Use of Unmanned Aircraft Systems (UASs) to monitor coastal hazard, design mitigation measures, and evaluate long term health of Louisiana coastline

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Research Abstract

Coastal property development, oil and water extraction, global climate change, coastal land subsidence, loss of barrier islands, and other natural and man-made factors have resulted in high rates of wetland loss, water quality degradation, decline in fisheries and reduced storm surge protection in coastal areas in Louisiana and throughout the world. Currently, the monitoring of coastal land loss and coastal features is performed by traditional surveying methods and manned aircraft flights, which are both time consuming and costly.

An unmanned aircraft system (UAS), commonly known as a drone, is an aircraft system without a pilot aboard. The flight of UASs may be controlled either autonomously by onboard computers or by the remote control of a pilot on the ground or in another vehicle. These autonomous, hand-launched aircraft systems can be equipped with an onboard global positioning system (GPS), inertial navigation system (INS), high resolution digital camera and computer.

For this research project, a sUAS was utilized for rapid acquisition of high-resolution aerial photographs and to collect geospatial data for multiple coastal projects in Louisiana. The aerial images collected were processed and analyzed to evaluate land erosion from storm events and performance evaluation of coastal features. The use of a small unmanned aircraft system (sUAS) can significantly reduce the time and cost to monitor and document coastal land loss and performance of coastal infrastructures in Louisiana.

This research report summarizes the benefits of using a remote controlled small UAS equipped with high resolution camera to successfully evaluate Louisiana coastal land loss and increase in land mass due to coastal restoration projects. The research report also summarizes the advantageous use of an UAS to monitor performance of coastal protection features (levees, floodwalls, pumping stations etc.) during and immediately after a storm and hurricane event.

Chapter 1: Introduction

Coastal property development, oil and water extraction, global climate change, coastal land subsidence, loss of barrier islands, and other natural and man-made factors have resulted in high rates of wetland loss, water quality degradation, decline in fisheries and reduced storm surge protection in coastal areas in Louisiana and throughout the world. The loss of marshland in Louisiana coastal zones has also exposed significant infrastructure to open water conditions and has degraded the habitat of nearby areas. Published data indicate that coastal Louisiana and the Mississippi river basin have an annual marsh land loss of about 16 square miles. Figure 1 shows the historical and projected land loss map in the southeast Louisiana deltaic plain.

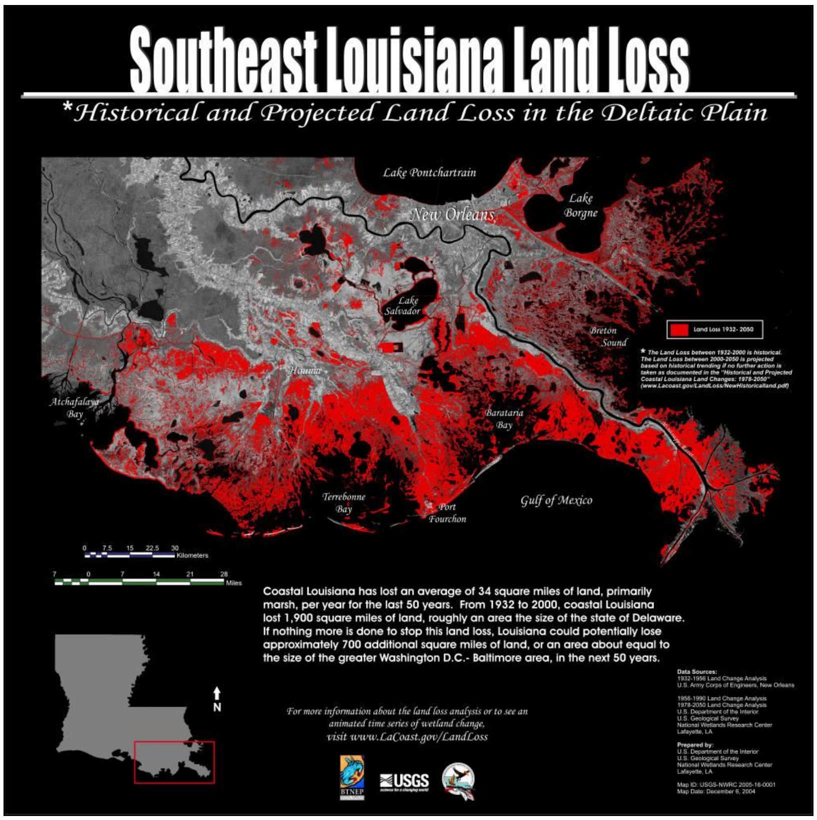

Figure 1: Southeast Louisiana land loss prediction
(source: USGS)

The Louisiana Coastal Protection and Restoration Authority (CPRA) and related governmental agencies, with assistance from multiple public organizations and private companies, are tasked with monitoring Louisiana coastal land loss and developing scientific and engineering solutions that will help reduce future land loss and protect the coastal environment from the damaging effects of tropical storms, hurricanes, and continued rainfall events. Currently, the monitoring of coastal land loss is performed by traditional survey methods and manned aircraft flights, which are both time consuming and costly. The use of a small unmanned aircraft system (sUAS) can significantly reduce the time and cost to monitor and document coastal land loss in Louisiana.


Figure 2: Marshland loss in southeast Louisiana (source: google images)

A major goal towards reestablishing a healthy coastal ecosystem is to rebuild the world's coastal wetlands with river diversion or sediment conveyance projects that will optimally manage and allocate sediments, minimally impact native flora and fauna, and positively affect the water quality. Restoring the marshes through deposition of dredged material from adjoining navigation channels and close by river bed and subsequent reestablishment of emergent wetland vegetation will help to protect the levees and storm protection systems from accumulated damage due to elevated water levels and storm surge forces as well as create a sustainable coastal environment to booster vital economic, social, and recreational opportunities for millions of people. Native or recently deposited in-situ material is mechanically or hydraulically dredged from its location below the mudline in a fresh, brackish, or saltwater environment and transported in pipelines and distributed in the open water areas for marsh re-nourishment. The 2017 Louisiana coastal master plan indicates several (a) coastal restoration (marsh creation, shoreline restoration), (b) coastal protection (levees, floodwalls, pump stations), and (c) large scale Mississippi river sediment diversion projects. Figure 2 shows the map indicating some of these projects that has been either completed, funded, or proposed.

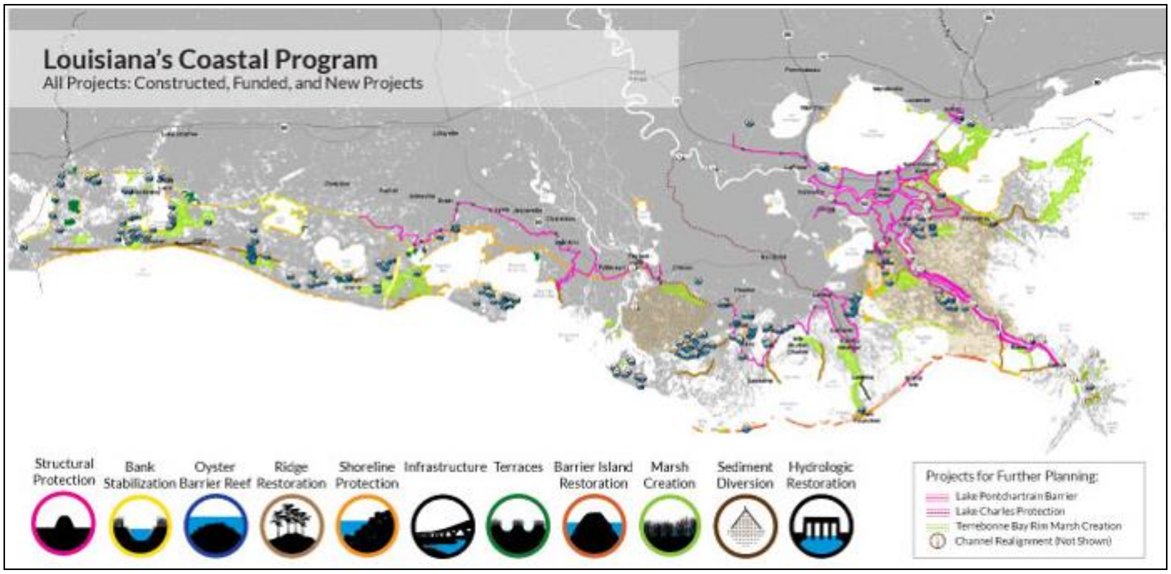

Figure 2: Projects related to Louisiana Coastal Master Plan
(source: CPRA)

In addition, since hurricane Katrina (August 2005), the United States Army Corps of Engineers (USACE) have planned, designed, and managed construction of multiple coastal protection systems (levees, floodwalls, pump stations etc.) as part of the greater New Orleans Hurricane and Storm Damage Risk Reduction System (HSDRRS). Figure 3 shows a map of all coastal protection projects in the vicinity of New Orleans.

