Chapter 11: Legal and Safety Requirements

# Mini Abstract

1-2 paragraph chapter description. Should generally go over contents, expectations, and results. Abstracts are usually the last part of something to be written out since it is a summary of the article, but we can use them here to help flesh out our ideas a bit for how to structure. Final abstract should be overhauled at the end of the chapter though, the chapter dictates the abstract, not the other way around.

A number of legal and safety considerations were made for the system. STR 9.0.0, Legal Compliance, required legal actions that were investigated but could not be verified, since the drone could not be registered with the Federal Aviation Administration(FAA). However, several different laws and regulations were studied and confirmed that our drone would follow the requirements. A number of safety precautions were also taken to ensure the safe flying of the drone and the safety of those around it, including collision, electrical, and helium safety to fulfill STR 7.0.0, Drone Saftey. These safety implementations all fulfill one or more requirements of our system, but most could not be verified due to no complete flight tests being done.

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# Chapter Outline

Develop the chapter outline here. Should become very detailed and broken down to paragraph level. Remember, if we invest time and effort into making a detailed outline, the actual writing will be far easier since we understand the flow and structure before we lay out the details. Before even writing a subsection, take the time to outline that subsection in the chapter outline. A lot of writing is in the layout. Remember to update this chapter in the Master Outline file so we can all keep track of the full outline of the report, its large so breaking it up this way should help everyone keep track of each other's ideas and work.

## Section 1 Legal Requirements

### Subsection 1 FAA Compliance

* Explain FAA procedures:
  + Part 107, drones must be below 30kg in (Weight or mass)
  + Statutory provision PL 115-254, Section 350, use of drones at institutions of higher education
  + Registering drone with FAA with FAADroneZone account

### Subsection 2 University Permittance

* Explain how permit would be acquired to fly drone on campus
  + Say university automatically gives insurance to drone when flight permits are acquired

### Subsection 3 Westside Research Park

* Explain contact with professor Mircea Teodorescu and the precautions that had to be followed to test in the indoor flight room.

## Section 2 Safety Requirements

### Subsection 1 Lift Bag Safety

* Mention safety precautions taken to avoid sharp edges of outside drone parts

### Subsection 2 Electrical Safety

* Include mechanical switch on the drone to turn it off by separating power source from loads
* Explain how voltage alarm and the shutoff voltage were decided

### Subsection 3 Handling Helium

* Explain method for transporting the helium necessary to fill up the balloon
* How to inflate and deflate the balloon with helium correctly
* How to avoid and/or check for helium leaks using internal pressure sensor

### Subsection 4 Noise Test

* Explain how noise test was conducted and how the results of the noise test were interpreted
  + Noise test will need to be tested outside to confirm that it can stay below 65 decibels as in the technical requirements.

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# Chapter 11

A number of legal and safety considerations were made for the system. STR 9.0.0, Legal Compliance, required legal actions that were investigated but could not be verified, since the drone could not be registered with the Federal Aviation Administration(FAA). However, several different laws and regulations were studied and confirmed that our drone would follow the requirements. A number of safety precautions were also taken to ensure the safe flying of the drone and the safety of those around it, including collision, electrical, and helium safety to fulfill STR 7.0.0. These safety implementations all fulfill one or more requirements of our system, but most could not be verified due to no complete flight tests being done.

## 11.1 Legal Requirements

Since the drone was unable to be completed, FAA registration could not be undertaken since it requires a fully functioning drone. Also, a number of steps would have had to be taken to fly the drone outside on campus, but since we were able to get permission from Professor Mircea Teodorescu and the West Side Research Park faculty to use their indoor flight room for a controlled flight test, these steps were able to be done before testing in an uncontrolled environment.

11.1.1 FAA Compliance

To meet requirement STR9.1.0, FAA Compliance there are two ways to register drones with the FAA, which are the Part 107 and the Exception for Recreational Flyers processes. Our drone would always weigh less than the 55 pound limit when flying under Part 107[57]. However, even though the Exception for Recreational Fliers specifies that it is only allowed for flying for fun, we may operate under the Exception for Recreational Flyers since we will be using our drone for educational and research purposes under an institution of higher education. This is confirmed with an FAA statutory provision[58]. This registration would cost $5 and would expire after 3 years.

Additional rules that need to be followed for flying the drone under the Part 107 and Exception for Recreational Fliers would have included marking the drone with the registration number assigned. Other rules to be followed during flight include ensuring a line of sight to the drone is always available, making way for any manned aircraft that the drone may interfere with, flying below 400 feet in both controlled and uncontrolled airspace, and not interfering with any emergency response vehicles or personnel. Since we plan to fly our drone under these conditions, we can fulfill SRT 9.1.2, Statutory Provision and SRT 9.1.0, Part 107 Compliance, but cannot verify them until an outdoor flight test is done.

