

Important Considerations for Implementing a Drone-based Activity within a Construction Surveying Course

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The use of small Unmanned Aircraft Systems (sUAS), often referred to as drones, is changing construction and specifically construction surveying. The goal of this paper is to describe the lessons learned during the instructional design and development of a construction surveying activity at a large, tier-one, south-central university in the United States. This includes the rules and regulations, the hardware and software, the safety and insurance and the 3D mapping technologies that allow for precise measurements. This paper will contribute to construction education by identifying considerations and discussing the current challenges that will be faced by instructors as they move to embrace drone technologies within their construction curriculum.

Key Words: Construction Undergraduate Education, Construction Education Research, Construction Surveying, small Unmanned Aircraft System, Drone

Rational

The construction industry often evolves at a slow pace, but with respect to small Unmanned Aircraft System (sUAS) or drones, it has advanced at a rapid rate in response to the need for greater efficiency in every aspect of the business model. An 'unmanned aircraft' is an aircraft that operated without the possibility of direct human intervention and an 'unmanned aircraft system' is the aircraft and the associated elements that are required for a pilot to safely and efficiently operate the aircraft in national airspace (49 U.S.C. 40101, §332, 2012). The term sUAS refers to an aircraft weighing less than 55 pounds.

The manifestation of drones means significant changes for traditional construction project development, monitoring, control and cost. Drone construction and surveying technology will continue to innovate and grow while offering a lasting cost savings effect since its beginnings in World War II (Fahlstrom & Gleason, 2012). According to DroneDeploy (2018), construction drone use has increased 239% in the last year as compared to 198% in mining, 172% in agriculture, 171% surveying, and for real estate 118%. Their cloud based software has process data from more than 400,000 job sites and includes over 100,000,000 images. Within this image inventory, construction ranks second and surveying ranks third. DroneDeploy further identifies the primary uses of drones, by order of magnitude, are progress tracking and communication, preconstruction and site planning, quality control and assurance, the bid process and finally, job site risk mitigation. The Federal Aviation Administration (FAA) has registered over 110,000 drones in 2017 which represented a 2.5% increase over 2016 and a 110% change over 2015. It is estimated that more than 600,000 drones will be registered by 2022 (Canis, 2015).

Within 2018, the Occupational Safety and Health Administration (OSHA) began using drones to collect evidence while inspecting certain workplace settings with the expressed permission of the employer, such as, areas that were inaccessible or that were a safety risk to the inspector. In addition, drone use was approved for technical assistance in emergencies, during compliance, and training activities (Galassi, 2018). Recently, Hagen (2018) offered Beck Group's perspective of the five things contractors needed to know about sUAS and the impact upon their company. First, they have been around for a while, 2) there are regulations you need to know, 3) they are both safe and smart, 4) they provide immediate value, and 5) they are here to stay. Hagen provided the following descriptive counts that indicate the significance of aerial operations within the Beck Group since 2014 (see Table 1).

Table 1

BECK Aerial Operations

Count	Operation	Count	Operation
4	States flown in	**75+**	Projects with captured drone data
4	Countries flown in	**10,000**	Acres of sites mapped
10	Part 107 certified pilots	**5,000**	Hours of recorded flight time
12	Units in company fleet	**125,000**	Media files captured and stored

(Descriptive note. Adapted from Hagen, 2018)

The drone industry and its supporting software technologies are in their infancy, but are poised to grow exponentially. The construction companies that are taking advantage of these technologies are the project innovators, the initiators, the movers and shakers, because they realize the huge economic upside to employing these tools. As such, they also have a vested interest in seeing that colleges and universities provide classroom exposure to the use of drones and the technologies that will change their bottom line in the near future and over time. The future is here and we, in academia, must embrace it to be responsive to our industry's need. The specific curricular context or area of interest of this paper is construction surveying. The drone enhanced tools that have the most significant effect within surveying would be site measurement and mapping. Therefore, this paper describes the important issues a faculty member must consider while implementing this technology into their curriculum with specific interest in construction surveying.