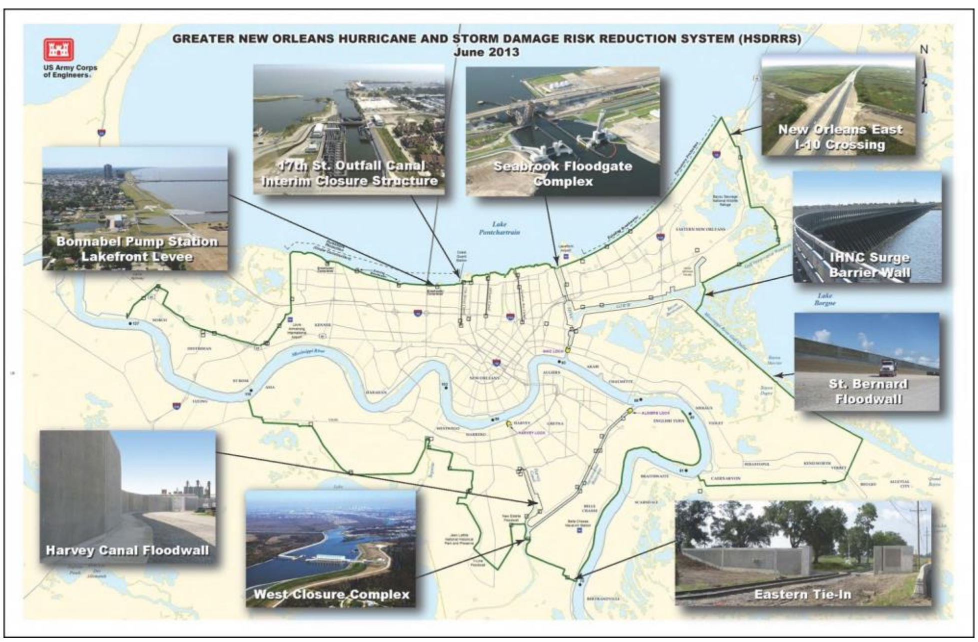

Figure 3: Greater New Orleans HSDRRS projects
(source: USACE, New Orleans district)

Construction and long term performance monitoring of these coastal protection and restoration systems will be of utmost importance to evaluate their effectiveness in preventing loss of life and infrastructure in south Louisiana. sUAS has not been widely used to evaluate and monitor coastal restoration and protection projects in Louisiana. This research project summarizes the benefits of using a remote controlled small UAS equipped with high resolution camera to successfully evaluate Louisiana coastal land loss and increase in land mass due to coastal restoration projects. The research project will also summarize the advantageous use of an UAS to monitor performance of coastal protection features (levees, floodwalls, pumping stations etc.) during and immediately after a storm and hurricane event.

Chapter 2: Literature Review

Originally UASs were developed for military reconnaissance and surveillance. In 1849 Austria sent unmanned, bomb-filled balloons to attack Venice. Unmanned aircraft system (UAS) innovations started in the early 1900s and originally focused on providing practice targets for training military personnel. The development of sUAS ontinued during World War I, when the Dayton-Wright Airplane Company invented a pilotless aerial torpedo that would explode at a preset time. It is believed that the U.S. Air Force, concerned about losing pilots over hostile territory, began planning for the use of unmanned aircraft around 1950s.

With the maturing and miniaturization of applicable technologies in the 1980s and 1990s, interest in sUASs grew within the higher echelons of the U.S. military, private organizations, and universities for different application other than during conflict. Unmanned vehicles have a distinct advantage over manned vehicles in operations considered to be "dull, dirty, and dangerous," and can perform long endurance missions, and operate in contaminated or high-risk areas all without risking aircrew (Carlson, 2001). For similar reasons, UASs can be better suited for the assessment and management of some disaster situations in which the terrain is inaccessible or dangerous (Adams, 2011).

Today, UASs have developed in a multitude of commercial and recreational applications, however, many scientists have found advantages in the use of UASs in their research. In a study performed by the University of Miami on the southeast coast of Florida it was determined that UASs provide a cost effective alternative to airborne Light Detection and Ranging (LiDAR) scans in tracking coastal erosion, especially before and after major storm events (Maguire, 2014). Another study of coastal change in Songjung Beach, Korea which utilized an UAS found there to be similar advantages. According to Yoo (2016), "neither 2-D shoreline nor profile mapping can fully capture the rapid coastal changes caused by natural processes" (p.1201), however, more accurate and repeated monitoring is made possible with the use of an UAS.

UASs is being used successfully in search and rescue, precision agriculture assessment, law and enforcement, TV and film production, engineering assessment, structural failure evaluation, and environmental investigations.

Types of sUAS

In general, there are two broad categories of small unmanned aircraft systems available today:(i) multi-rotor and (ii) fixed wing drones.

Figure 4 : X8+ Octocoptor manufactured by 3DR

A multi-rotor drone, as shown in Figure 4, comprises of several motors connected to a flight controller, electronic speed controller, and GPS. The drone is powered by on-board battery and the flight is controlled by a hand-held flight controller. The multi-rotor drones have the capability to take off and land from virtually anywhere and hover in space. Due to the weight of the drone, multi-rotor drones generally have flight time within 30 minutes. The drones has the capability to carry different payloads.

Figure 5 below shows a typical layout of the different components of a multi-rotor drone.

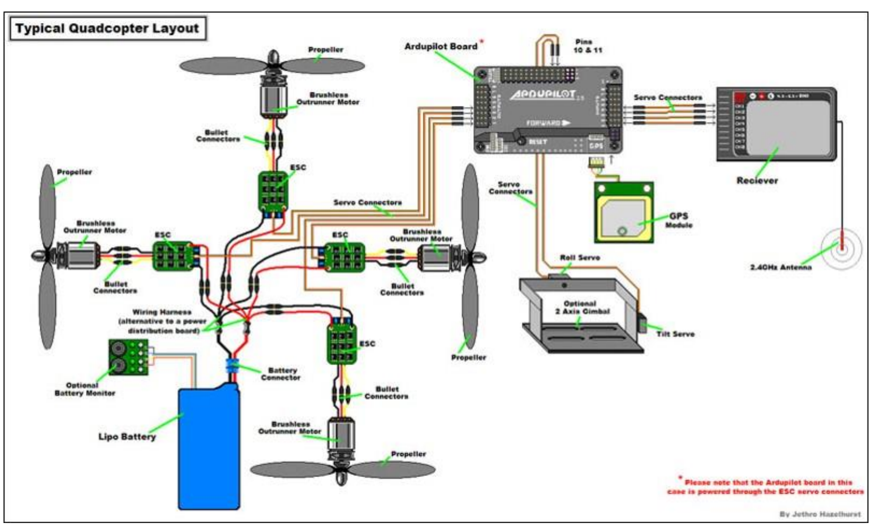

Figure 5: Typical Quadcoptor layout (source: google images). Should not be used for drone design, assembly or flight

A fixed wing UAS or drone, on the other hand, generally consists of one motor connected to a flight controller, electronic speed controller, and GPS. The drone is powered by on-board battery and the flight is controlled by a hand-held flight controller. Due to the light-weight construction of a fixed-wing drone, the flight time is significantly increased. However, a fixed-wing drone has to take off and land like a regular airplane. They also can't hover in one place in space. Figure 6 below shows a picture of a fixed-wing drone.

Figure 6: A photograph of a fixed-wing drone (source: google images)

Figure 7 below shows typical layout of the different components of a fixed-wing drone.

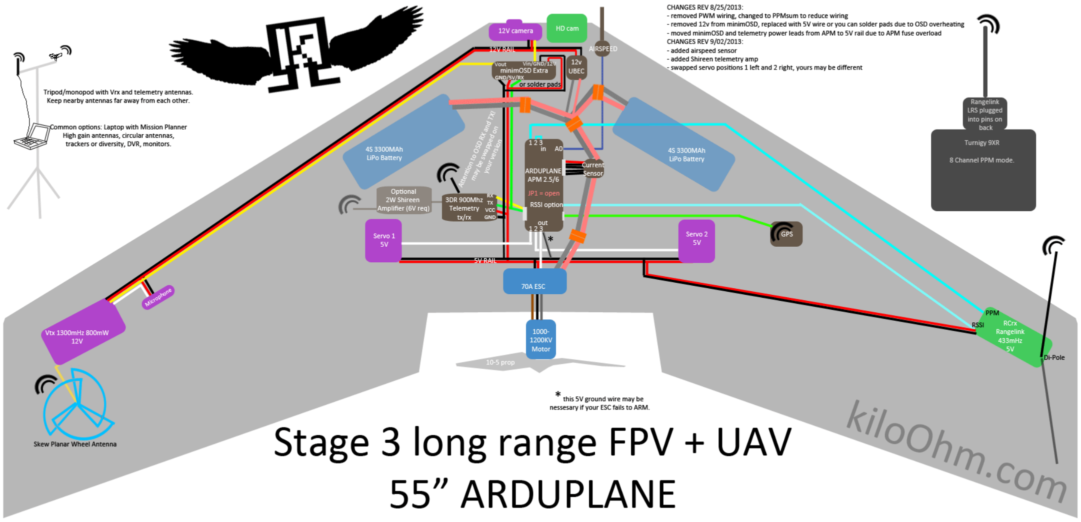

Figure7: Typical fixed wing drone layout (source: google images and kiloohm.com). Should not be used for drone design, assembly or flight

Planning a drone flight:

For this research, the flights of the sUAS (termed missions) were controlled by a software named Mission Planner. Figure 8 and 9 shows the layout of this software. The flight path can be specified in the software in relation to GPS coordinates and start-end points.

Figure 8: Flight path of a drone during a mission (source: google images)

Figure 9 shows the grid pattern of a drone flight along with the points where the on-board camera will take pictures (indicated in green bulbs).

