Faculty of Engineering and Applied Science
ENGR 4940U Capstone Systems Design for ECSE I

Low Cost Drone Light Show

Report 1: Project Identification, Research and Requirements Specification

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1. Problem Identification

Fireworks are known to be used around the world for special occasions or holidays. They create excitement and noise while creating a celebratory environment for people, however, the negative impacts of fireworks outweigh the positive effects. Fireworks negatively impact the environment, causing noise pollution and air pollution. Along with this, the use of fireworks causes harm to not only the environment but animals and humans as well.

The chemicals released when creating fireworks are usually metallic compounds like Barium and Aluminum. The bright colors that are created within fireworks use these metallic elements which have major negative impacts on animal and human health. Moreover, the use of oxidizers within fireworks creates water pollution as these oxidizers contaminate rivers and lakes.

Fireworks are continually being used especially during holiday seasons and due to the excitement it creates people as well as organizations tend to still use them despite the negative effects. This capstone project will focus on essentially creating a Low Cost Drone Light Show imitating the colors and eliminating all the negative effects that come with the use of fireworks.

Drone light shows have recently been introduced by different organizations and have been implemented in the world in many countries during events and celebrations. This capstone project will focus on creating a low cost drone light show as normal drone light shows are extremely expensive creating the way to go back to using normal fireworks.

The drones used for light shows are usually specialized in that which make them more complex and expensive [3]. We aim to make drone light shows slightly affordable so they can be commonly used. We also aim to create simple simulations imitating regular fireworks that would give the same effect to viewers without the negative environmental effects.

This project will focus on making drone light shows affordable and enjoyable. As mentioned above, the drones that we will be using will be more aimed towards taking simpler drones and attaching lights to them which can be used for the simulation of different designs with a mobile application with the use of Internet of Things.

The Internet of things is a commonly used method within many drones connecting it to different objects and they overlap with the technologies used. IoT can be used within our project to connect the drone simulations to the mobile application which will create firework like simulations. The materials that we would use within this project would aim to be low cost.

2. Background and Research Review

To understand the background of our project, we conducted research on already existing technologies for drone light shows, research into what core materials will be required for the project and research on how—or what—will be needed to achieve the goal of low costs for drone light shows. Below are these highlighted research areas.

Existing Technologies: Intel’s Shooting Star System

In February of 2017, Lady Gaga performed at the Super Bowl Halftime show. In this performance, she gave a stellar production featuring fireworks, back up dancers, jumping off the roof, and even an incredible showcase of acrobatics. But something that caught the attention of people watching that night was not only the show itself but what was made out to be a captivating display of moving stars. Well, anyone who wouldn’t know what to call it would say ‘moving stars’ but we now know that these were the handiwork of nothing cooler than drones. Intel is a technology company that was responsible for this stunning display at America’s biggest sporting event having made a system, called Shooting Star system, which has a show controller software that, prior to go-time, runs a check on all drones to ensure the most optimal ones for performances based on GPS Reception and battery life [1]. Only one computer is needed to control the fleet of hundreds, sometimes even thousands, of Shooting Star drones resulting in beautifully stunning exhibitions of twinkling stars, the American Flag and even the Pepsi logo, as seen at the Halftime Show.

The details of just how exactly a computer is able to control these drones to move to their choreographed positions, enabling these light shows, would be explained further in the report. For now however, some highlighted features of the Shooting Star system, from research, are: purpose-built hardware; custom-designed Intel software; a system that constantly optimizes for better performance; one-to-many flight operations [1]. The drone itself is made out of Styrofoam and plastics of lightweight substance and it has built-in Light Emitting Diodes (LEDs) for the purpose of light displays [2].

