

Use of Small Unmanned Aerial Systems in Construction Management Curriculum in Compliance with FAA Regulations: A Case Study

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This paper describes the use of Small Unmanned Aerial Systems (sUAS) in a graduate course in a construction education program. It is meant to share the experience of the author in implementing this technology in compliance with U.S. Federal Aviation Administration (FAA) regulations. The process for inclusion of the technology, its applications in the course, and challenges and opportunities are discussed. The author's goal is that by sharing this experience, faculty in construction education programs will be able to incorporate sUAS technology into their courses in compliance with FAA regulations governing its use in education environments.

Key Words: Unmanned Aerial Systems, Construction Education, Technology, Photogrammetry

Introduction

Unmanned Aerial Systems (UASs) are increasingly being considered for government and civilian applications around the world. In 2015, the U.S. Federal Aviation Administration (FAA) established policies and certification requirements for UAS integration into the National Airspace System (NAS). Currently, unmanned aircraft are allowed to operate under specific conditions that comply with established regulations, including for educational applications (FAA, 2016). This paper describes the use of Small Unmanned Aerial Systems or sUAS into the construction management curriculum at the Georgia Institute of Technology. Aiming at understanding the challenges and opportunities of sUAS use in construction courses, this paper describes the topics covered in the BC6005 Technology Applications in the Construction Industry course (BC6005), the hands-on activities performed, and the requirements that had to be met to perform course activities in compliance with FAA regulations. For clarification purposes, reference to UAS means Unmanned Aerial Systems in general and sUAS means Small UAS which is a subset of UAS. sUAS is the term used by the Federal Aviation Administration to describe vehicles of less than 55 pounds and more than 0.55 pounds. These systems are the most commonly found in industry and are the ones the FAA refers to when issuing the Remote Pilot Certificate with Small UAS rating commonly referred to as a Part 107 license.

UASs were first widely adopted in military operations and now occupy a permanent position in the military arsenals of many countries (Nisser and Westin, 2006). Current civilian applications of such systems include the following:

- border patrol
- search and rescue
- damage assessment during or after natural disasters (e.g. hurricanes, earthquakes, tsunamis)
- locating forest fires
- identifying farmland frost conditions
- monitoring criminal activities
- mining activities
- advertising
- scientific surveys
- securing pipelines and offshore oil platforms (Anand, 2007).

A UAS consisting of a rotary wing aircraft with several sensor devices and the ability to hover for extended periods is a well-suited platform for studying UAS applications, e.g., autonomous surveillance/navigation (Krajník et al., 2011), human-machine interaction (Ng and Sharlin, 2011), and sport training assistance (Higuchi et al., 2011). In a study conducted by Irizarry et al. (2012), a UAS quadcopter was used to explore the benefits of providing safety managers with still images and real-time video from a range of locations on a construction jobsite. Another study conducted by Rosnell and Honkavaara (2012) showed how virtual point clouds can be generated from image sequences collected by small UASs. A similar study in Finland by Lin et al. (2013) proposed a novel aerial-to-ground remote sensing system for surveying land scenes of interest. Continuous improvements in UAS functionality and performance create opportunities for applied research on integrating this leading-edge technology into education environments.