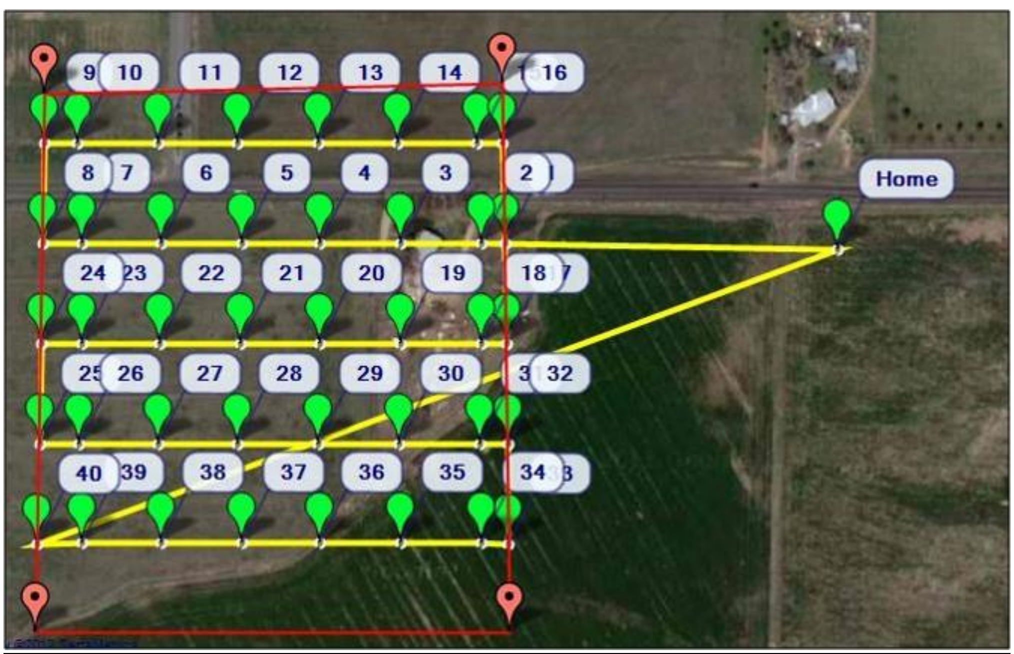

Figure 9: Mission planning for a drone flight (source: google images)

Image Processing:

For this research, a trial version of the Pix4D (https://pix4d.com/) software was used to process the aerial photographs and create the 2D/3D models. The following section briefly demonstrates the image processing steps. The following pictures have been borrowed from the Pix4D website.

Image processing software, like Pix4D, can be used to combine (stitch) the overlapping images together and create an aerial view of the project area. Figure 10 shows the layout of the Pix4D software and the information from a project.

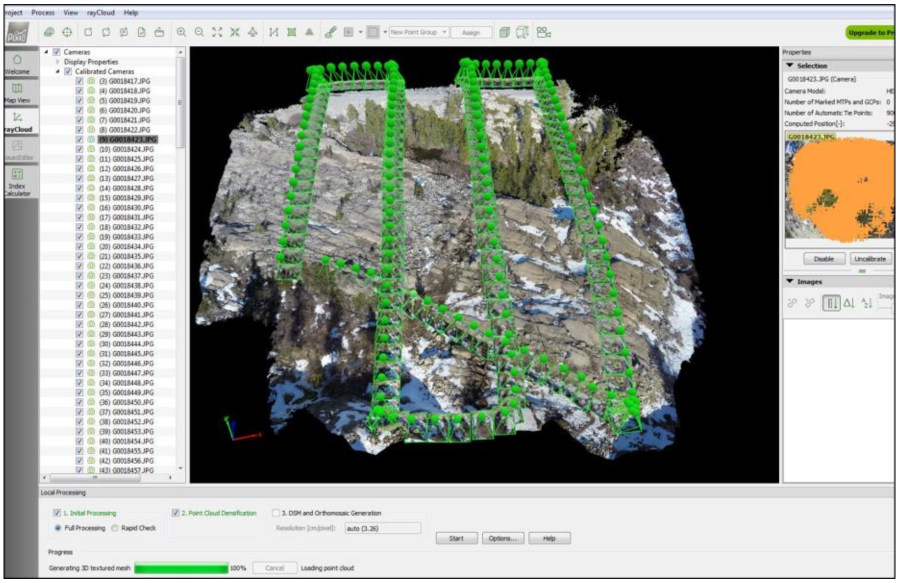

Figure 10: Layout of the Pix4D software (source: www.pix4d.com)

Figure 11 shows the aerial locations of the points where the camera took the different images which typically has an overlapping ratio between 70 and 80 percent.

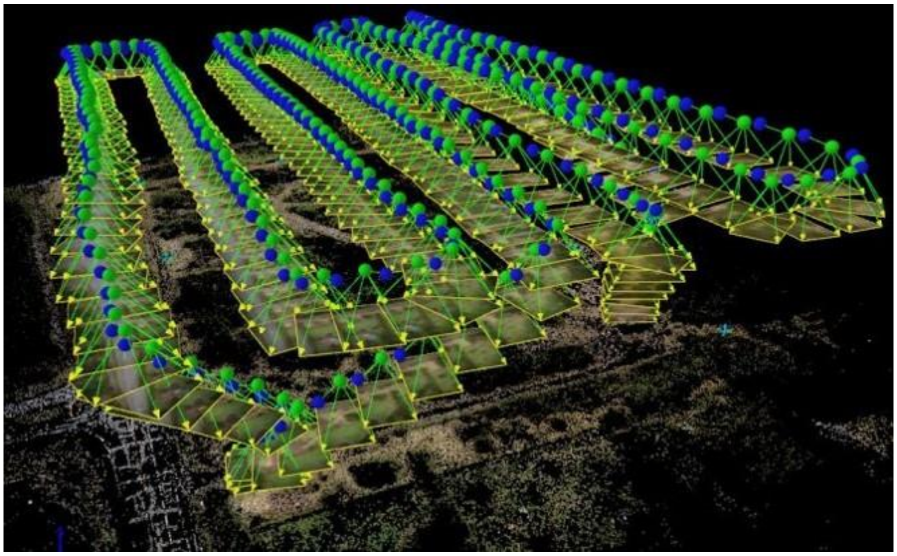

Figure 11: Image processing usingPix4D software (source: www.pix4d.com)

Figures 12 shows the process of combining several images to triangulate a point on the ground. Figure 13 shows the final 3 dimensional model of the project site.

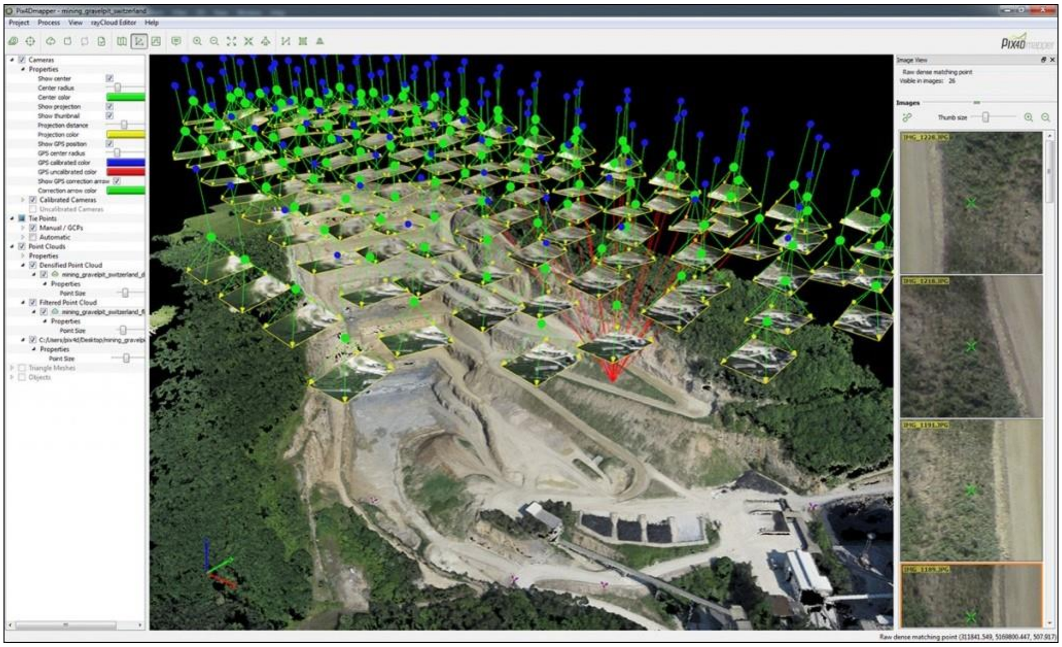

Figure 12: Use of several overlapping images to draw a point on the ground (source: www.pix4d.com)

Figure 13: Final three dimensional model for the project site (source: www.pix4d.com)

Currently there are other commercial softwares available to perform the image analyses and developing a 2 dimensional and 3 dimensional model using aerial photogrammetry.

Chapter 3: FAA Regulations related to sUAS

In recent years, the Federal Aviation Administration (FAA), in collaboration with multiple private and governmental agencies, has developed regulations and policies related to small Unmanned Aircraft Systems (sUAS). Part 107 of the Code of Federal Regulations (CFR) includes rules related to small aircraft registration and operating requirements. The latest rules and regulations can be found on FAA's webpage https://www.faa.gov/uas

According to FAA, Small unmanned aircraft means an unmanned aircraft weighing less than 55 pounds on takeoff, including everything that is on board or otherwise attached to the aircraft. Small unmanned aircraft system (small UAS) means a small unmanned aircraft and its associated elements (including communication links and the components that control the small unmanned aircraft) that are required for the safe and efficient operation of the small unmanned aircraft in the national airspace system. A summary of the Part 107 regulations is presented below:

Operational Limitations:

- Unmanned aircraft must weigh less than 55 lbs. (25 kg).
- Visual line-of-sight (VLOS) only; the unmanned aircraft must remain within VLOS of the remote pilot in command and the person manipulating the flight controls of the small UAS. Alternatively, the unmanned aircraft must remain within VLOS of the visual observer.
- At all times the small unmanned aircraft must remain close enough to the remote pilot in command and the person manipulating the flight controls of the small UAS for those people to be capable of seeing the aircraft with vision unaided by any device other than corrective lenses.
- Small unmanned aircraft may not operate over any persons not directly participating in the operation, not under a covered structure, and not inside a covered stationary vehicle.
- Daylight-only operations, or civil twilight (30 minutes before official sunrise to 30 minutes after official sunset, local time) with appropriate anti-collision lighting.
- Must yield right of way to other aircraft.
- May use visual observer (VO) but not required.
- First-person view camera cannot satisfy "see-and-avoid" requirement but can be used as long as requirement is satisfied in other ways.
- Maximum groundspeed of 100 mph (87 knots).
- Maximum altitude of 400 feet above ground level (AGL) or, if higher than 400 feet AGL, remain within 400 feet of a structure.
- Minimum weather visibility of 3 miles from control station.
- Operations in Class B, C, D and E airspace are allowed with the required ATC permission.
- Operations in Class G airspace are allowed without ATC permission.
- No person may act as a remote pilot in command or VO for more than one unmanned aircraft operation at one time.
- No operations from a moving aircraft.
- No operations from a moving vehicle unless the operation is over a sparsely populated area.
- No careless or reckless operations.
- No carriage of hazardous materials.
- Requires preflight inspection by the remote pilot in command.