To register under the Exception for Recreational Flyers, Title 14 Code of Federal Regulations Part 47 needs to be followed[59]. Title 14 requires submitting an aircraft registration application AC form 8050-1 or through registering at the FAA Drone Zone website[60]. Also a notarized affidavit showing the full legal name of builder, model designation, serial number, number of engines, type of engines, max takeoff weight, class, and evidence of purchase must be shown. Since our drone was built by the team, it needs to be stated that we cannot provide a bill of sale document or most of the information on the affidavit, requiring another AC form 8050-88, Affidavit of Ownership for Amateur-Built and Other Non-Type Certificated Aircraft, that must be completed instead of giving model designation and serial number[61]. Form 8050-88 will require us to give specific motor information, the number of engines, and the specific class of aircraft, which is a small unmanned aircraft system. The drone must also not be registered in another country. After providing the following information and receiving the certificate of registration in the mail after an unspecified amount of time, the certificate must be carried at all times when flying the drone[60].

This registration process, broken down, would fulfill STR 9.1.2, FAA Drone Registration, but it could not be completed due to an incomplete drone. This means STR 9.1.0, FAA Compliance was not verified but could be fulfilled with the steps given to register the drone and fulfilled through a successful outdoor flight test once all the legal steps are done.

11.1.2 University Permittance

While flying a drone on campus, insurance and liability under the Unmanned Aircraft System Liability Policy may be provided by the university up to $25,000 if the drone is sanctioned by the university, if a line of sight is always kept, if the drone stays below 400ft, and if the aircraft weighs less than 55 pounds at the time of takeoff[62]. Since our drone is only meant to be 1 meter above the ground, weighs less than 55 pounds and will be flown within sight at all times, our drone follows all of these except for getting the drone sanctioned by the university.

In order to be sanctioned by the university, the drone must be registered with the FAA and the user must have a small Unmanned Aircraft System License, as stated in section 7.1.1. The drone must also be given permission to fly through contacting the university’s Unmanned Aircraft System or through the UC Drones Web app. Once permission is granted from the app through a flight request form, which would require registration with the FAA, the drone would be available to fly for the requested flight times inputted. Since our drone cannot be registered with the FAA yet, an outdoor flight test could not be performed.

11.1.3 Helium Handling

Since our drone cannot be registered with the FAA, it cannot be flown outside on campus. Before testing outside, we were able to get access to an indoor flight room at Westside Research Park. We got in contact with Professor Mircea Teodorescu, who was able to give us access to use the indoor flight room at Westside Research Park. Only one of our team members, Dylan Harootunian, could get direct access to the lab, and was able to bring in one other unregistered team member as long as they were personally observed by either Professor Mircea himself or his graduate student Gordon Keller.

We first had to get helium to test our system, so we made contact with Praxair in Watsonville to get a T-size 4.8 helium tank with a purity rating of 99.998%. The helium did not have to be industrially pure, as this kind of helium is commonly used in commercial balloons and the effect of further purity would be miniscule to the buoyancy of the helium since the purity grade is already over 99.99%. This tank was transported using a truck while also ensuring it was strapped down for transport to West Side Research Park. Laura Ciravolo, the facility manager, and Ben Coffey, the facility coordinator, were then contacted and they confirmed that the helium tank could be stored at an adjacent room from the flight testing room for storage as long as it was strapped down to a secure metal fastening with two sets of chains and locks. For testing, the tank was then moved into the flight room, where a nozzle was connected to an vinyl airtight tube in order to fill the lift bag with helium. While filling up the helium, someone always had to be holding the helium tank for safety while they released the helium into the balloon. The nozzle itself was secured using rubber bands around the lift bag entrance. The lift bag inside the drone envelope was then able to be filled for testing while inside a netted testing area for flight.

The measures here are proof of verification of STR 7.3.0, Helium Safety, since it was verified to be sufficient safety measures when preparing for the incomplete flight test with the drone. The flight test was unable to be completed due to errors handling the drone itself instead of the helium that was used.

## 11.2 Safety Requirements

Some additional safety requirements had to be followed in order to avoid complications during testing and later functions. Popping the balloon was an issue during initial inflation of the lift bag within the envelope that was caused by sharp edges of the 3D printed parts. The puncturing of the liftbag during a test flight could be potentially dangerous to those in the surrounding area as control of the system would not be able to be maintained.By adding a layer of bubble wrap to the inside of the 3D printed mounting plates the issue of puncturers caused by the parts was solved. Over-discharging the battery was to be avoided by including a voltage alarm that would give the user a loud alarm when any cell of the battery went below 3.2V, since damage occurs to the battery if below 3V per cell was reached. However, in future iterations of the drone, a remote battery monitoring process will be needed for long distance flights.Hearing damage to bystanders from exposure to over 85dB was verified to not be a concern through a noise level test of the drone with motors at full throttle. For more on the noise test see Chapter 9. STR 7.1.2, Propeller Safety was not met because propeller guards were not implemented with the system. This was due to an oversight when deciding on the motors needed and not finding a propeller guard that would fit in time for testing, resulting in not fulfilling STR 7.1.0, Collision Considerations. The rest of the safety requirements are described in the following subsections.

