EFFECTS OF SIMULATOR TRAINING FOR UNMANNED AERIAL SYSTEMS IN UNDERGRADUATE EDUCATION

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Unmanned aerial systems (UAS) are being added to the national airspace (NAS) in very large numbers. Many universities have seen this demand for UAS operators and begun to create programs in order to train undergraduate students in their use. The UAS industry currently lacks adequate training requirements for beginning operators. This fact makes university training important, because universities are one of the few places that offer structured training. While the UAS industry in the US is in its infancy it is possible to draw parallelisms the training history of manned flight in order to avoid pitfalls and offer training in the most efficient way possible. This study utilizes a mid-fidelity UAS simulation program in order to test the application of this technology. Preliminary results show that simulator technology is helpful in teaching UAS flight in an undergraduate setting.

Unmanned aerial systems (UASs) are being introduced into the United States national airspace system (NAS) by the hundreds of thousands. As this new technology is implemented, the question of how the operators of these vehicles will be trained is raised. With the implementation of code of federal regulations (CFR) 14 part 107, the Federal Aviation Administration (FAA) has set the framework for commercial operations of UASs inside the NAS. These regulations not only allow for commercial use of UASs in the NAS, it places limitations on the vehicles that can be used. The limitations are; the vehicle must weigh less than 55lbs, have a maximum speed of 100mph, stay at or below 400ft above ground level (AGL), and stay within line of sight (Federal Aviation Administration, 2016). CFR 14 part 107 was released in 2016 but in December 21, 2015 the FAA began requiring that all UASs between .55-55lbs be registered. February 5, 2016 saw the number of registered UASs surpass the number of registered manned aircraft, and by May 12, 2016 over 466,000 vehicles had been registered (Federal Aviation Administration, 2016). This rapid growth far surpassed any of the forecasting attempts done in the previous years.

In 2013, Darryl Jenkins and Dr. Bijan Vasigh, researchers for the Association for Unmanned Vehicle Systems International (AUVSI), published a report on the economic impact of these vehicles in the US. In this report, Jenkins and Vasigh used 100,000 vehicle sales as a benchmark for the number of vehicles sold per year, for commercial purposes. They went on to forecast that UASs would add over $82.1 billion to the economy by 2025 as well as add over 103,000 jobs paying on average $40,000 per year (Jenkins & Vasigh, 2013). However, in 2016, the FAA predicted that around 600,000 UASs would be sold for commercial use. This large difference in predictions will likely have an effect on the forecasted economic impact of UAS integration into the NAS, as well as the jobs they create. The incredible potential that UASs have to influence the US economy in a positive manner make it extremely likely that these vehicles will quickly become an integral part of the NAS.

Assuming that these vehicles will become a vital part of the NAS the question of how these operators will be trained is incredibly important. One training option is to have individuals follow CFR 14 part 107 requirements, as they exist at this time, which requires no experience flying these vehicles. While this follows the letter of the law, it may not be the safest way to train new UAS operators. Another approach is to implement UAS training at universities, and have this training mimic flight training already done at universities. This style of training is being used across the country by many different universities. One popular method is having students build and flight test a UAS from a kit. This student built vehicle is then utilized in that course and later courses. This method has a good amount of merit as it allows students to learn the components of a UAS, learn how the construction methods affect flight, and allows them inexpensive flight experience. However, this method alone allows for a wide range of hazardous errors.

This method generates two very prominent errors when used with students that have no prior experience with UASs; the first problem is the possibility of components being installed incorrectly leading to the vehicle to function incorrectly; the second problem is the increased risk of crashes during flight. The first error can be easily fixed by providing more comprehensive instructions to the students as they construct the vehicles, or by having a professor or teaching assistant oversee the construction. The second error however is much more difficult to mitigate, as any time an individual attempts to develop a new skill it is almost guaranteed that they will make mistakes as part of the learning process. While this outcome is expected during any new skill development, it becomes dangerous when teaching UAS operations. Kit built vehicles tend to weigh between 3-5lbs, but their performance capabilities increase the possible damage from a ground collision. Many are capable of maintaining speeds of 30 miles per hour or more, and climbing to altitudes over 400 feet. This factor accompanied by the risk of laceration by the propellers on the vehicle are the sort of risks that accompany an UAS flight. By solely training new UAS operators with "real world" flight experience the likelihood of personal or property damage is increased..

