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An Online Drone Course for Construction Management Students: Curriculum, Simulation, and Certifications

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It is incumbent upon higher education institutions to teach students how to use emerging technologies and best practices of advanced workflows. Unmanned aircraft systems (UAS) are rapidly expanding tools that support various industries, including construction management, civil engineering, and surveying. There are many challenges to offering a course focused on the use of an outside, hands-on tool. These challenges can be exacerbated by the online delivery method.
This paper describes the curriculum and delivery method of an online drone course taught at a large land grant institution in the southeast. The course allows students to earn their FAA Part 107 remote pilots certificate and their Airborne Public Safety Association (APSA) flight proficiency certification, and it prepares them to become a Level 1 UAS thermographer. This paper will indicate where this institution has found success and where future development is needed when offering this course online. The paper can also be a roadmap for other schools to create a similar UAS course.

Key Words: Online Course, Drones, UAS, Simulation, Certifications

Introduction

Unmanned Aircraft Systems (UAS), commonly referred to as "drones," are an emerging technology that supports many industries. Only a short time ago, drones were a novelty rarely seen in practical application. The FAA significantly restricted access to the national airspace for commercial drone purposes. This regulator barrier all but stifled the development of cost-effective hardware and the development of supporting software applications. However, there was a seismic shift in the drone community with the release of CFR Title 14 Part 107 (Part 107) in 2016. Part 107 removed most of the regulatory barriers and opened the national airspace to the public. This led to the development of affordable prosumer hardware and high-powered software applications tailored to individual industries. In less than seven years, drones have gone from an experimental novelty to a critical part of many contractors' marketing, estimating, and project management workflows.

Universities have a long history of researching new technologies and preparing their graduates to use them (Harper, et al., 2022). The use of UAS in the construction industry is no different. Several ASC schools have created elective drone courses for their students. However, because of the newness of the technology, there is a significant gap in the literature related to UAS-based curricula and case studies of successful drone classes. This paper will help fill this gap by describing a drone course

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delivered by a major land grant institution in the Southeast. While there are a few UAS-course case studies available in the literature, this paper is unique because it describes the curriculum of a fully online course exclusively focused on UAS use in the built environment. Moreover, the course is promoted as "comprehensive" because it provides students with FAA licensure, flight skills certified by a nationally recognized public safety organization, and critical UAS skills such as photogrammetry and thermography. Universities wishing to create a UAS program can adopt or modify the curriculum described in this paper for their specific purposes.

Literature Review

Drones have a wide range of use cases, including cinematography, search and rescue, plant monitoring, and surveillance. Despite the relative newness of the technology, the literature is well-populated with descriptions of how the construction industry has used the technology for safer and more productive jobsites. Common uses include safety inspections, site management, and surveying (Lie & Liu, 2019). A more detailed list of drone uses in the construction industry can be found in Table 1.

Published Drone Course Case Studies

Several schools have published their experiences incorporating drones into their construction management programs. A local contractor helped incorporate UAS technology into Youngstown State University's civil and construction engineering program (Sanson, 2019). Texas A&M created a drone course that included FAA regulations, safety, insurance, and 3D mapping (Williamson & Gage, 2019). The focus of this course was using drones to support surveying activities, as well as learning about the regulatory challenges experienced during the initial release of Part 107. Irizarry published a case study in 2019 highlighting the success Georgia Tech had in incorporating drones at the graduate level. This case study underscored the importance of understanding government regulations applied to UAS education. It also made the reader aware of the challenges associated with operating a drone on a campus located in a major metropolitan area.

As an alternative to offering a course solely focused on UAS technology, some schools have adopted the approach of adding drone modules into existing courses. A California Polytechnic State University paper proposed that courses focusing on construction surveying, heavy civil construction management, and emerging technologies are well suited for incorporating a UAS curriculum (Sanchez, 2021). The University of Florida followed this model and integrated a UAS module into an undergraduate Building Information Modeling course (Pereira et al., 2018). The module focused on photogrammetry and showed how it could be used to support model updates.

These case studies indicated several common challenges to the incorporation of UAS technology into their curriculum. Part 107 limits where drones can be operated based on airspace classification. Schools in proximity to major airports may not be permitted to fly drones outside, making the instruction of practical flight skills difficult. Even when airspace classification wasn't an issue, acquiring university approval to operate a drone was a common challenge at some institutions. The cost of the equipment was also a common challenge mentioned. Limited administrative support, faculty training, low industry support, and lack of a program champion have also been listed in the literature as challenges (Harper et al., 2022).