Construction Surveying

Construction surveying is the spatial science and technology of determining the location and three-dimensional characteristics of the natural and built environment on the surface of the earth. Surveying is used in measuring and computing areas and volumes; vertical, horizontal, sloped distances and angles; grades and elevations in the description of land, buildings, roads and other structures. It aids in the construction processes of project design, quantification, layout, and structural control, and as-built archival (Williamson, 2017). The junior level surveying laboratory course has between 120 and 140 student each semester and these students are divided into 40 to 45 three person survey crews. The laboratory has one hour of lecture followed by four laboratory contact hours. All instructional materials are provided online through a course website and an online video textbook. In the progression of a week, students conduct the laboratory assigned for completion in that week and study the materials required for the laboratory that will be assigned the following week. The lecture is held on the first day of the week and responds to any questions that a student might have from the previous week's study and the current week's laboratory. The first two-hour laboratory period is dedicated to making field measurements and the second two-hour laboratory is to make application of those field measurements.

In the past there were nine activities conducted during the semester. A tenth laboratory, a 4D visualization and measurement activity, has been added to accommodate using a drone as a surveying and measurement tool. In an interpretation of the federal certification rules, a review of the course curriculum, and a review of the activity design, the FAA allowed the student flights of the drone to be considered as recreational, in that, the drone usage was "incidental" to the content of the course (PLH, personal communication, UAS Safety and Integration Division AUS-400, 8/1/2018). The first two-hours of the drone 4D laboratory will be the flight and data collection. The second two-hour laboratory will be using the mapping technologies to make photogrammetry measurements of distance, area, and volumes. The following will identify the requirements and challenges of designing the drone instruction and will provide a description of the equipment and software used in the drone activity's laboratory periods.

The students will be able to:

- Pass a test over federal, state, local and university rules and regulations,
- read and understand the drone safety plan,
- design and plan their flight,
- purchase insurance for their flight,
- execute their flight plan and collect image data,

- use photogrammic software to measure site distances, areas, and volumes, and
- create a topographic mosaic

The flight portion of the laboratory took place on the System's RELLIS campus which is an old airfield eleven miles from the main campus. There is a university bus route that runs between campuses every 15 minutes. Students took a bus from the main campus to the RELLIS campus and the department rented a 15 person van to take them from the bus stop to the flight area which was beyond the research security fencing (see Figures 1 & 2). With the drone flight being only eight minutes of a two hour laboratory period, students had little to no conflict of class schedules, in that, they could arrive late and leave early.

Figure 1: RELLIS campus.


Figure 2: Laboratory flight area.

Rules and Regulations

The first and foremost question concerned whether or not the students, teaching assistants and faculty member needed to be certified or could they operate the drone as non-certified recreational pilots. The FAA has authority over the airspace of the United States. As early as 2007 the FAA had argued that drones are indeed aircraft because of the intended use for flight (72 Fed. Reg. 6689, 2007). However, others had argued against this definition in the attempt to protect hobbyist and recreational pilots. In 2012, the Federal Aviation Administration Modernization and Reform Act (the Act) was passed requiring the development of a plan to integrate civilian unmanned aircraft systems into the national airspace. The FAA has issued several interpretations on UASs in order to provide clarity within the Act. Significantly there is the distinction between recreational and commercial use giving some measure of protection from stringent government control and intrusion of government into recreational flying. The commercial distinction implies that the operator is profiting from the flight or enhancing their business interest and is required to hold a UAS Remote Pilot Certificate.

This distinction is extremely important if an instructor wishes to have a student operate a sUAS within a course activity without having to require the student to be UAS certified. Section 336 of the Act defines a model aircraft as being flown for hobby or recreational use, operated in accordance with a community-based set of safety guidelines, limited to not more than 55 pounds, operated in a manner that gives way to manned aircraft and if flown within 5 miles of an airport then traffic control is notified prior to flight. If all of these conditions are met the FAA was prohibited from promulgating any rule or regulation regarding model aircraft. In addition, the FAA issued a memorandum extending this distinction into public education. Any student at an accredited education institution may conduct sUAS operations in accordance with Section 336 as long as the student is not compensated or any compensation is not related directly or incidentally to the sUAS operation (Lawrence, 2016).