While there is no way to teach new operators without allowing them to fly their vehicles, these flights can be augmented with simulator training. Simulator training has been the standard of training in aviation for decades. This long usage offers a great deal of experience and refinement for the emerging UAS industry can use to create the most efficient training programs. One of these lessons is the idea that utilizing simulators that are extremely realistic, high fidelity, in order to give realistic flight experiences does not mean that the simulator training is effective. For many years aviation has placed a premium on how realistic a simulator is, because these simulators are being used as a replacement for using an actual aircraft for familiarization and recurrent training. In order to replace flying the aircraft with flying a simulator it appears that replicating the flight environment is of the upmost importance. In this setting, it would seem that a company would get the best training for their flight crews by spending money on the most recent and most high tech simulators available. However, these simulators are often used to train crews on day-to-day flying activities like standard operating procedures and crew roles (Dahlstrom, Dekker, Winsen, & Nyce, 2009). This style of training has come about because training evaluation has generally been done by having the trainees evaluate the training upon their completion, this idea has led to high fidelity simulators to be rated extremely high because they very flashy and include a great deal of “bells and whistles” (Salas, Bowers, & Rhodenizer, 1998).

This approach to simulator training evaluation has come about because of the lack of opportunity for research with high fidelity simulators. A high fidelity simulator is very costly, and in order to make sure this equipment is used in a cost effective manner they are generally in use for training continuously (Salas, Bowers, & Rhodenizer, 1998). In the place of high-fidelity simulation training for normal operations, it has been suggested that lower fidelity simulators that focus on adverse tasks and crew resource management (CRM) are more useful in practice. Dahlstrom, et al. (2009) tested the use of a mid-fidelity simulation of a ship’s bridge, during this simulation the subjects were given time critical and event driven scenarios in order to see if the subjects could begin to develop skills useful in the target environment. This training experiment was conducted over two days and included; two runs of the simulation along with briefings, discussions, and lectures (Dahlstrom, Dekker, Winsen, & Nyce, 2009). These experiments showed the subjects adapting quickly to different situations, and breaking out of their predefined roles to better control the situation at hand (Dahlstrom, Dekker, Winsen, & Nyce, 2009). The participants of this study also requested more simulation training similar to the experiment, which shows that while they not only did better the subjects found the training enjoyable (Dahlstrom, Dekker, Winsen, & Nyce, 2009). Dahlstrom, et al. go on to state that high-fidelity simulations run the risk of reducing the imaginative and creative involvement of the participants. This in turn can lead to the “internalization of a series of highly contextualized instrumental stimulus-response relationships-putatively stress-resistant procedural response that may be insensitive to, or even make actors unprepared for, contingencies outside of rehearsed routines,” (Dahlstrom, Dekker, Winsen, & Nyce, 2009, p. 311).

Currently the only large operator of UASs in the US is the US military, and all four branches utilize this technology. The United States Air Force (USAF) and the United States Army differ greatly in their UAS missions and in their training methods. Both of these organizations apply simulator technology in their training to differing degrees of success. The USAF requires that all UAS pilots be trained pilots that have flown a minimum of one tour of duty (Tvaryanas, Thompson, & Constable, 2005). A 2002 report by the United States Air Force Research Lab describes the kind high-fidelity simulation used to cross train these experienced pilots into the RQ1 Predator (Schreiber, Lyon, Martin, & Confer, 2002). By 2005, this simulation training had proven to have a great many flaws (Tvaryanas, Thompson, & Constable, 2005). A study conducted over the UAS mishaps in every branch of the military showed that despite the greater flight experience of USAF operators, and their simulation training, they had the highest rate of skill based errors (Tvaryanas, Thompson, & Constable, 2005). One of the main causes of these errors was that this “high-fidelity” simulation did not represent the handling characteristics of the vehicle (Tvaryanas, Thompson, & Constable, 2005). The US Army chooses UAS operators from enlisted personnel and gives these individuals UAS specific training (Tvaryanas, Thompson, & Constable, 2005). The UAS specific training that is given to US Army personnel consists of 88 simulator hours in a 20 day period as well as training with the actual system (Rosenberg, 2012). Unlike the USAF, the US Army uses many small, rugged, and relatively inexpensive vehicles, which allows them to utilize them for real world training at a lesser cost than if the USAF utilized it’s vehicles for many training flights (Rosenberg, 2012). This training approach led the US Army having the lowest number of skill-based errors when compared with the other three branches of the US military (Tvaryanas, Thompson, & Constable, 2005).