Unmanned Arterial Systems use in Construction Environments

Unmanned aerial systems are increasingly being considered for applications in the construction environment. Hart and Gharaibeh (2011) conducted field tests with UASs on ten roadways in Texas, to determine whether UAS use would improve the safety of roadside conditions and the accuracy of construction inventory surveys. Roadside conditions were evaluated by the examination of visual data collected with the UAS. Weather and field conditions were identified as major variables affecting overall UAS performance. Two other studies by Metni & Hamel (2007) and Eschmann et al. (2012) considered UAS applications for bridge inspection and detection of cracks on buildings respectively. Blinn and Issa (2016) explored possible applications of UASs in active construction environments. Their study compared traditional task performance (without UASs) to UAS-supported task performance. They found that visual data provided by the UAS is indeed useful in project management and control on construction sites. In addition, the study showed that the use of a UAS for certain tasks was superior to traditional methods, since it could decrease operational costs. Irizarry and Costa (2016) investigated possible UAS uses in construction management. The study involved collecting qualitative and quantitative data through interviews with and surveys of construction managers. The findings indicated that construction progress monitoring and jobsite logistics could benefit from the visual assets captured and provided by the UAS. Kim et al. (2016) identified performance factors, user requirements, and operational challenges associated with the use of UASs for construction site inspections—particularly, for safety inspections on jobsites. A survey questionnaire was distributed to safety and project managers in the field. A total of 31 factors and 17 measures were identified and used to evaluate the performance of UAS operations. Flight plans and documentation methods were determined to be the most critical user requirements, whereas FAA regulations and pilot certification were considered the most significant challenges for safe UAS operations in construction environments. Irizarry et al. (2012) proposed an initial concept of how UAS could be used to improve jobsite safety then Gheisari and Esmaeili (2016) identified user and technical requirements for UAS safety applications. Safety managers indicated the following hazardous operations as the ones that would benefit the most from UAS use: 1) working around traffic or cranes; 2) working near an open area; and 3) working in the blind spot of heavy equipment. The three most critical technical requirements identified were as follows: 1) real-time communication; 2) a high-precision navigation system; and 3) a sense-and-avoid system. Integrating UAS technology is construction courses would provide students with the knowledge and skills needed to effectively employ UAS technology in the construction industry. The studies discussed put into context the importance of UAS technology in the construction industry and supports the use of the technology in construction education.

Using UAS in Construction Courses

Eiris and Gheisari (2018), noted that there were no publications in the construction literature that addressed the use of UAS in construction management education. This motivated the author if this paper to share the experience gained over the last two years using sUAS in construction curriculum (Grayson, 2017). The author hopes that faculty in construction programs will learn from the experience presented in integrating hands-on exercises using flight simulation, indoor and outdoor sUAS practical exercises with sUAS similar to what is used in industry.

Course Background

As part of revisions to the curriculum of the School of Building Construction at the Georgia Institute of Technology, the BC6005 course focused on the application of various technologies in the construction industry was created. The course includes technologies such as Unmanned Aerial Systems, 4D scheduling, laser scanning, virtual and augmented reality, Building Information Modeling, and contract management software among others. The goal of the course is to provide students with working knowledge of the technologies introduced and is taught by one instructor. The first iteration of the course was offered in the Fall of 2016. Since the focus of this paper is to share the author’s experience with the use of UAS into construction management curriculum, only this technology will be part of the discussion in the paper.

The sUAS Portion of BC6005 Technology Applications in the Construction Industry

Topics covered in the sUAS portion of the BC6005 course include the following; Introduction to sUAS, sUAS selection, sUAS operations, sUAS Applications in Construction Environments, and Legal and Regulatory Considerations. These topics rely heavily on the operational framework established by current FAA regulations, mainly Code of Federal Regulations (CFR) 14 Part 107 (CFR, 2018). The instructional content of the theoretical part of the sUAS topic includes capabilities and technical features of the various sUAS platforms introduced as well as basic aeronautical knowledge relevant to the operation of sUAS in construction environments. An additional benefit for students who take the course is that the instructional content provided, prepares them for the Part 107 certification exam. As of the Spring of 2018 semester, 11 students have passed the Part 107 exam and obtained their FAA sUAS Remote Pilot Certificate. Although taking the Part 107 exam is not required from students due to the $150 cost that they would have to cover, students that do take it receive credit towards the course final exam as incentive. The practical portion of the sUAS topic includes a 4-step lab-based process designed to teach students how to operate the sUAS platforms most used in the construction environment. A total of 11 out of 28 class sessions are devoted to the topic of sUAS.

The first step of the practical sUAS portion of the course involves a lab setting exercise in which students use a sUAS simulator to become acquainted with the basic controls of a multi-rotor sUAS. The class uses a mobile device-based simulator for the first step. A screenshot of the simulator and an illustrative example of students using the application is shown in Figure 1.