- A person may not operate a small unmanned aircraft if he or she knows or has reason to know of any physical or mental condition that would interfere with the safe operation of a small UAS.
- Foreign-registered small unmanned aircraft are allowed to operate under part 107 if they satisfy the requirements of part 375.
- External load operations are allowed if the object being carried by the unmanned aircraft is securely attached and does not adversely affect the flight characteristics or controllability of the aircraft.
- Transportation of property for compensation or hire allowed provided that- o The aircraft, including its attached systems, payload and cargo weigh less than 55 pounds total; o The flight is conducted within visual line of sight and not from a moving vehicle or aircraft; and o The flight occurs wholly within the bounds of a State and does not involve transport between (1) Hawaii and another place in Hawaii through airspace outside Hawaii; (2) the District of Columbia and another place in the District of Columbia; or (3) a territory or possession of the United States and another place in the same territory or possession.
- Most of the restrictions discussed above are waivable if the applicant demonstrates that his or her operation can safely be conducted under the terms of a certificate of waiver.

Remote Pilot in Command Certification and Responsibilities:

- Establishes a remote pilot in command position.
- A person operating a small UAS must either hold a remote pilot airman certificate with a small UAS rating or be under the direct supervision of a person who does hold a remote pilot certificate (remote pilot in command).
- To qualify for a remote pilot certificate, a person must: o Demonstrate aeronautical knowledge by either: Passing an initial aeronautical knowledge test at an FAA-approved knowledge testing center; or Hold a part 61 pilot certificate other than student pilot, complete a flight review within the previous 24 months, and complete a small UAS online training course provided by the FAA. o Be vetted by the Transportation Security Administration. o Be at least 16 years old.
- Part 61 pilot certificate holders may obtain a temporary remote pilot certificate immediately upon submission of their application for a permanent certificate. Other applicants will obtain a temporary remote pilot certificate upon successful completion of TSA security vetting. The FAA anticipates that it will be able to issue a temporary remote pilot certificate within 10 business days after receiving a completed remote pilot certificate application.
- Until international standards are developed, foreign certificated UAS pilots will be required to obtain an FAA issued remote pilot certificate with a small UAS rating.

A remote pilot in command must:

- Make available to the FAA, upon request, the small UAS for inspection or testing, and any associated documents/records required to be kept under the rule.
- Report to the FAA within 10 days of any operation that results in at least serious injury, loss of consciousness, or property damage of at least $500.
- Conduct a preflight inspection, to include specific aircraft and control station systems checks, to ensure the small UAS is in a condition for safe operation.

- Ensure that the small unmanned aircraft complies with the existing registration requirements specified in § 91.203(a)(2). A remote pilot in command may deviate from the requirements of this rule in response to an in-flight emergency.

<u>Aircraft Requirements:</u>

- FAA airworthiness certification is not required. However, the remote pilot in command must conduct a preflight check of the small UAS to ensure that it is in a condition for safe operation.

<u>Model Aircraft:</u>

- Part 107 does not apply to model aircraft that satisfy all of the criteria specified in section 336 of Public Law 112-95.
- The rule codifies the FAA's enforcement authority in part 101 by prohibiting model aircraft operators from endangering the safety of the NAS.

Chapter 4: Objectives and Scope of Research

The main objectives of this research project are to evaluate and summarize the:

- use of a small unmanned aircraft system (sUAS) to conduct geospatial aerial photogrammetry of coastal Louisiana to evaluate and monitor coastal land loss,

- use of a sUAS to monitor performance of coastal protection features like levees, floodwalls, and pumping stations, and

- the beneficial use of sUAS in Louisiana coastal restoration and protection projects

Chapter 5: Research Benefits

The use and integration of small unmanned aircraft systems (sUASs) in Louisiana coastal protection and restoration projects will offer the following significant contributions to the advancement of coastal science and engineering in Louisiana:

- Improved outcomes: the use of high-resolution aerial video, imagery and geospatial data will allow for more accurate coastal land loss and land building estimates in coastal Louisiana. Specifically, area and volume of coastal sediment needs can be estimated using the data obtained from the field.

- Continued Monitoring: UAS can be used to continuously monitor and evaluate existing coastal protection and restoration features. This capability can be extended during a hurricane or tropical storm event

- Reduced time and cost: Use of UAS will significantly reduce the time and cost needed to monitor and evaluate coastal restoration and protection features. This will also make the design more efficient based on local knowledge and real time data acquisition.

- Improvement of Project Implementation: This applied engineering technology will enable design engineers to more accurately and efficiently determine the required marsh fill area volumes and monitor performance of coastal protection systems, thus reducing the design engineering task time and contractor risk.

Chapter 6: Research Methodology

A sUAS can be used effectively and economically to evaluate and monitor several Louisiana coastal restoration and protection projects and research activities. The following section lists some of the possible application of a sUAS.

1. To perform periodic topographic survey of the Mississippi river levees using aerial photogrammetry and/or aerial LIDAR mounted on a sUAS;
2. To monitor subsidence and seepage of federal and non-federal levees in Louisiana;
3. To monitor and evaluate long term performance of Louisiana coastal protection features like floodwalls, levees, sediment diversion structures, spillways, and dams;
4. To perform periodic survey of Louisiana coastland and evaluate acreages of land loss or land creation;
5. To monitor and evaluate long term performance of Louisiana marsh creation and restoration projects and observe long term ground subsidence and health of marsh vegetation;
6. To perform aerial survey after a natural disaster like flooding, storm, or hurricane event; and
7. To monitor and evaluate long term performance of Louisiana barrier island and observe beach erosion and subsidence;

The following methodology and procedures were used to complete this undergraduate research project:

1. The faculty advisor (Malay Ghose Hajra) is a FAA certificated remote pilot to fly the sUAS mission in the field.
2. Two different octocopters carrying high resolution digital cameras were utilized to collect the field data (aerial images and videos) from multiple sites in Southeast Louisiana
3. The sUAS mission (geo-referenced flight path) was controlled by softwares that either came with the sUAS or were available through third-party source.
4. An image processing software, Pix4D, was used to compile the geo-referenced aerial images together and create the 2-dimensional and/or 3-dimensional models.

Chapter 7: Results and Discussion

A small Unmanned Aircraft System (sUAS) can be used to capture aerial images to evaluate different aspects of engineering and science. The following list provided some beneficial use of sUAS in the field of science and engineering:

1. Coastal protection project monitoring
2. Coastal land loss investigation
3. Beach erosion monitoring
4. Vegetation health analysis
5. Civil infrastructure health monitoring
6. Structural health monitoring of bridges
7. Construction site progress monitoring
8. Slope stability analysis
9. Seepage analysis in levees and dams
10. Surveying with aerial photogrammetry and LIDAR
11. Stockpile and construction debris volume analysis
12. Historical site investigation
13. Analysis of historically and culturally significant cemeteries
14. Before and after storm/hurricane event monitoring
15. Monitoring of habitat and migration of wildlife and fisheries

The following sections describe some projects in coastal Louisiana that were photographed and evaluated with the use of multiple sUASs as part of this undergraduate research project.

Project #1: Bayou St. John Marsh Creation Project

The project is located near the intersection of Bayou St. John and Lake Pontchartrain in Orleans Parish, Louisiana. Figures 14 and 15 show the flight path of the sUAS as the on-board digital cameras were taking overlapping photographs of the project area.

Figure 14: Site vicinity Map

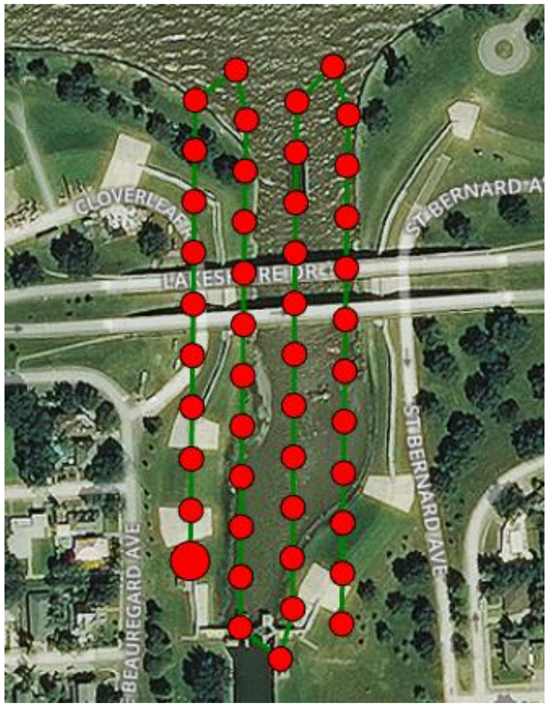

Figure 15: Flight path of the drone

Figure 16 shows the orthomosiac map of the project area with location of the camera where aerial pictures were taken.