Under this memorandum a faculty member or teaching assistant may not operate a sUAS under Section 336 as a part of their professional teaching or research duties for which they receive compensation. However, if an instructor that uses a sUAS as a component that is incidental to the course content then the FAA found that any de minimis participation does not rise above the hobby or recreational construct. In layman's terms, if it was a drone course the instructor could not participate under Section 336. But as with the course content being surveying and the drone activity being only one of ten activities both the faculty member, teaching assistant, and student may operate under Section 336. This includes any curriculum development activities required of the activity (PLH, personal communication, UAS Safety and Integration Division AUS-400, 8/1/2018).

As of October 5, 2018, Section 336 of the FAA Modernization and Reform Act of 2012 was repealed. At this time the FAA is evaluating the impact this law will have upon the sUAS rules and regulations. For the current and foreseeable future the public is directed to continue to follow all current policies and guidance with respect to the use of drones (GH, personal communication, UAS Safety and Integration Division AUS-400, 10/19/2018).

Within state law, educational UAS use is generally well defined and is given great latitude. The intent within most state laws emphasize protection of the individual's image and property privacy while establishing penalties for any violation of the law. It is important for citizens to have a basic knowledge of state statutes to be responsible sUAS operators. sUAS operators should take care to review the statutes and understand that there are a number of situations under which drones may capture or not capture images legally. Finally, another level of rules and regulations is at the college and university level. These rules are comprised more of property risk and security guidelines in that it is not a legal jurisdiction. Additionally, the institution will likely establish a supervising authority to evaluate and approve all UAS activity on its property. It is strongly advised that the faculty member who is teaching with a sUAS become an active member of this governing body.

In the weeks prior to the week of the drone activity, students were required to study regulatory materials from the federal, state, and university system levels. The readings were provided online and were scored dynamically by time on task. During the lecture periods the students were quizzed upon these readings and the quiz scores become a portion of their grade in the course. The following are those readings; 1) FAA Part 107 UAS Summary, 2) FAA Interpretation of Educational Use of UAS, 3) State Government Code 423, 4) University System UAS Regulations, and 5) University System UAS Definitions.

Safety Plan and Insurance

To meet the university system's rules a safety plan had to be developed. This plan included; 1) Scope, 2) Responsibilities, 3) sUAS Operations, 4) Flight Crew and Observer Requirements, 5) In-flight Emergency Plan (IFEP), 6) Downed Aircraft Recovery Plan (DARP), 7) Accident Reporting, and 8) Logs and Records. Internal to the IFEP are sections on, 1) Loss of Power, 2) Loss of Aircraft Control, 3) Aircraft Fly-Away, 4) Airspace Encroachment, Fixed Object Strikes, and 5) Interference with Flight Crew.

The university system requires that the Pilot in Control (PIC) have a $1M liability policy with the university system and the university as additional insured. Liability includes personal injury, invasion of privacy claims, damage to public or private property, and medical expenses. Most insurance companies would only insure commercial 107 certificate holders. Verifly.com would insure recreational pilots and the cost was to be $10 per student pilot. Interestingly, the flight was to take place on an old air field. The FAA did not have it as an active airfield, but the insurance companies did. This increased the cost to $25 or $3,700 total. The construction department's decision was to not add any additional student costs for the activity. After negotiating with Verifly, the systems UAS Supervisory Committee was able to establish a new policy type that provided a policy to the PIC at $40 per 8-hour day. The total cost then became $320, which was paid out of the Differential Tuition account. The PICs in this activity were the instructor and teaching assistants and the students fell under the PIC's coverage. We were also able to get the airfield declassified as non-active.

Hardware

The China-based DJI is by far the leader in drone manufacturing. DroneDeploy (2018) lists the DJI Phantom 4 Pro as the most popular mapping drone (Figure 3). That is followed by the DJI Mavic Pro at 27% which is a foldable model. The Phantom 4 is the third most popular drone and is used by 16% of all pilots. There is a new Phantom V Pro+ that has its own mobile device, but no additional software can be downloaded to this device. This limits its capability to be a scalable control system. One which would optimally afford the user with the ability to use unique software applications specific to their mission. After review of several options, the iPad mini 4 32gb was chosen as the remote control's mobile device over students using the mobile phones. A normal sized iPad or Android are too large to be held by the remote control holding device. Therefore, it was determined to purchase four Phantom 4 Pro V2.0 drones coupled with iPad 4 mini mobile devices.