Table 1

Summary of How Drones Are Being Used in Construction

Activity	**Citation No.**
Mapping	6
Inspection	1, 4, 5, 7, 8, 10
Safety	1, 4, 6, 7, 8, 14
Surveys	1, 2, 3, 4, 5, 6, 7, 9, 11
As-Built	11, 12, 13
BIM	3, 4, 7, 13
Marketing	10
Automated Assembly	1
Material Delivery	7, 10
Thermal Imaging/Scanning	2, 5, 10, 11
Photography	1, 2, 3, 4, 6, 9, 10, 11, 12, 13
Monitoring	7, 8, 10, 12, 13

1) Tatum & Liu, 2017; 2) Williamson & Gage, 2019; 3) Irizarry, 2019; 4) Zaychenko et al., 2018; 5) Agapious, 2021; 6) Aiyetan & Das, 2022; 7) Li & Liu, 2019; 8) Howard et al., 2018; 9) Adjidjonu & Burgett, 2021; 10) Cajzek & Klansek, 2016; 11) Varbla et al., 2021; 12) Bognot et al.2018; 13) Anwar, et al., 2018

Drone Course Curriculum

The published case studies have common curriculum topics, including Part 107 regulations, flight skills, photogrammetry and volumetrics, surveying, and BIM. However, the literature does not specify which topics are, or should be, taught in a construction management drone class. Burgett surveyed 50 contractors, asking them to rate curriculum topics based on usefulness (2021). In addition to the topics addressed in the other case studies, the Burgett survey found that contractors also saw value in teaching students how to use pre- and post-flight checklists, how to file FAA accident reports, how to file air traffic authorization requests, how to file FAA waivers, how to use UAS-specific weather tools, and how to program autonomous (autopilot) missions.

The most comprehensive survey of drone-related curricula in construction management and civil engineering programs was conducted by Harper et al., (2022). Over 1,300 survey invitations were sent through the ASC and ASEE listservs, and 92 were returned. Of the 92 returned survey questionnaires, only 22 (12 engineering and 10 construction programs) indicated that they were currently using UAS in the classroom. The most common skills taught were photogrammetry, measuring quantities, and site mapping and layout. Surveying, BIM, inspections, tracking work progress, quality control, positioning and navigating a UAV, tracking resources, and inventory management were also taught in some programs.

Online Drone Course

The instructor's drone course is the only UAS-specific class consistently offered at his home institution. With a traditional on-ground course, the number of students that could be enrolled is limited by lab space, the number of drones available, and the physical limitations of supervising too many students flying at the same time. However, the online environment removes these limitations. The objective of the course was to make this course available to as many students as possible from across a wide range of disciplines. It had no prerequisites and was offered asynchronously.

The class was divided into five topic areas each with corresponding modules. The specific topics and modules are provided in table 2. Each module contained video tutorials, readings from a course workbook, and various assignments and lab exercises. The video tutorials were recorded using Articulate Storyline. Articulate Storyline is an e-learning platform that has an end product similar to a well-animated PowerPoint presentation. However, it also includes periodic knowledge check questions and embedded resources. The instructor wrote the Basic UAS Reference Guide and Manual (B.U.R.G. manual) as a course workbook. It provided step-by-step instructions for all the assignments and lab exercises. The instructor expected that as time went on, the students would forget some of the tools used in the class. The hope was that students would keep the B.U.R.G. manual and use it as a reference guide in the field after they graduated. The instructor held optional web calls at the beginning of each week. These calls often lasted 15 minutes and included only the instructor's review of the required deliverables for the week. However, some calls lasted longer when a student presented questions or needed additional clarification. The calls were recorded, and the links were provided in the class.

Part 107

A Part 107 requirement is that commercial drone pilots must pass a knowledge test and earn their remote pilot certificate. The knowledge test includes 60 multiple-choice questions over two hours given at a third-party testing site. The exam fee is approximately $175. The first five modules of the course were focused on preparing students to pass this test. The first assignment of Module 1 was to provide documentation that the exam was scheduled by the end of Module 5. Student feedback typically included comments like "nothing is as motivating as a deadline." Knowing the date also allowed the instructor to provide an encouraging email the morning of their exam. The FAA provides a Part 107 Study Guide (Federal Aviation Administration [FAA], 2016). The study guide is not a body of knowledge, however, and does not contain sufficient information to guarantee success on the exam. The video tutorials are structured around the chapters of the study guide. They reinforce the material in the text and provide the missing information needed to pass the exam. The modules contain hundreds of sample questions with automated feedback. Students were required to complete two practice exams that simulated the actual exam. After students took the FAA exam, they uploaded their results. Their performance on the FAA exam accounted for 25% of their overall course grade. The course had 16 students in which 12 (75%) passed the FAA exam. See table 3.