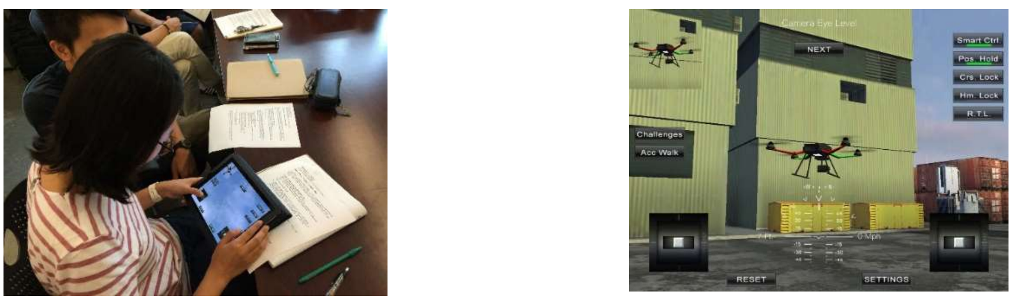

Figure 1: Simulation-based class activity with software controls

Students are provided with a list of tasks to be performed using the simulator program using the version of the “virtual” sUAS that does not make use of sensors that assist in stabilizing flight. These sensors include a gyroscope, a compass, an altimeter, and an accelerometer. Not using these sensors in the simulation allow students to experience what it would be like to fly the sUAS in a completely manual manner. Once students have performed the tasks and gained confidence in their ability to use the basic controls they can move to step 2 of the process. In this step, students perform the same tasks but with the assistance of all sensors which provide stabilized flight. This allows students to experience what it would be like to fly the sUAS in manual mode, but assisted by sensors, which means they only need to steer the aircraft and not worry about stability in terms of altitude and orientation. Step 3 involves the use of a simulation program that uses hardware controls instead of the virtual controls provided in the tablet-based simulation. The purpose of step 3 is to allow students to experience sUAS flight with the use of physical controls like the ones used in actual sUAS operations in the field. The system used in step 3 is a 3D Robotics Solo sUAS simulator as shown in Figure 2.

Figure 2: 3D Robotics Solo UAS use for UAS simulation activity with hardware controls

The fourth step has two parts. First, students operate micro UASs with hardware controls in an indoor environment. The micro UASs used are Parrot Mambos with sensors similar to what larger UASs provide. Using micro UAS in the early part of the piloting learning process has the benefit of allowing students to use a platform that has minimal risk of injury due to its small size. However, the use of micro UAS has the limitation of short battery life requiring having multiple units with spare batteries. Once students have performed an exercise using these micro UASs, they then use small UASs to gain experience with platforms very similar to the ones used in the construction industry. The sUAS and micro UAS platforms used for hands-on activities and their technical specifications relevant to the course and this paper are included in Table 1. In order to ensure the safety of students during the indoor practical flight sessions of the first part of step 4, an indoor flight enclosure is used as shown in Figure 3. The enclosure is 30 feet long by 10 feet tall by 10 feet wide.

Table 1

Technical specifications of sUAS platforms used in hands-on class activities

UAS Platform		**Weight (g)**	**Flight Time (min)**	**Photo (MP)**	**Video**	**Cost (US$)**
DJI Mavic Pro		734	27	12.35	4K	$999
DJI Phantom 4		1,380	28	12.4	4K	$799
Yuneec Typhoon H		1,695	25	12.4	4K UHD	$1,199
Parrot ANAFI		320	25	22	4K HD	$699
Parrot Mambo		63	9	0.3	720p	$179

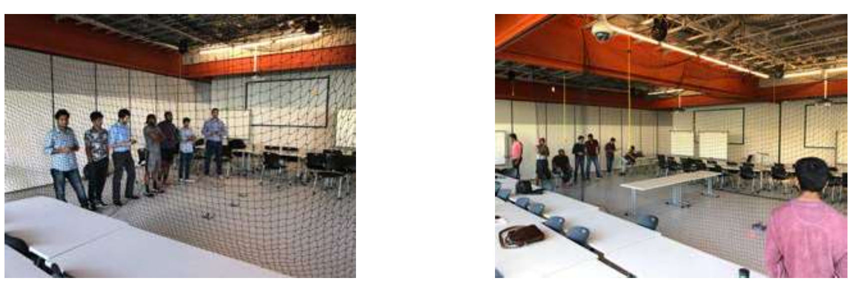

Figure 3: Indoor flight enclosure used in practical sUAS flight sessions

The second part of step 4 involves students performing outdoor flight tasks. This step of the process requires strict safety precautions in order to comply with Part 107 regulations. The FAA allows the use of sUAS in educational environments with no restrictions when flights are performed indoors. When performing flights outdoors, the following conditions must be met.

