as the forces of a spin will exceed the normal operational limits of the aircraft. Spins should be practiced as high as possible to allow for recovery (without breaking the 400-foot AGL limit for sUAS).

Begin by executing a power-on stall. Hold the climb angle but do not recovery the stall. When the aircraft breaks (nose will fall left or right, usually left on a single engine propeller aircraft) allow it to develop into a full rotation. On many training aircraft some rudder input in the direction of the spin may be required to hold the airplane in a spin. To exit the spin, reduce power, relax back pressure, and apply opposite rudder. Once rotation stops reapply power smoothly and enter straight and level flight.

Left-hand traffic pattern
When practical a standard left-hand traffic patter should be followed for landing. A right-hand pattern can be used when obstacles, noise restrictions, or other factors do not allow for a left-hand pattern. A standard left-hand pattern is made up of the following four legs.

Upwind
Crosswind
Downwind
Base
Final

The upwind leg is flown after takeoff and is simply a straight line climbing up and away from the end of the takeoff runway into the wind. Crosswind is entered after climbing out and is a left hand 90 degree turn which will place the wind on the right side of the aircraft and may push the aircraft back toward the runway if not corrected for. Downwind is entered by executing another 90-degree left turn and will place the aircraft parallel to the takeoff runway with the wind now at the read of the aircraft increasing ground speed by the speed of the present wind. Base will be entered by executing another 90-degree left turn when the aircraft is beyond the landing end of the runway at the point when the airplane intersects an imaginary 45-degree line coming from the end of the runway. On base, the wind will be at the left side of the aircraft pushing the aircraft away from the runway if not corrected for. Final is achieved by making one last 90 degree turn to the left and lining the aircraft up with the end of the runway. The aircraft should be pointed into the wind when on final.



Rejected Landings (go-around)
Any landing attempt that is unstable on final approach should be rejected. Any aircraft that is making large pitch, power, or alignment inputs on final approach is unstable and the approach should be terminated with a "go-around". Landings may be rejected for any other reason that the PIC determines presents a hazard to the people or property on the ground, the aircraft, or for any reason the PIC determines is unsafe.

To execute a rejected landing (go-around) smoothly add full power, retract any retractable landing gear. If full flaps are deployed retract one notch of flaps, then slowly retract the remaining flaps one notch at a time as altitude and airspeed increase to the settings specified in the aircraft operating handbook or instruction manual. Maintain vigilance of airspeed and pitch to prevent a stall. Climb back to a safe altitude and re-enter the traffic pattern to attempt a second landing.

Landing

When practical, fly a standard left-hand traffic pattern and land into the wind. If landing directly into the wind is not possible select the approach that will place the airplane into the oncoming wind as much as practical for the final approach.

Approach the traffic pattern at approximately 100 feet AGL. Enter the downwind in straight and level un-accelerated flight. When abeam the end of the runway (or landing point of grass or gravel field) reduce power and enter a gentle glide slope. Aircraft should descend slowly and smoothly at about a 4-degree slope. Continue the approach by turning left base and further slowing the aircraft but maintaining glide slope. Make a final 90-degree left turn and continue to slow the aircraft while maintaining glide slope. Make small additions or reductions to power to maintain airspeed and glide slope. Continue toward the ground until about 3 feet AGL then reduce power to idle, raise the nose of the aircraft and flare just before touchdown. The airplane should gently touch the ground and slide (or roll) to a smooth stop. If the approach is unstable by the turn to final, execute a "go-around" and repeat the landing pattern described above.

Appendix C Raw Data Set

Student	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**
1	1	1	1	1	1	1	1
2	1	1	1	2	2	1	2
3	1	1	1	1	1	1	1
4	1	2	1	1	1	1	2
5	1	1	1	1	1	1	2
6	2	2	2	1	1	3	4
7	1	1	1	2	1	1	4

8	2	1	1	2	2	1	3
9	1	1	1	1	1	1	3
10	1	2	2	2	2	1	3
11	1	3	3	4	1	1	1
12	1	2	1	1	1	1	3
13	1	1	1	1	1	1	3
14	1	1	1	1	1	1	1
15	1	4	4	4	1	4	4
16	1	2	1	1	1	1	3

Prior Flight Experience	**gender**	**year**	**major**
7	f	junior	Agricultural Education, Agricultural Education
10	f	sophomore	Agricultural Education, Agricultural Education
7	f	senior	Agricultural Education, Agricultural Education
9	f	senior	Agricultural Education, Agricultural Education
8	f	senior	Agricultural Education, Agricultural Education
15	m	sophomore	Agricultural Education, Agricultural Education
11	m	sophomore	Technology Education
12	f	junior	Agricultural Education, Agricultural Education
9	m	senior	Agricultural Education, Agricultural Education
13	f	junior	Tech Ed Broadfield Option, Agricultural Education
14	m	senior	Technology Education
10	m	junior	Technology Education
9	f	junior	Agricultural Education, Agricultural Education
7	m	sophomore	Agricultural Education, Agricultural Education
22	m	junior	Agricultural Education, Agricultural Education
10	f	senior	Technology Education

GPA	**Test 1**	**Test 2**	**Test 3**	**Final Exam**	**FAA_Exam**
3.78	96	71	77	100	no
3.77	93	95	88	100	yes
3.79	96	91	96	100	yes
3.54	93	83	92	100	yes
3.56	93	70	77	98	no
2.82	79	59	62	64	no
3.44	100	78	88	100	yes
3.19	79	76	50	78	no
3.04	93	82	96	100	yes

3.49	86	88	92	100	yes
3.31	68	68	88	80	no
3.98	100	83	85	100	yes
3.43	79	62	81	100	no
3.52	100	68	81	100	no
3.47	100	86	96	100	yes
2.85	61	62	0	0	no

Flight Instructor	**Sim**	**Lab1**	**Lab2**	**Lab Avg**	**Checkride**	**FAA Exam**
1	14.5	3		3	13.75	
2	12.5	7.5	17.5	12.5	21	93
3	6	15	20	17.5	26	82
1	14.5	4.5	17	10.75	22	80
4	9	7.5		7.5	20.25	
4	15	7.5	15	11.25	19.75	
2	9	7.5*	17.5	17.5	15.5	72
4	9	8.9		8.9	15.5	
1	14.5	6	13.5	9.75	20	83
3	4		16	16	18	83
2	9.5	7.5*	20	20	21	
2	10.5	7.5*	17.5	17.5	25	88
4	9		7	7	13.25	
3	4	7.5	8	7.75	9	
1	25.5	9		9	28.75	78
n/a	n/a	n/a	n/a	n/a	n/a	n/a