Methodology

By utilizing commercially available simulation software, Real Flight 7.5, students enrolled in 300 level UAS courses were able to gain and practice UAS flight skills. These students had to complete 14 labs over the course of the semester, five simulator labs and nine outdoor flying labs. Each of these simulator labs was designed to present the students with a different aspect of UAS flight.

The first lab required the students to hover a very basic quadcopter, one without equipped stabilization assistance, in different orientations during a 10mph cross wind from a third person perspective. This task introduced students to the challenges of dealing with wind as well as the challenges of partial and complete control reversal. The second lab required students to operate the same vehicle from the previous lab in order to locate a missing item, this lab was done in first person. This lab introduced one of the functions of UAS, and forced the students to maintain constant situational awareness during the search. Lab three used the same quad-rotor vehicle to navigate a course of tubes placed at different altitudes throughout the flight area, this lab was also done in first person. Students performing this lab quickly learned that their vehicle's battery would deplete if they did not perform the course quickly enough. This challenge forced the students to learn how to quickly and accurately make flight corrections in a time critical environment. Labs four and five required the students to use a specific fixed wing vehicle instead of the quad-rotor vehicle used for labs 1-3. During lab four, students had to demonstrate their ability to land a fixed wing vehicle, from a third person perspective, consecutive times and in wind. Flying a UAS from a third person view presents a problem with depth perception when tracking the vehicle. The fifth lab required students to fly the same obstacle course as lab three with a fixed wing vehicle. For this lab, the battery life of the vehicle was still a factor, but the fixed wing vehicle was able to travel much more quickly, which mitigated this factor. Highlighting this difference between vehicles allowed students to learn that certain vehicles are better suited for certain applications.

The students who took this course also completed labs with quadcopters built from a kit in a previous class. After completing this course these students continued onto the following course that focuses on flying vehicles equipped with payloads. After this continued flight experience, the students were given a survey asking their perceptions of the UAS simulator and its usefulness. In this survey students were asked to state which simulator lab they felt were the most helpful, least helpful, easiest, most difficult and if the labs increased their confidence operating a UAS. Along with rating the labs the students were asked to describe the reasoning behind their ratings.

Real Flight 7.5

Real flight 7.5 is a mid-fidelity UAS simulator that utilizes a mock UAS controller for control inputs. This simulator contains over 140 aircraft of many configurations, and over 40 flight areas. Each of these aircraft is accurately modeled to the flight characteristics of their real counterparts, and each of the flight areas has controllable atmospheric conditions present. This simulator allows the user to operate their UAS from a third person view, as if they were looking at the vehicle and flying, or from a first person view, as if they are looking through a camera mounted on the vehicle.

Results

At the time of publication, this study is ongoing. However, preliminary results suggest that there is a correlation between gaining experience with the simulation equipment and skill with the UAS in flight operations.

Conclusions

By utilizing simulators alongside inexpensive vehicles, undergraduates can be professionally trained for safe operations in the NAS. This method mimics the training given to enlisted personnel in the US Army, and should be easily adapted to undergraduate education. In order to improve this study in the future, these surveys should be completed yearly and the results compiled.

References

Dahlstrom, N., Dekker, S., Winsen, R. v., & Nyce, J. (2009). Fidelity and validity of simulator training. *Theoretical Issues in Ergonomics Science*, 305-314.

Federal Aviation Administration. (2016). *FAA Releases 2016 to 2036 Aerospace Forecast.* Washington DC: U.S. Department of Transportation.

Federal Aviation Administration. (2016). *FAA Releases Drone Registration Location Data.* Washington DC: US Department of Transportation.

Federal Aviation Administration. (2016). *Fact Sheet – Small Unmanned Aircraft Regulations (Part 107).* Washington D.C.: Department of Transportation.

Jenkins, D., & Vasigh, D. B. (2013). *The economic impact of unmanned aircraft systems integration in the United States.* Arlington, VA: AUVSI.

Salas, E., Bowers, C. A., & Rhodenizer, L. (1998). It is not how much you have but how you use it: Toward a rational use of simulation to support aviation training. *The International Journal of Aviation Psychology*, 197-208.