- sUAS must fly below 400ft above ground level
- sUAS must fly within visual line of sight of pilot in command
- sUAS cannot fly over those not involved in the sUAS operation
- Pilot in command must be Part 107 certified (the course instructor or teaching assistant)
- One student at a time can fly an sUAS for each Part 107 Pilot in Command involved in the operation

The last requirement is important because it restricts how many students can perform the outdoor practical flight activity at one time. The reason only one student can fly at one time is that the course instructor, who has to be a Part 107 certified pilot, has to be able to take control of the sUAS in case of an emergency situation during flight.

In addition to the relevant FAA requirements, the Georgia Institute of Technology has a policy that requires faculty using sUAS for courses to provide notification to campus police regarding the proposed sUAS operation. Information provided to campus police before sUAS operations take place include the items listed next.

- Description of the proposed operation including launch location and recovery location if different from launch location, date and time of the operation as well as duration including start time and end time, and tasks to be performed during the operation.
- Safety precautions (launch area). This includes measures taken to restrict access to the launch area to those not participating in the operation.
- Pilot in Command's Part 107 Certificate Number and cellphone number (faculty in charge of the course in this case).
- sUASs to be used in the practice session and their FAA registration numbers.

The listed information accompanies a flight plan diagram that is provided to campus police before each flight. A sample of the flight plan graphic is shown in Figure 4.

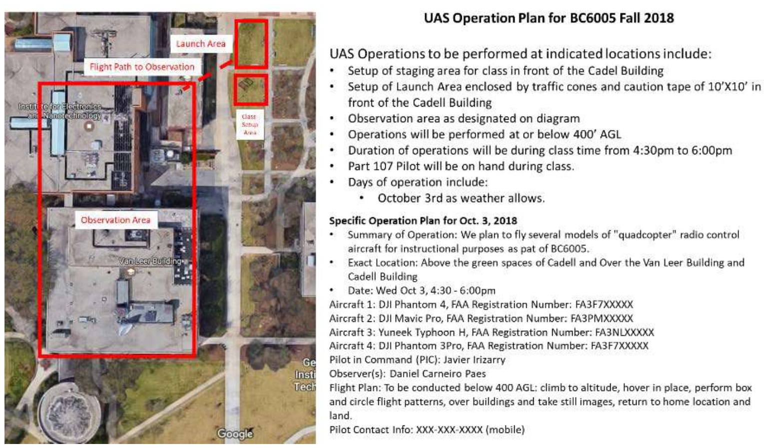

Figure 4: Sample Flight Plan for UAS operation on campus at the Georgia Institute of Technology

Application Activities

Once students have completed the UAS simulation and hardware practical flight activities, they apply what they have learned by collecting images with the UAS and using photogrammetry software to develop orthomosaics and point clouds. Students use the Pix4D software to work on this task. Once they have collected the data and processed it with the photogrammetry program, they use the results to perform linear, area, as well as volumetric measurements. Students also perform a second activity where they take the created point cloud and they merge it with a point cloud obtained with another technology used in the course (laser scanner) and combine them in a BIM application such as Autodesk Revit. Since collecting the sUAS images needed for the photogrammetry activity is performed outdoors, FAA regulations must be complied with. It could be possible to provide students with image sets collected by the instructor, but this would deprive students of the hands-on component which is important for their learning.

Challenges and Opportunities

There are always challenges when incorporating new technologies into coursework. sUAS use in construction curriculum presents some unique challenges. The challenges identified during the over two years that the BC6005 course has been offered are divided into 3 categories including pedagogical, resources, and regulations. Some of the challenges identified coincide with findings in Eiris and Gheisari (2018).