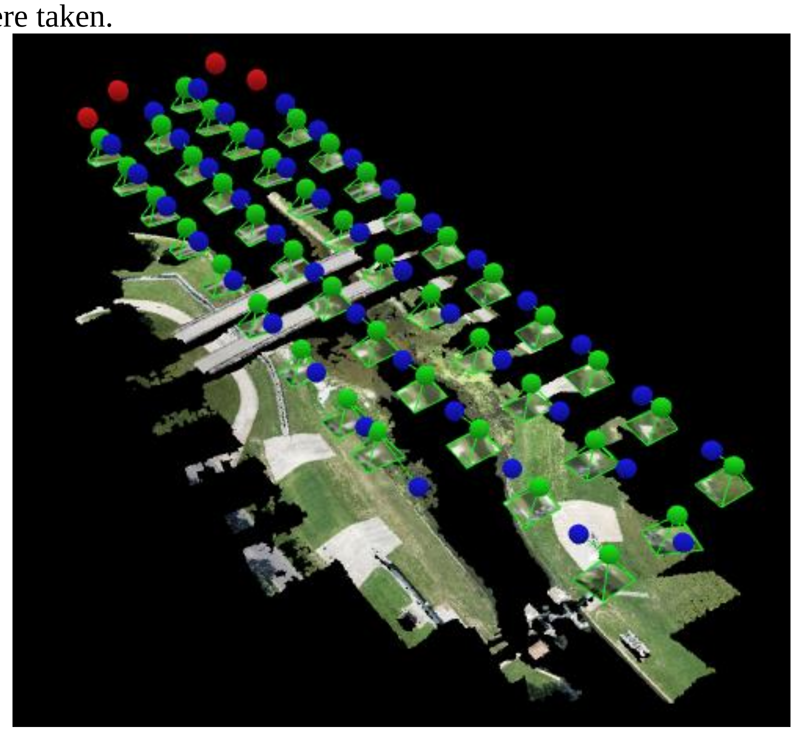
Figure 16: Orthomosiac map of the project site

Figure 17 shows the RGB color model of the project area and Figure 18 shows the Normalized Difference Vegetation Index (NDVI) model of the project site

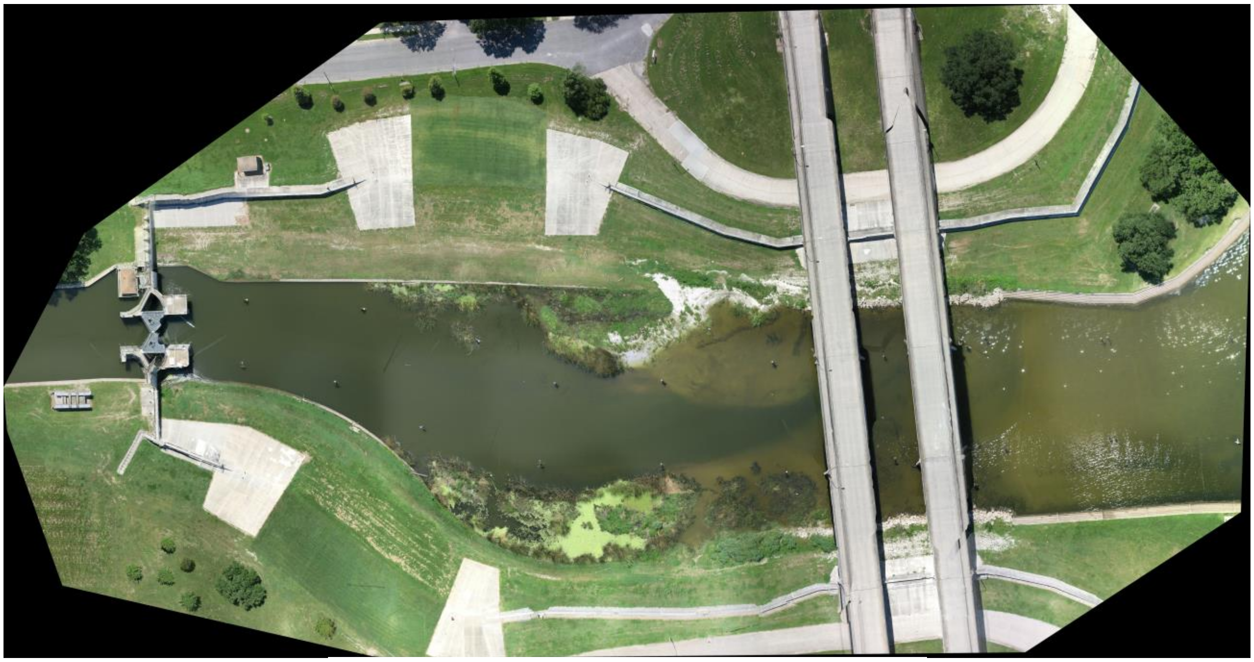

Figure 17: RGB color model of the project site

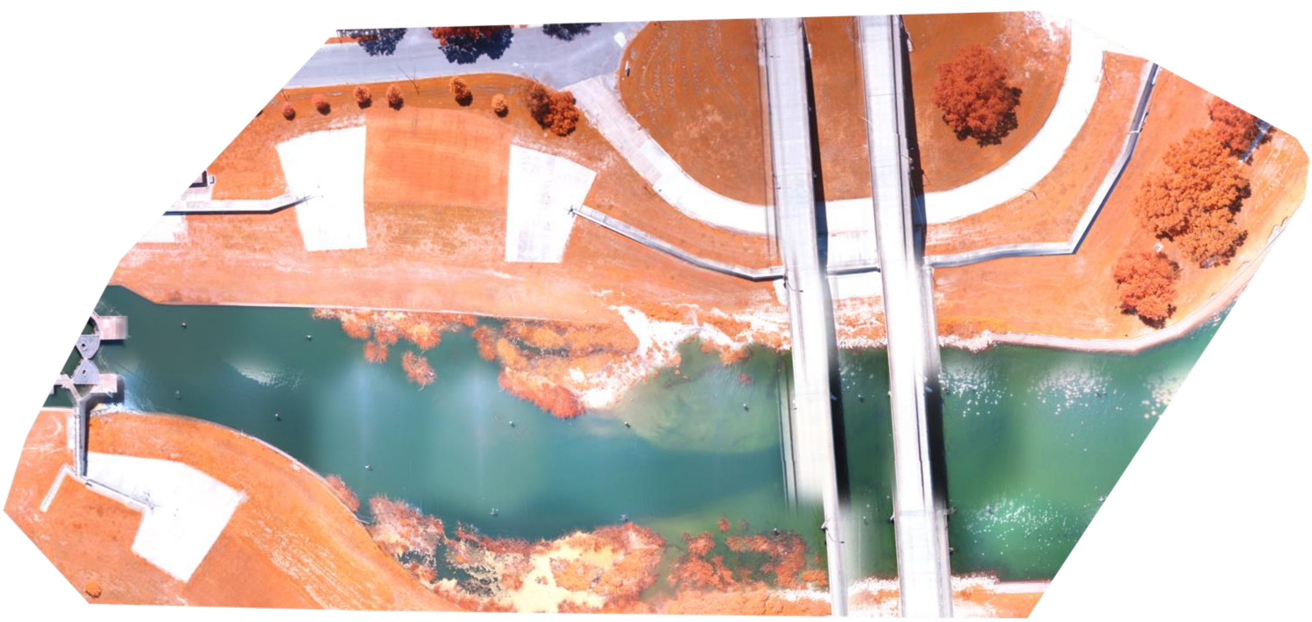

Figure 18: Normalized Difference Vegetation Index (NDVI) model of the project site

A sUAS can also be used to take aerial photography and videography of the project site. Figure 19 shows an aerial image taken using the on-board camera of the drone. This images can be used to assess the different components of the project site.

Figure 19: Aerial image of the project site

Project #2: Roadway Project in St. Bernard Parish

This project is located in St. Bernard Parish, Louisiana. Figures 20 shows the flight path of the sUAS as the on-board digital cameras were taking overlapping photographs of the project area.

Figure 20: Flight path of the drone

Figure 21 shows the orthomosiac map of the project area with location of the camera where aerial pictures were taken.

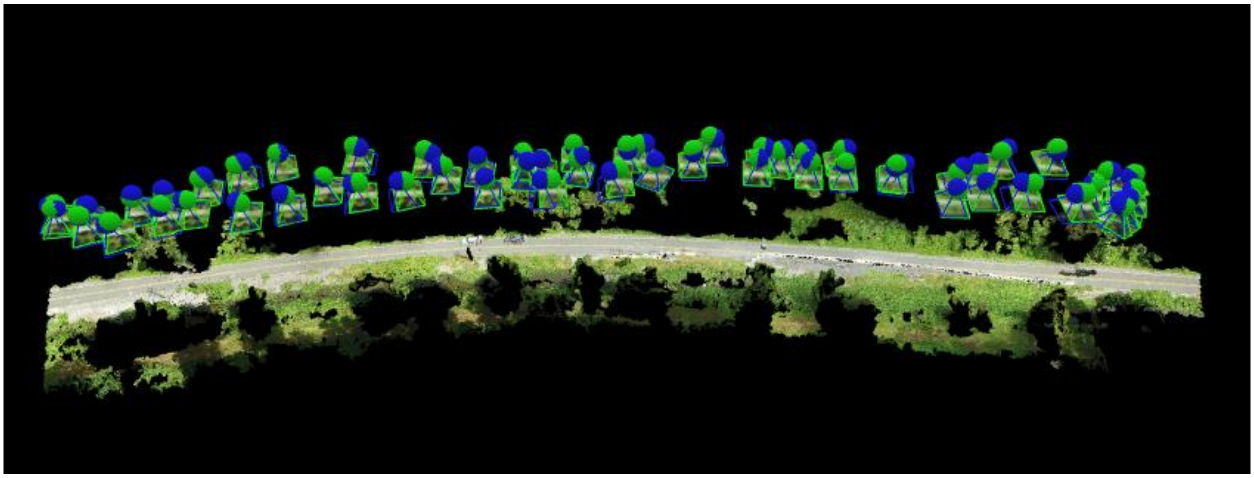

Figure 21: Orthomosiac map of the project site

A sUAS can also be used to take aerial photography and videography of the project site. Figure 22 shows an aerial image taken using the on-board camera of the drone. This images can be used to assess and evaluate the different components of the project site.