Prior to the flight laboratory students were required to read the Phantom 4 Pro operating manuals and view these DJI videos; 1) Unboxing, inside the box, 2) How to fly safe, flight advice, 3) Pre-flight checklist, and 4) Orientation and basic flight maneuvers. On a laboratory section's flight day the section's eight crews are divided into two four-crew groups. The flight timing requires four concurrent drone flights, each separated by 20 foot Above Ground Level (AGL) flight levels. Each group of four crews had one hour to complete their drone flights (see Figure 4).

Figure 3: Phantom 4 Pro V2.0

Figure 4: Crew Flights

Software

The Phantom 4 Pro is controlled through the DJI Go 4 interface software. This application allows for the user to adjust the drone and camera settings, navigate and view the flight, and to edit, transmit and store images and videos. However, the concern within the instructional design of the laboratory was that the student have no prior drone flight experience and would be unable to successfully operate a manual-flight mission. It was determined that software must be included that offered automated-flight setups in addition to aerial imaging and mapping applications.

Four software application were investigated, 1) DroneDeploy, 2) Litchi, 3) OpenDroneMap, and 4) Pix4D. Neither DroneDeploy nor Pix4D software companies would offer a meaningful educational discount and were not interested in negotiating a financial solution. The cost of Litchi is minimal and the OpenDroneMap is free. Therefore, the main concern became the cost for qualifying software. The open source software, OpenDroneMap, was too difficult to install and did not offer an automated-flight solution. Litchi did not have imaging and mapping applications. Therefore, those two did not qualify for acceptance. DroneDeploy offered a 14 day free trial version, but within the trial version the imaging and mapping applications necessary for the activity were unavailable. That left us with the Pix4D software applications. Pix4D has a free 14 day unlimited trial version of their desktop imaging and mapping software, Pix4Dmapper, and a free automated-flight application for the mobile device, Pix4Dcapture. One copy, two seats, of the Pix4D mapping software was purchased for the instructor and TA desktops.

Two weeks prior to the flight, students were required to watch the Pix4D capture application video. One week prior, students submitted an automated flight plan using the Pix4D application on the iPad that was paired with the drone they would be flying (Figure 5 & 6). Additionally, the students watched these Pix4D videos; 1) 3D Mapping, How it works, 2) Getting started with your first project, 3) Georeferencing, and 4) Measurements.

Figure 5: DJI Remote with Pix4D.

Figure 6: Pix4D Flight Plan.

Measurement Activity

A major concern within the instructional design was computer processing time. A 10 acre mission took 17 hours to render on a desktop with 16GB of RAM. Students likely do not have this level of computing capability, so the flight box had to be modified to 2.5 acres where rendering would only take 1.5 to 2.5 hours (Figures 7 & 8).

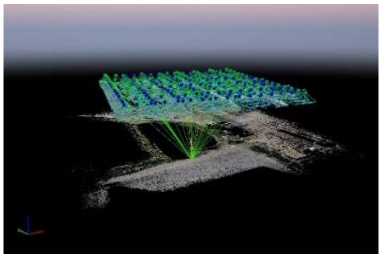

Figure 7: Camera and Ray Cloud.

Figure 8: Point Cloud with Triangle Meshes.

The selected project area has many characteristics that a construction student would be interested in measuring. The following are examples of the graded product of the activity. Figure 9 is measuring the volume of the settlement dam from its top to the waterline. Figure 10 is an area calculation for the roof of the water erosion research lab and Figure 11 is a linear measurement of the height of the lab building. Finally, Figure 12 is a heat map of the area topography and Figure 13 is a contour map of the area topography. All drone flights, map processing and measurements were intended to only require 4 hours of laboratory time.

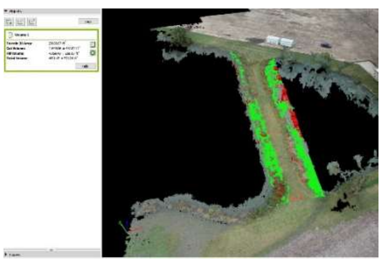

Figure 9: Volume Calculation.