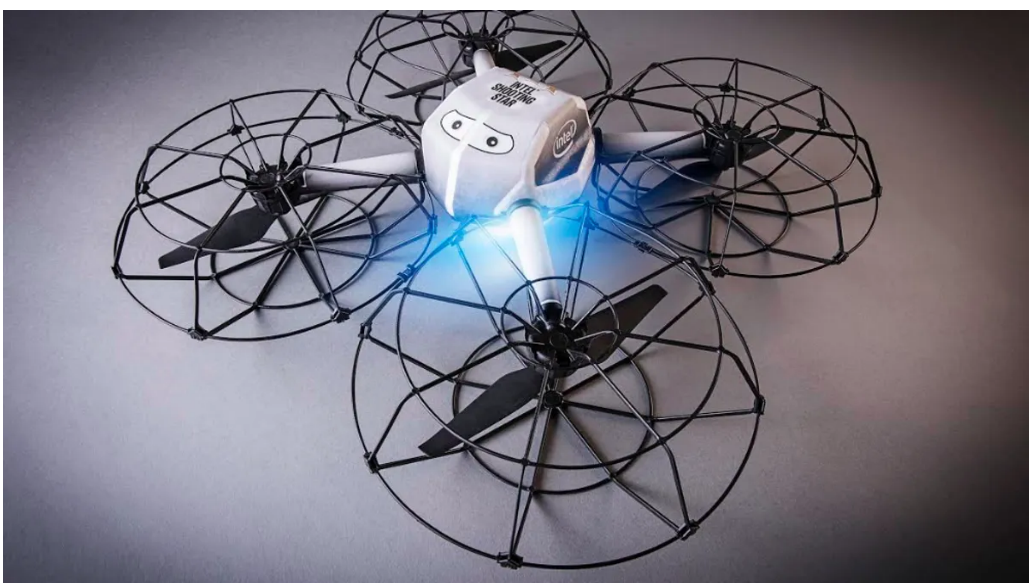

Fig 2.1 An Intel’s Shooting Star Drone
Source: Adapted From [8]

Existing Technologies: Spaxels

Forms of visual representations have endured numerous evolutionary modifications through simple to complex technology innovations. From video holography, celluloid film to LED and stereoscopic displays. The Ars Electronica Futurelab unveiled Spaxels in 2012 with LED-equipped quadcopters that were initially created in the sky as a 3D light art show. Spaxels are space elements that are analogous to pixels. They are fundamentally points of light called space pixels which can be positioned in space. Spaxels with long exposure photography are collabed with static and animated aerial displays modified into smart atoms that are virtually linked arrays of quadcopters which can be visualized as flying building blocks by hand. There are two main concepts that have to be considered to illustrate the perception of Spaxels which are the nature of a singular Spaxel and the nature of a collective of Spaxels from a Spaxel sculptural image (SSI).

Fig 2.2 Spaxels - Ars Electronica Futurelab Show
Source: Adapted From [10]

How Drone Light Shows Work

With all the research done on existing technologies for drones purposed for light shows, the curious mind bids the question: so how *do* drone light shows work? The basic, straightforward answer to this would be that a hundred, to thousands, of drones are controlled by a computer, or rather, a software on the computer, to communicate and execute choreographed patterns. How is the choreography done? It is created using 3D animation tools which allows the software to assign a flight path to each drone in the fleet of choreographed displays [3]. Now, we will delve a little deeper into three different aspects of creating these drone light shows: the drones themselves, flight planning, and testing. These are examined in the section below.

I. Drones

The modern consumer drone has become an increasingly popular item for a variety of users and we can see its impact they are starting to take in our daily lives. From assisting search and rescue, firefighting, surveillance, casual videography and in more recent years, light shows. No matter how they are used, drones have adapted to unmanned aerial vehicle technology (UAV) and include a variety of complex mechanics. Some of the main components of a drone include rotors, connectivity, accelerometer, altimeter, motors and a landing gear.

Rotors consist of propellers that are attached to motors and allow the drone to ascend up and down. When the pilot increases the speed, the upward force is greater than the force of gravity causing the drone to ascend. When the speed is decreased, the upward force is less than force of gravity causing the drone to descend. Drones are able to hover when these forces remain equal and when half of the rotors move clockwise while the other half move counterclockwise This ensures that balance is maintained in the drone. To move forward, the speed is increased in two of the rotors and decreased to move backward [5].

Connectivity is the ability for the drone to be controlled wirelessly through a controller or smart device. This allows pilots to control the drone or in the case of a light show, this allows for an automated flight path to be determined for the drone.

Accelerometer and Altimeter are another essential part of a drone.The Accelerometer retrieves information about the drone speed and direction, along with the altimeter which records the altitude. These metrics are needed to allow the drone to depart, fly and land safely. Similar to a regular human-led aircraft, maintaining these values while flying is essential to avoid getting caught in the air vacuum that could pull the aircraft downwards.

Motor choice plays a part in the battery life consumption which ultimately determines how long the flying time can be. Landing gear can be both retractable or not depending on the price of the drone. This ensures that the drone has a smooth landing and can protect expensive components such as cameras, LEDs and sensors.