Figure 22: Aerial image of the project site

Project #3: Roadway bridge in St. Bernard Parish

This project is located on Highway 90 near Chef Menteur in St. Bernard Parish, Louisiana. Figure 22 shows the site vicinity map of the project.

Figure 22: Site vicinity Map

Figures 23 shows the flight path of the sUAS as the on-board digital cameras were taking overlapping photographs of the project area.

Figure 23: Flight path of the drone

Figure 24 shows the orthomosiac map of the project area with location of the camera where aerial pictures were taken.

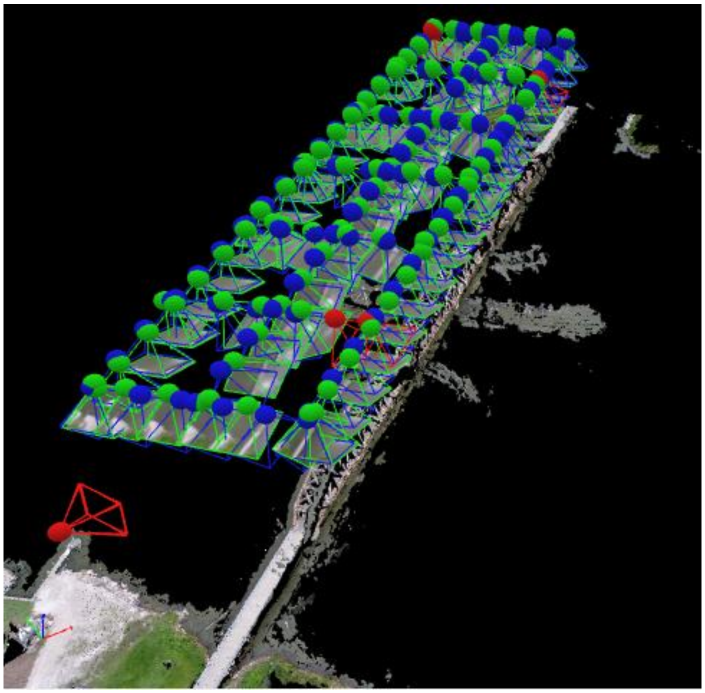

Figure 24: Orthomosiac map of the project site

Figure 25 shows the three dimensional model of the bridge obtained from the image processing.

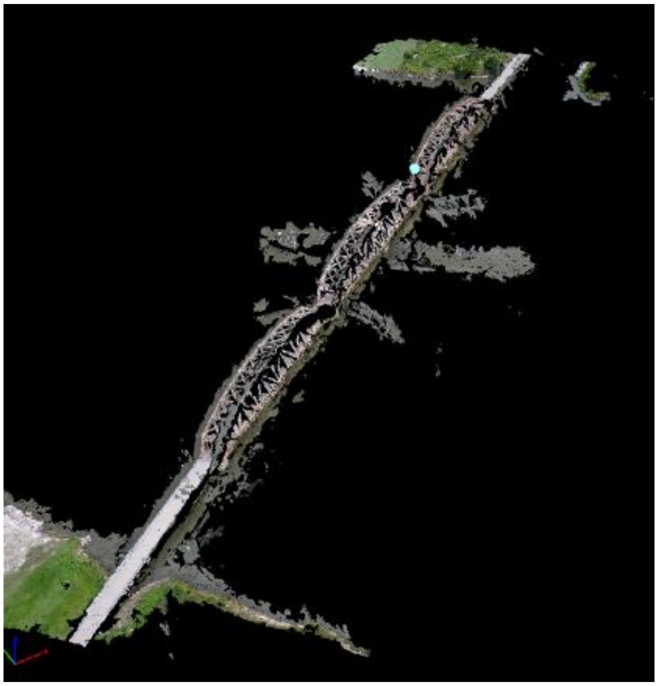

Figure 25: Three dimensional model of the bridge

A sUAS can also be used to take aerial photography and videography of the project site. Figure 26 shows an aerial image taken using the on-board camera of the drone. This images can be used to assess and evaluate the different components of the project site.

Figure 26: Aerial image of the project site

Figure 27 shows close up pictures of the bridge. These photographs can be utilized to perform long term health monitoring and evaluation of critical infrastructures.

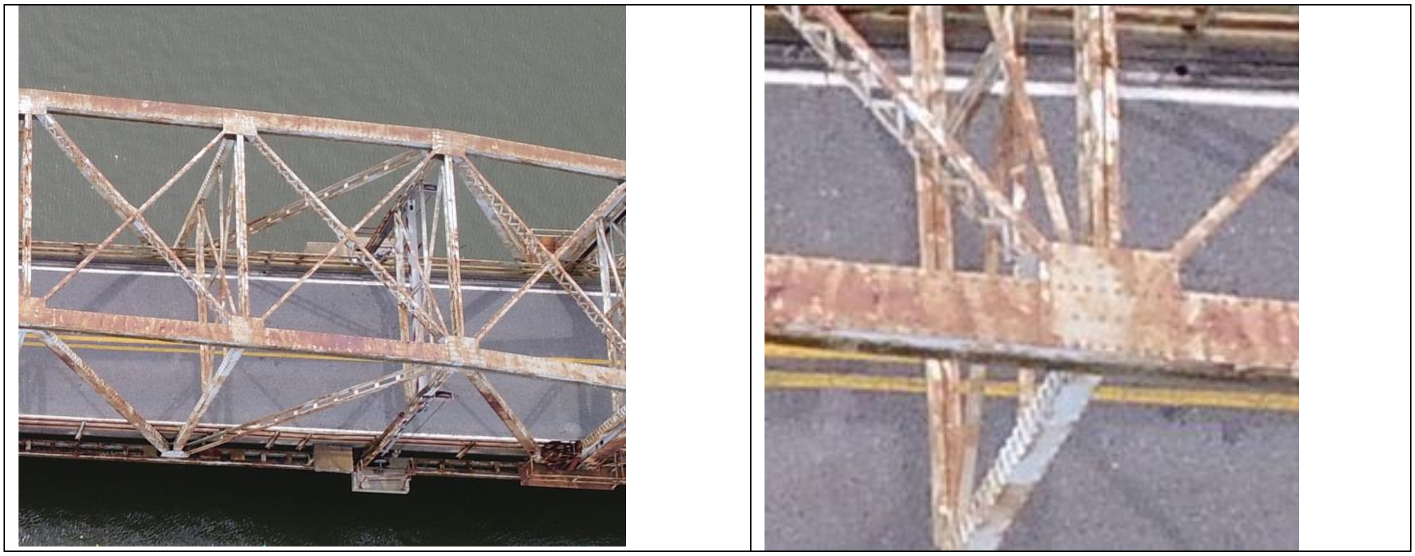

Figure 27: Close up image of bridge component

Project #4: Bucktown Marina Shoreline

This project is located adjacent to the Bucktown marina in Orleans parish, Louisiana. A site vicinity map of the project area is shown in Figure 28.

Figure 28: Site vicinity map

Figure 29 shows the orthomosiac map of the project area with location of the camera where aerial pictures were taken.

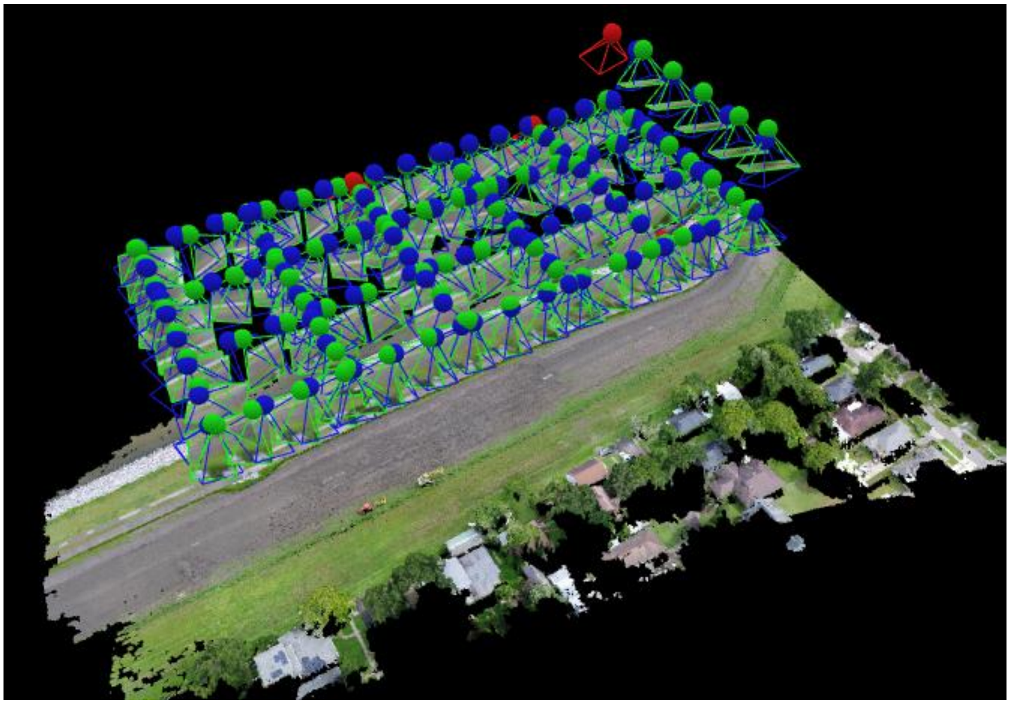

Figure 29: Orthomosiac map of the project site

Figure 30 shows the three dimensional model of the project area obtained from the image processing.