Table 2

Course outline with topics and certifications issued

Topic	Wk.	Module	Certification Issued
Part 107 Regulation and Knowledge Test Preparation	1	Introduction	FAA Remote Pilot Certificate
	2	Ch. 1 & 2 of FAA Study Guide	
	3	Ch. 3A, 3B & 4 of FAA Study Guide	
	4	Ch. 5 - 12 of FAA Study Guide	
	5	FAA Part 107 knowledge test	
Regulatory Compliance Tools	6	FAA waiver, accident reporting, weather tools, and LAANC	
Flight Training	7	Flight training with simulator	APSA Flight Proficiency Certificate
	8	Flight training with simulator	
	9	BPERP examination	

Photogrammetry	10	Data collection, photogrammetry, and intro to Drone Deploy	
	11	Photogrammetry with DroneDeploy	
	12	Thermal dynamics & movement, IR fundamentals, and emissivity	
Thermography	13	IR cameras, palettes, FOV and thermal tuning	Level 1 UAS Thermography Certificate
	14	Standards, IR applications, and UAS night operations	
	15	Level 1 Thermography Exam	

Table 3

Number of Students who Earned the Certificates Associated with Class

	Total Students	FAA Part 107 Knowledge Test	APSA Flight Proficiency Test	Level 1 UAS Thermography Exam
Passing Exam	16	12 (75%)	16 (100%)	11 (69%)

Compliance Tools

The part 107 exam assesses the pilot's knowledge of various rules. The *FAA-CT-8080-2H* booklet published by the FAA contains sectional charts selections, aeronautical weather forecasts, and other sample data. This booklet accompanies the exam, and students must refer to it to answer many questions. This approach works well for a basic assessment; however, it is important for students to be able to check airspaces, temporary flight restrictions, and UAS-specific weather forecasts in the real world. The focus of Module 6 is to teach practical online and app-based tools to comply with Part 107 regulations. See table 2 for a list of specific topics addressed.

Flight Simulator

Flight skills are the primary focus of Module 7, 8 and 9. Given that this is an online delivery, all the fight training is completed with a computer simulator. A license to operate the Zephyr Drone Simulator (zephyr-sim.com) and a FlySky FS-i6S controller are provided to the students to use on their personal computers. The simulator includes over 50 unique drone missions and approximates the physics of 14 of the most commonly used commercial UAS. An advantage of using Zephyr in the institutional setting is that the student performance is automatically uploaded to the cloud, where the instructor can see hours logged, mission scores, and detailed flight performance data.

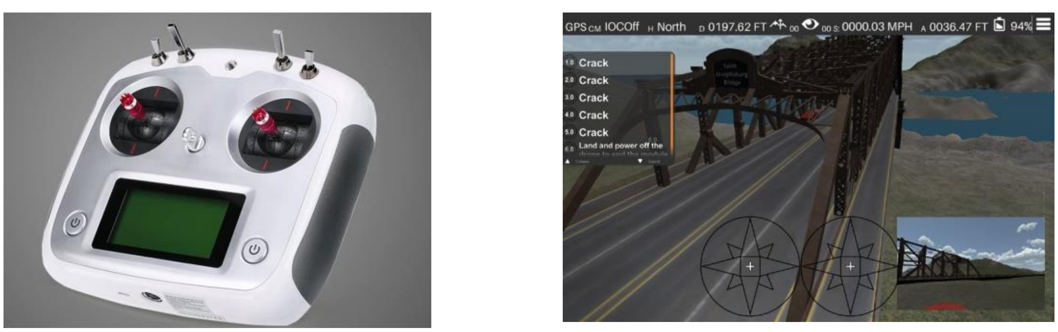

Figure 1. Controller and Zephyr Simulator

Flight performance is not assessed with the FAA licensure. However, the Airborne Public Safety

Association (APSA) has adopted the federal government's Basic Proficiency Evaluation for Remote Pilots (BPERP) exam for flight proficiency certification. APSA's BPERP certification is the only nationally recognized credential for UAS flight proficiency. Traditionally, the BPERP exam is given in person by a certified APSA proctor. Pilots must navigate a course and take pictures of targets at the bottom of 2-gallon buckets. The instructor has worked with APSA and Zephyr to offer the BPERP exam through the simulator. One limitation is that an APSA proctor must review and certify the test results before a certification can be earned. The instructor has gone through the APSA training to become a proctor, so he can certify his students' BPERP scores. The certification comes from APSA at the cost of approximately $75. All 16 students passed the BPERP examination and earned their APSA certificate. See table 3.