Pedagogical Challenges

Student proficiency was identified by Eiris and Gheisari (2018) as a challenge in using sUAS in construction management courses. The author has encountered a similar challenge but to a lesser extent since the BC6005 course uses a multistep approach to sUAS piloting instruction. The use of flight simulation allows students to obtain the initial skills needed for operating sUAS with physical controls. During indoor hands-on flight sessions, there are multiple micro UAS devices that multiple students can operate simultaneously. However, there is another challenge encountered by the author when teaching students in outdoor environments. FAA Part 107 regulations for educational use of sUAS, requires that only one sUAS is operated for each licensed pilot. In the case of the BC6005 course, the course instructor can only supervise one student operating an sUAS at a time. This creates some challenges with the amount of time students can spend on hands-on tasks. This issue has been addressed by conducting indoor and outdoor activities that can be performed simultaneously. The indoor activity can be supervised by the course Teaching Assistant. This approach has increased the time each student gets to perform the outdoor task. The time varies according to the number of students in the course but has changed from an average of 3 minutes per student in the Fall of 2016 session to an average of 7 minutes per students in the Spring 2018 session.

Resource Challenges

In order to provide students with a meaningful learning experience with sUAS, it is important to have adequate systems for students to learn with. In order to provide students with the simulation section of the learning sequence, mobile devices are needed. The author has used tablet devices for this activity. A challenge with the use of this technology involves the maintenance and upkeep involved to maintain the equipment in good working condition. In terms of the sUAS units, the course has used several models similar to what is used in industry. In addition to sUAS units acquired by the academic program, the author has leveraged several sUAS units used on research projects for use in the course. This may not be the case in other academic programs and would require investment from the program to provide adequate sUAS units. In order to safely use sUAS in indoor environments, the use of a safety net enclosure is recommended. This present the challenge of space that can accommodate the indoor flight activity. The School of Building Construction's Flex Space room can accommodate the indoor enclosure, but it must be installed and removed after each use.

Regulation Challenges

In order to use sUAS technology in outdoor environments as part of construction courses, an FAA Certified Remote Pilot is required. The pilot could be the instructor, TA, or a guest lecturer for the course. It is also important to comply with FAA Part 107 regulations when the UAS is used outdoors. This requires coordination with appropriate University policies if they exist.

There are also opportunities that can benefit students when they are exposed to cutting edge technology that is gaining acceptance in the industry. Some of the identified opportunities are listed next.

- Obtaining FAA Remote Pilot Certificate can provide students with a credential that allows them to implement new technology in the industry in compliance with FAA regulations.
- Gaining hands-on knowledge and experience in the use of sUAS units used in industry would allow students to compliment the theoretical knowledge acquired.
- Gaining hands-on knowledge and experience in the planning and executions of data collection missions for photogrammetry applications would allow students to make productive use of sUAS technology in the construction environment beyond obtaining progress images of the jobsite.

Conclusions

This paper aimed at sharing the lessons learned in the use of sUAS in construction curriculum and make the information available to faculty who would consider using sUAS technology in the courses they teach. In general, the experience of the author in integrating sUAS into the BC6005 course has been positive. The challenges presented by such endeavor require the commitment of administrators in order to provide students with the tools needed. In addition, faculty is required to comply with FAA regulations for operation as well as for certification to be able to legally use sUAS in outdoor environments. Using the technology outdoors was found to be very beneficial to students as it provides a realistic experience of using the technology for real world applications. A total of 97 students have taken the BC6005 course since it was first offered in the Fall of 2016. The experience of students has been positive and many have been able to obtain their FAA Remote Pilot Certificate. This sets them apart in the job market and gives them skills that they can use in their careers in the construction industry.

The experience gained using sUAS in the classroom has also sparked questions that could be investigated further. For example, are there other applications of sUAS in the construction environment that could leverage the capabilities of sUAS technology beyond the use of the images obtained. Also, the impact of student sUAS experience on employment opportunities is not widely known. This raises the question of what benefits does the knowledge gain on sUAS technology has for students beyond the classroom.

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