Figure 30: Three dimensional model of the project site

A sUAS can also be used to take aerial photography and videography of the project site. Figure 31 shows an aerial image taken using the on-board camera of the drone. This images can be used to assess and evaluate the different components of the project site.

Figure 31: Aerial image of the project site

Project #5: Historical site monitoring (Fort Pike): This project site is located off Highway 90 in New Orleans, Louisiana. A site vicinity map of the project site is shown in Figure 32.

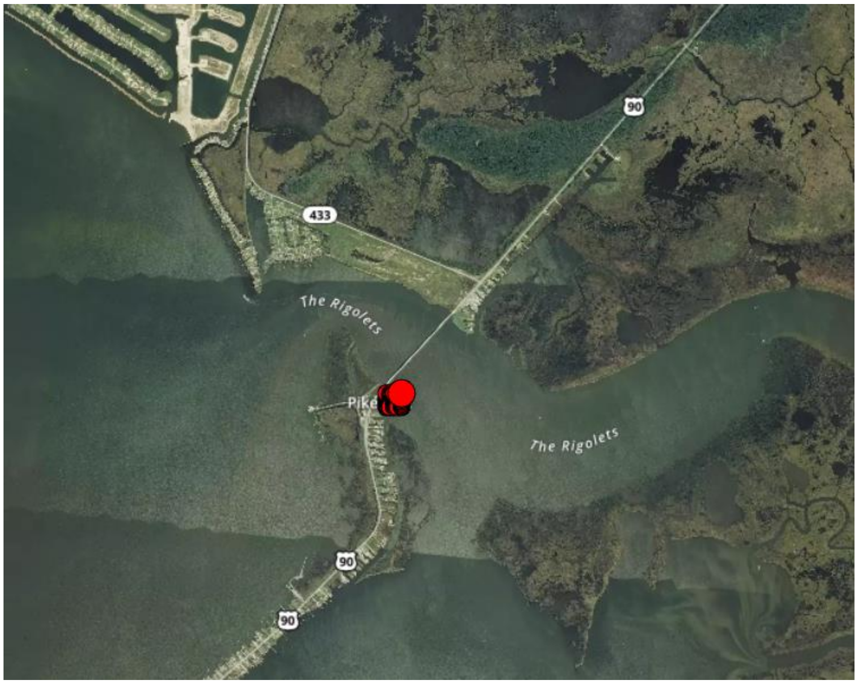

Figure 32: Site Vicinity Map

Figure 33 shows the orthomosiac map of the project area with location of the camera where aerial pictures were taken.

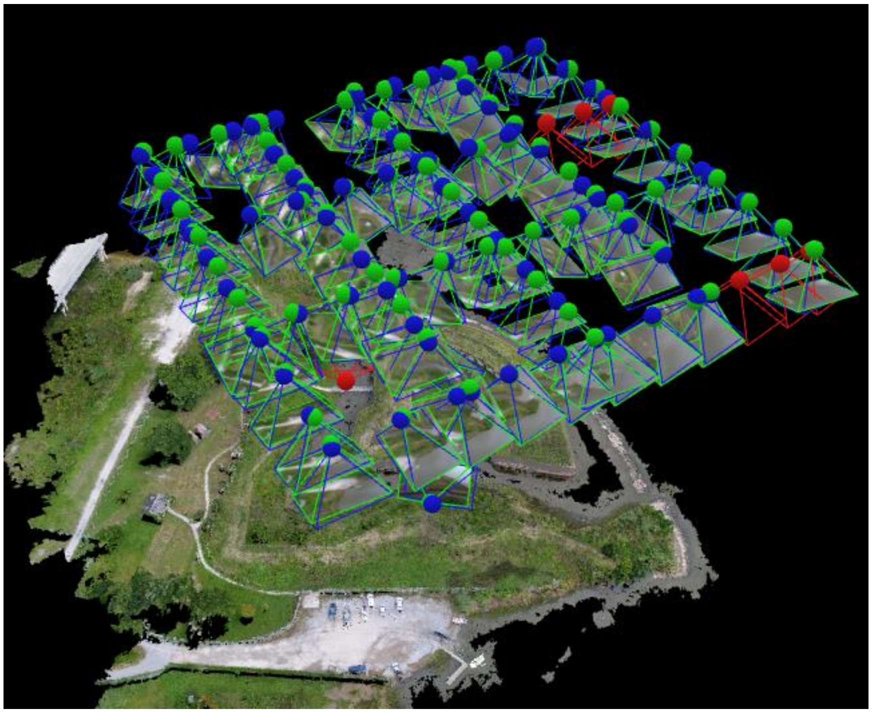
Figure 33: Orthomosiac map of the project site

Figure 34 shows the three dimensional model of the fort obtained from the image processing.

Figure 34: Three dimensional model of the project site

A sUAS can also be used to take aerial photography and videography of the project site. Figures 35, 36, and 37 show aerial images of the historical site and its components taken using the on-board camera of the drone. This images can be used to assess and evaluate the different components of the project site.

Figure 35: Aerial image of the project site

Figure 36: Aerial image of the project site

Figure 37: Aerial image of the project site

Opportunities for use of sUAS for other coastal Louisiana Projects

The following section illustrates beneficial use of sUASs to evaluate and monitor multiple project types in coastal Louisiana.

(a) **Louisiana Barrier Islands**: According to United States Geological Survey, Louisiana's barrier islands are eroding so quickly that according to some estimates they will disappear by the end of this century. Although there is little human habitation on these islands, their erosion may have a severe impact on the environment landward of the barriers. As the islands disintegrate, the vast system of sheltered wetlands along Louisiana's delta plain are exposed to increasingly open Gulf conditions. Through the processes of increasing wave attack, salinity intrusion, storm surge, tidal range, and sediment transport, removal of the barrier islands may significantly accelerate deterioration of wetlands that have already experienced the greatest areal losses in the U.S. Because these wetlands are nurseries for many species of fish and shellfish, the loss of the barrier islands and the accelerated loss of the protected wetlands may have a profound impact in the billion dollar per year fishing industry supported by Louisiana's fragile coastal environment. Figure 38 shows the barrier islands near the shoreline of Louisiana.

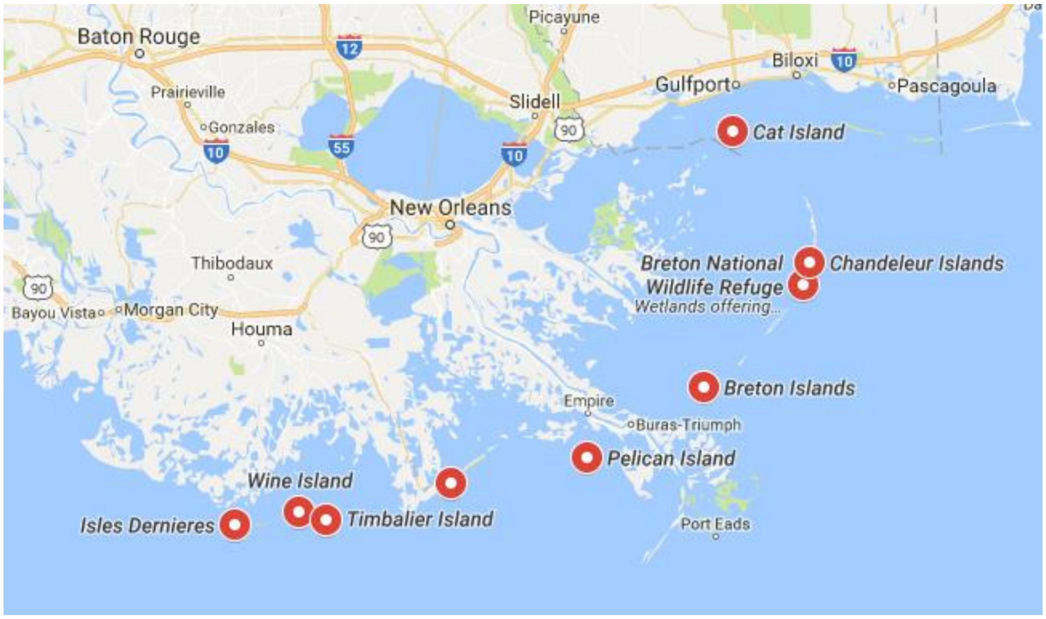

Figure 38: Map of barrier islands around Louisiana (source: google maps)

As shown in Figure 39, a sUAS can be used to monitor the land loss and evaluate the long term performance of these barrier islands in coastal Louisiana. The three dimensional model can also be used to calculate volume of sand loss after a storm event in these barrier islands.

Figure 39: An aerial view of a barrier island (source: google images)

(b) **Louisiana Coastal Protection System:** The southeast Louisiana's hurricane and storm protection system consists of levees, floodwalls, canals, and floodwalls. A sUAS can be used effectively and economically to monitor the performance of these important coastal infrastructure systems. Figures 40, 41, and 42 shows two critical coastal protection system around Louisiana.

Figure 40: IHNC surge barrier aerial photo (source: google images)

Figure 41: West closure complex (source: google images)

Figure 42: Canal and pump station along Lake Pontchartrain

Projects like those mentioned above can use sUAS flights on a regular interval to evaluate any change in their operating conditions.

(c) Louisiana Marsh Creation: Dredged sediments mixed with water is pumped from a borrow area (Mississippi river, canals, or the gulf of Mexico) and transported to an open-water area through pipelines to build new land. Due to the highly compressible nature of the foundation soil, the dredged sediments and the underlying soil will undergo long term settlement over several years.