Photogrammetry

The tenth module of the course focuses on creating 3D maps and models from drone data. The course provides students a license to use DroneDeploy, one of the leading flight control and photogrammetry software applications. The flight control application allows students to create waypoint-assisted missions for data collection. The app has a built-in simulation that will mimic the mission programmed without actually being connected to the drone. DroneDeploy's photogrammetry application is web based. This is particularly useful in an academic setting because students don't need a high-powered computer to operate it. The instructor provides students with sample data, and the students then create 2D orthophotos and 3D models. They are asked to extract quantity takeoff data from the models they create. There is also a surveying component where the students are provided with geolocated ground control points. Students are shown that adding ground control points can have minor improvements in relative accuracy but improve absolute accuracy by feet if not more.

Thermography

An emerging use case for drone technology is aerial thermography. Drones with high-resolution infrared imagers are being used more frequently by contractors to detect roof leaks, build energy audits, and perform various quality control activities. However, like most sophisticated equipment, the user needs training to operate it. This is especially true with infrared images. There is more to thermography than identifying "blue as cold and red as hot." Figure 2 shows a piece of plywood with two different coatings. Both coatings have the same temperature but significantly different infrared profiles. Modules 11 through 15 focus solely on UAS thermography. The curriculum was developed based on the recommendations of the American Society for Nondestructive Testing (ASNT) document SNT-TC-1A. It specifically addresses basic thermodynamics, the science of infrared radiation, emissivity, thermal image tuning, camera operations, thermal loading, and various infrared related standards.

A significant portion of the thermal modules focuses on using software to tune thermograms by adjusting emissivity and environmental conditions. The course uses DJI's Thermal Analysis Tool for this application. DJI is the largest commercial drone manufacturer and commands approximately three-quarters of the commercial drone market (Statista, 2022). Thermograms from DJI thermal cameras can only be tuned by their proprietary software. The DJI Thermal Analysis Tool is limited compared to other thermal tuning software, but it has the advantage of being free to use.

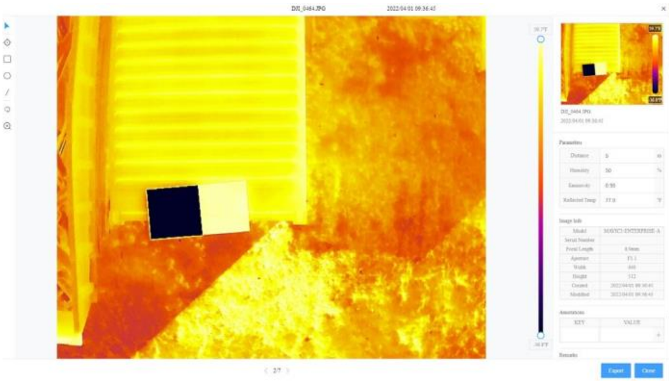

Figure 2. DJI Thermal Analysis Tool

While not part of the recommended ASNT curriculum, the course also addresses specific considerations for the operation of a UAS at night. Most building-related infrared inspections are conducted at night, making this a critical topic to address. Because the instructor is a certified Level 3 thermographer, he is qualified under ASNT standards to develop the curriculum and certify the examination to credential his students as Level 1 thermographers. Eleven students (69%) earned the minimum 80% required to receive their Level 1 UAS Thermography certification. See table 3.

Conclusions

This paper provides describes how drones are being taught online at a large university in the Southeast. The course is promoted as a comprehensive UAS course because it provides all the basic skills to operate a small UAS in the national airspace. Specifically, the main curriculum topics include Part 107 licensure, regulatory compliance tools, flight skills through simulation, photogrammetry, and UAS thermography. The course provides students with three certifications which include 1) the FAA Part 107 Remote Pilots Certificate, 2) APSA BPERP flight proficiency certification, and 3) becoming a level 1 UAS thermography. This paper can be used as a road map to create a similar drone course at other universities. Interested faculty are encouraged to contact the author for additional information and collaboration.

Future Work

The instructor is exploring a second UAS class to follow the course described in this case study. One activity that would be taken to a higher level would be creating an FAA Part 107 waiver application. The photogrammetry modules would be expanded to address advanced accuracy diagnostics and surveying best practices. Multispectral sensors mounted on drones have been shown to detect plant health and have numerous agricultural applications. Flight skills would continue to be developed in the second class. APSA provides a certification beyond the BPERP using an obstructed test lane. This advanced certification is being considered for the second class. Finally, developing the coursework for students to become Level 2 or 3 thermographers is also being explored. In addition, a future study is planned to evaluate if student learning retention is impacted with an online delivery method.

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