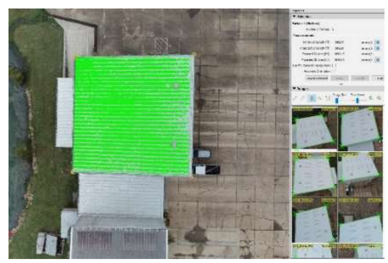

Figure 10: Area Calculation.

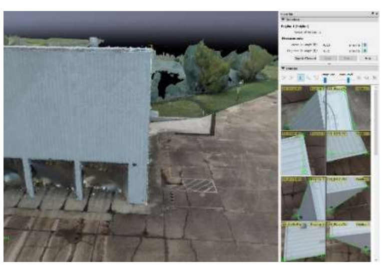

Figure 11: Linear Measurements.

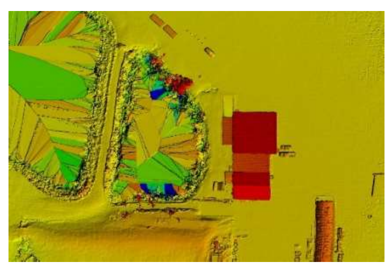

Figure 12: Topography Heat Map.

Figure 13: Topography Contour Lines.

Conclusion

In conclusion, the initial development and design of the course was easily completed. However, the University System's approval process started in April of 2018 and was not completed until November 2018. Four days prior to the activity's laboratory period. This course offering was the first time, System wide (eleven universities), that a drone was utilized for learning within a classroom setting. The System had rules and guidelines in place for research involving drones, but was totally unprepared for a drone's use in education. The most difficult portion of the approval process was the lack of a certified pilot, even with FAA's approval as a recreational event. It would be most advisable for the instructor to be Part 107 certified, but realistically finding or certifying TAs prior to the activity cannot be expected. The future of the activity is still unknown, in that, the FAA still has yet to introduce their new rules and regulations on educational flights. However, it was a practical and very useful activity for the students. This will enhance their marketability to potential employers. The construction industry has expressed excitement about the activity and they are watching developments closely. Many wanting to be a teaching participant. In the long run, the students will come away with a greater breath of knowledge that includes flying a drone with construction as the emphasis while discovering the cost and time savings that can be exploited given the simplicity of photogrammetry mapping technology.

References

Canis, B. (2015). *Unmanned aircraft systems (UAS): Commercial outlook for a new industry* (CRS Report No. R44192). Retrieved from Congressional Research Service website: https://fas.org/sgp/crs/misc/R44192.pdf

DroneDeploy. (2018). *Commercial drone industry trends*. San Francisco, US: Winn, Mike

Fahlstrom, P. G. and Gleason, T. J. (2012). *Introduction to UAV systems* (4th ed.). Hoboken, NJ: John Wiley & Sons

Federal Aviation Administration Modernization and Reform Act of 2012, §332, 49 U.S.C. 40101 (2012).

Galassi, T., Occupational Safety and Health Administration (2018). *OSHA's use of unmanned aircraft systems in inspections*. Washington, D.C.: OSHA.

Hagen, G. (2018). *5 things you need to know about drones in construction*. PowerPoint presented at the TEXO Educators Conference, Dallas, TX.

Lawrence, E., Federal Aviation Administration (2016). *Educational use of unmanned aircraft systems (UAS)*. Washington, D.C.: FAA.

Unmanned aircraft operations in the national airspace system, 72 Fed. Reg. 6689 (2007).

Texas Government Code Title 4. Executive Branch Subtitle B. Law Enforcement and Public Protection Chapter 423. Use of Unmanned Aircraft (2013)

Williamson III, K. C. (2017, April). A comparison between mini-mester and full semester achievement in a construction surveying course. In T. Sulbaran & C. Sterling (Eds.), *Proceedings of the Associated Schools of Construction*, 53rd Annual International Conference, Seattle, Washington, 5-7 April. Seattle, WA: The University of Washington.