Figure 43: Marsh creation project in progress (source: Louisiana CPRA)

Figure 44: Creation of new land using dredged sediments (source: Louisiana CPRA)

Currently, the ground subsidence and long term settlement monitoring of Louisiana coastal marsh creation projects are performed by traditional surveying methods and manned aircraft flights, which are both time consuming and costly. The use of a small unmanned aircraft system (sUAS) can significantly reduce the time and cost to monitor and document ground subsidence and long term settlement monitoring at a marsh creation project in Louisiana.

Chapter 8: Research Summary

The current research was performed with assistance from Louisiana Sea Grant under their Undergraduate Research Opportunities Program (UROP). A summary of the research activities is presented below:

1. The coastal areas of Louisiana is losing land at an alarming rate. This has exposed critical infrastructure to open water conditions.
2. Currently, monitoring of coastal land loss and coastal infrastructure systems is performed by traditional surveying methods and manned aircraft flights, which are both time consuming and costly.
3. An unmanned aircraft system (UAS), commonly known as a drone, can significantly reduce the time and cost to monitor and document coastal land loss and performance of coastal infrastructures in Louisiana.
4. This research report summarizes the benefits of using a remote controlled small UAS equipped with high resolution camera to successfully evaluate Louisiana coastal land loss and increase in land mass due to coastal restoration projects. The research report also summarizes the advantageous use of an UAS to monitor performance of coastal protection features (levees, floodwalls, pumping stations etc.) during and immediately after a storm and hurricane event.
5. Multiple sUASs were used to capture aerial photographs and videos of several sites in southeast Louisiana. AN image processing software was used to generate 2D orthomosaic maps and 3D models that can be used to evaluate the project site.

Chapter 8: Recommendations for Future Research

The following recommendation are provided for future research in this area:

1. Perform additional flights with both multi-rotor and fixed-wing sUAS on Louisiaan coastal restoration and protection projects and collect additional data for image analyses.

2. Compare the aerial photogrammetry data with traditional survey data and LIDAR data for comparison of data and accuracy in the data

3. Use the sUAS to monitor subsidence of Louisiana coastal ground over a period of several years to generate overlapping maps and calculate volume of mass loss.

Chapter 9: References

Adams, S. M., & Friedland, C. J. (2011). *A survey of unmanned aerial vehicle (UAV) usage for imagery collection in disaster research and management.* Retrieved from https://www.researchgate.net/profile/Carol_Friedland/publication/266465037_A_Survey_of_Unmanned_Aerial_Vehicle_UAV_Usage_for_Imagery_Collection_in_Disaster_Research_and_Management/links/54d8d9ab0cf24647581c9aa0/A-Survey-of-Unmanned-Aerial-Vehicle-UAV-Usage-for-Imagery-Collection-in-Disaster-Research-and-Management.pdf

Associated Press. (2012, May 12). Louisiana coastal erosion being assessed with drones. *The Times-Picayune*. Retrieved from http://www.nola.com/environment/index.ssf/2012/05/louisiana_coastal_erosion_bein.html

Carlson, B. J. (2001). *Past UAV Program Failures and Implications for Current UAV Programs* (No. AU/ACSC/037/2001-04). AIR COMMAND AND STAFF COLL MAXWELL AFB AL. Retrieved from http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA407103

Coastal Protection and Restoration Authority. (2017). *Louisiana's Comprehensive Master Plan for a Sustainable Coast.* Coastal Protection and Restoration Authority. Baton Rouge, Louisiana. Retrieved from http://coastal.la.gov/wp-content/uploads/2014/09/2017-Coastal-Master-Plan-Project-Development-Program.pdf

Lopez, J. A., Day, J., Miller, G., Hawes, S., Brown, C., Keddy, P., ... & Davis, M. (2005). The Multiple Lines of Defense Strategy to Sustain Louisiana's Coast. *Lake Pontchartrain Basin Foundation*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.555.140&rep=rep1&type=pdf

Maguire, C. (2014). *Using unmanned aerial vehicles and "structure from motion" software to monitor coastal erosion in southeast Florida.* Retrieved from http://scholarlyrepository.miami.edu/cgi/viewcontent.cgi?article=1539&context=oa_theses

McLaurin, S. (2017). *Achieving greater impact at the North Carolina Coastal Federation through Unmanned Aerial Systems (UAS).* Retrieved from https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/14147/Masters%20Project%20Report_v2.pdf?sequence=1

Yoo, C. I., & Oh, T. S. (2016). Beach volume change using UAV photogrammetry Songjung Beach, Korea. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 1201-1205. Retrieved from http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XLB8/1201/2016/isprs-archives-XLI-B8-1201-2016.pdf

Appendix

FAA Summary of small unmanned aircraft rule (Part 107, dated June 21, 2016)

FAA News

Federal Aviation Administration, Washington, DC 20591

June 21, 2016

SUMMARY OF SMALL UNMANNED AIRCRAFT RULE (PART 107)

Operational Limitations	• Unmanned aircraft must weigh less than 55 lbs. (25 kg). • Visual line-of-sight (VLOS) only; the unmanned aircraft must remain within VLOS of the remote pilot in command and the person manipulating the flight controls of the small UAS. Alternatively, the unmanned aircraft must remain within VLOS of the visual observer. • At all times the small unmanned aircraft must remain close enough to the remote pilot in command and the person manipulating the flight controls of the small UAS for those people to be capable of seeing the aircraft with vision unaided by any device other than corrective lenses. • Small unmanned aircraft may not operate over any persons not directly participating in the operation, not under a covered structure, and not inside a covered stationary vehicle. • Daylight-only operations, or civil twilight (30 minutes before official sunrise to 30 minutes after official sunset, local time) with appropriate anti-collision lighting. • Must yield right of way to other aircraft. • May use visual observer (VO) but not required. • First-person view camera cannot satisfy “see-and-avoid” requirement but can be used as long as requirement is satisfied in other ways. • Maximum groundspeed of 100 mph (87 knots). • Maximum altitude of 400 feet above ground level (AGL) or, if higher than 400 feet AGL, remain within 400 feet of a structure. • Minimum weather visibility of 3 miles from control station. • Operations in Class B, C, D and E airspace are allowed with the required ATC permission. • Operations in Class G airspace are allowed without ATC permission. • No person may act as a remote pilot in command or VO for more than one unmanned aircraft operation at one time. • No operations from a moving aircraft. • No operations from a moving vehicle unless the operation is over a sparsely populated area. • No careless or reckless operations. • No carriage of hazardous materials.

	• Requires preflight inspection by the remote pilot in command.
	• A person may not operate a small unmanned aircraft if he or she knows or has reason to know of any physical or mental condition that would interfere with the safe operation of a small UAS.
	• Foreign-registered small unmanned aircraft are allowed to operate under part 107 if they satisfy the requirements of part 375.
	• External load operations are allowed if the object being carried by the unmanned aircraft is securely attached and does not adversely affect the flight characteristics or controllability of the aircraft.
	• Transportation of property for compensation or hire allowed provided that-
	  o The aircraft, including its attached systems, payload and cargo weigh less than 55 pounds total;
	  o The flight is conducted within visual line of sight and not from a moving vehicle or aircraft; and
	  o The flight occurs wholly within the bounds of a State and does not involve transport between (1) Hawaii and another place in Hawaii through airspace outside Hawaii; (2) the District of Columbia and another place in the District of Columbia; or (3) a territory or possession of the United States and another place in the same territory or possession.
	• Most of the restrictions discussed above are waivable if the applicant demonstrates that his or her operation can safely be conducted under the terms of a certificate of waiver.

Remote Pilot in Command Certification and Responsibilities	• Establishes a remote pilot in command position.
	• A person operating a small UAS must either hold a remote pilot airman certificate with a small UAS rating or be under the direct supervision of a person who does hold a remote pilot certificate (remote pilot in command).
	• To qualify for a remote pilot certificate, a person must:
	  o Demonstrate aeronautical knowledge by either:
	    ▪ Passing an initial aeronautical knowledge test at an FAA-approved knowledge testing center; or
	    ▪ Hold a part 61 pilot certificate other than student pilot, complete a flight review within the previous 24 months, and complete a small UAS online training course provided by the FAA.
	  o Be vetted by the Transportation Security Administration.
	  o Be at least 16 years old.
	• Part 61 pilot certificate holders may obtain a temporary remote pilot certificate immediately upon submission of their application for a permanent certificate. Other applicants will obtain a temporary remote pilot certificate upon successful completion of TSA security vetting. The FAA anticipates that it will be able to issue a temporary remote pilot certificate within 10 business days after receiving a completed remote pilot certificate application.
	• Until international standards are developed, foreign-

	certificated UAS pilots will be required to obtain an FAA-issued remote pilot certificate with a small UAS rating. A remote pilot in command must: • Make available to the FAA, upon request, the small UAS for inspection or testing, and any associated documents/records required to be kept under the rule. • Report to the FAA within 10 days of any operation that results in at least serious injury, loss of consciousness, or property damage of at least $500. • Conduct a preflight inspection, to include specific aircraft and control station systems checks, to ensure the small UAS is in a condition for safe operation. • Ensure that the small unmanned aircraft complies with the existing registration requirements specified in § 91.203(a)(2). A remote pilot in command may deviate from the requirements of this rule in response to an in-flight emergency.
Aircraft Requirements	• FAA airworthiness certification is not required. However, the remote pilot in command must conduct a preflight check of the small UAS to ensure that it is in a condition for safe operation.
Model Aircraft	• Part 107 does not apply to model aircraft that satisfy all of the criteria specified in section 336 of Public Law 112-95. • The rule codifies the FAA's enforcement authority in part 101 by prohibiting model aircraft operators from endangering the safety of the NAS.