11.2.1 Lift Bag Safety

During various inflation tests of the lift bag inside the envelope, sharp edges of the 3D printed parts had to be softened to avoid popping the lift bag, as had happened previously. The inside of the envelope where the 3D parts were attached, such as the propulsion attachment, gondola mount, and ultrasonic mount, were lined with bubble wrap on the insides so the sharp edges would not pop the lift bag. Additionally hot glue was also used on the edges of the outsides of the servo shafts to help soften the edges. Once these measures were taken, the lift bag no longer popped during the inflation while inside of the envelope. The measures here are proof of fulfillment of STR 7.1.1, Body Design Safety, since the balloon was verified to not pop when these measures were taken for multiple inflation tests. However, this requirement was unable to be verified with regards to the safety of the user due to the flight test being incomplete.

11.2.2 Electrical Safety

To avoid the draining of the battery while the drone was not in use, a mechanical switch was decided to be implemented onto the drone. This switch was placed in series just before the battery ground. When the switch was on, the circuit was open and effectively turned everything off. When on, the system would run again, where the ESCs would drain approximately 40mA each while the motors were idle. During testing, it was suggested that there should have been a remote switch on our remote controller as well to ensure the motors can be turned off from a distance if they malfunctioned. In future iterations, the mechanical switch would be kept to avoid the 40mA constant drain from our ESCs, but a kill switch would also have to be programmed to our remote controller to turn off the RC receiver so the motors would be stopped without having to reach for the mechanical switch at the bottom of the drone.

Another precaution that was taken was avoiding the over-discharging of our battery. The LiPo battery cells used can range from 4.2V-3V, where 4.2V is max charge and 3V is minimum charge. However, discharging a battery below 3V on any cell can damage the battery[63]. 3.2V was chosen as the cutoff voltage of the battery due to the emergency landing feature our drone was designed to have, as well as the steep discharge curve once Lipo batteries reach that level[64]. The voltage alarm implemented will emit a loud alarm when it detects any cell below that 3.2V limit, which will signal the user to land the drone. In future iterations, the drone will need to be able to detect any of the cell voltages remotely by itself and be programmed to enter the auto landing sequence if the voltage of any cell falls below 3.2V.

The electrical safety here suggests that our drone has met STR 7.2.2, Electronic Safety, through the implementation of the manual kill switch and voltage battery alarm. STR 7.2.1, Protected Electronics, was fulfilled through using electrical tape and zip ties to ensure the motor wires were properly secured to the lift bag to make sure the propellers do not make contact with the wires. Therefore, the overarching STR 7.2.0, Electrical Safeguards, was fulfilled but was unable to be verified since a complete flight test could not be completed that would prove the electronic safety.

11.2.3 Noise Test

To ensure our drone met the noise requirements of 65 decibels or lower, it was tested in an indoor environment through walking around the drone at 5 feet away while holding a decibel meter on an Apple Watch. The experiment procedures are shown in section 9.3. This test resulted in a decibel level of about 76 decibels, which does not meet our requirement but is also below the 85 decibel limit that will cause hearing damage over time. This test must also be completed in an outdoor test environment, since the indoor testing environment can have an effect on the decibel count through constructive interference of sound waves. However, since we are unable to test our drone outside due to legal reasons, this test was not able to be completed in time. This means that STR 10.0.0, Noise Level, was verified to not be met since the indoor testing of the noise level was greater than the 65 decibel limit. This can also be verified again in an outdoor test when FAA registration and university permittance is acquired by measuring the decibels of noise 5ft from the drone, since the indoor testing may have resulted in constructive noise interference causing the noise level to be higher than it actually was.

## 11.3 Conclusion

All of the subsystem technical requirements fulfilled within STR 7.0.0, Drone Safety except for STR 7.1.2, Propeller Safety. There are additional actions to take to ensure the safety of the drone, such as a remote shutoff switch instead of a manual shutoff switch on the drone, in addition to the implementation of propeller guards. However, a majority of the safety considerations have been fulfilled. STR 9.0.0, Legal Compliance, was unable to be verified but a process for registering with the FAA was laid out and the rules to follow when the drone is being flown were defined and confirmed for use with our system, showing sufficient legal considerations were made even though the drone could not be registered with the FAA.

# Chapter Bibliography

We do have a full bibliography that should absolutely be updated with all content here. The point of the chapter bibliography is to help keep track of citations in the chapter since the numbering may change in the full bibliography with changes and additions. This way will isolate the sources in this section so you can cite here without having to worry about it, and can use a simple find and replace on your citations to update the new numbering when we combine everything in the final report.

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[63]“Lithium Polymer Charging/Discharging & Safety Information,” *MaxAmps.com*. [Online]. Available: https://www.maxamps.com/lipo-care.php. [Accessed: 04-Jun-2021].

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