Bringing it back to drone light shows, the most common type of drone used include quadcopters with mounted LED lights. Quadcopters consist of standard prop which are at the front of the drone to pull in forward motion and pusher prop which are at the back to push in forward motion. Electronic Speed Controllers (ESC) allow for a variety of electric motors speeds and directions. ESC circuits are found in the main frame of most quadcopters and some allow customization through the special development kit (SDK). The flight controller receives information about battery, GPS coordinates, steering and monitors motor speeds in the ESC [6]. A power distribution board is also required to regulate and distribute power to the ESC boards and connect to VTX(Video Transmitter). The brain of a quadcopter is the flight controller which holds sensors and sends signals to communicate with the ESC. The minimum channels needed for controlling a quad is four receiving units and having an antenna gives greater signal distance. A receiver connects to the fight controller and will provide signals received by a remote control transmitter.

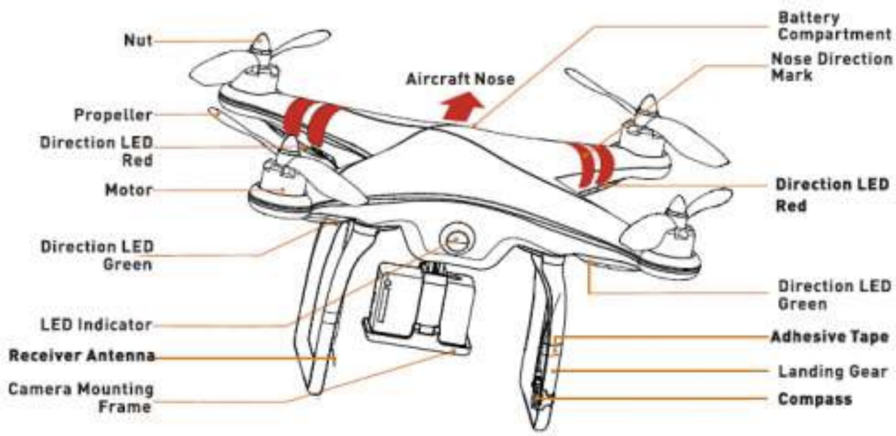

Fig 2.3 General Part Specification for Quadcopter
Source: Adapted from [6]

II. Flight path Planning

This is probably the most pivotal part of the Drone light show system-–planning and creating the path of choreography for each drone to contribute to a greater organized show of lights. Here, users of the drone will need to program the movements of the drones and can take a good amount of time [3]. Weeks, sometimes even months, depending on the number of drones involved in the light show. To achieve this, a 3D Animation software is required, like Blender or Base Motion Studio, and allows the user to exercise their creativity [3]. There are really no bad or best practices with this part of the project, all that needs to be done is to tell a story or create art with the drones. Some things that need to be considered, however, in this process are [4]:

- Speed of Drones.
- Altitude.
- Coordinates.
- Timing.
- Distance between drones.

III. Testing

Once choreography is completed, testing is needed to ensure everything is working as it should be. Correct execution of choreography and deployment of drones is important here and having to manually do that can possibly lead to errors which is why using a software to do so is best. A software like ‘DroneShow’ can be used to conduct testing and make necessary adjustments, in the process, stimulating the drone’s size and speed therefore enhancing the accuracy of the test [3].

Achieving Low Cost Drones

Seeing as drones are a relatively ‘new’ technology, the average cost of it can range from $300 to $1000. From conducting research, we’ve concluded as a group that the factors that typically contribute to the cost of drones are the technologies required for the drones, material that they're made out of, the various elements on the drones, battery life, and size of the drones. For this project, to achieve lower cost of marketable drones for drone light shows, we have decided to create and build a drone from scratch, eliminating all unnecessary technology and elements like video camera and speakers and building the drone from a cheaper material of Carbon Fiber. To achieve better mobility of the drone for better and lighter movement, we hope to make the drone smaller in size than a typical one. And finally in terms of battery life, A 4 cell/4S (14.8v) pack. This voltage is very versatile and finds for a greater performance of drones [9].

3. Design Process

For our capstone project, we have decided to adopt an agile methodology due to its flexibility for change and the evolving nature of this project. This approach allows us to modify project needs and solutions as needed. The agile software development life cycle has the main stages as listed below[7]:

1. Stage 1: Ideation
2. Stage 2: Development
3. Stage 3: Testing
4. Stage 4: Deployment
5. Stage 5: Operations

The first stage of agile development is the ideation or in other words, defining the purpose, requirements and allocating resources as needed. An architecture schematic for the project was created to support this initial development stage and the diagram attached below shows how we intend for the drones to interact with the software. By using a 3D animation software we will be able to provide the drones with a predefined flight path and this signal will be communicated through the transmitter to the drone. The Drone receiver will send this signal to the flight controller, where the ESC will appropriately set the speed for the motors to control the motion of the drone. The signal received will also include information for the LED, sensor and other components required for smooth control.

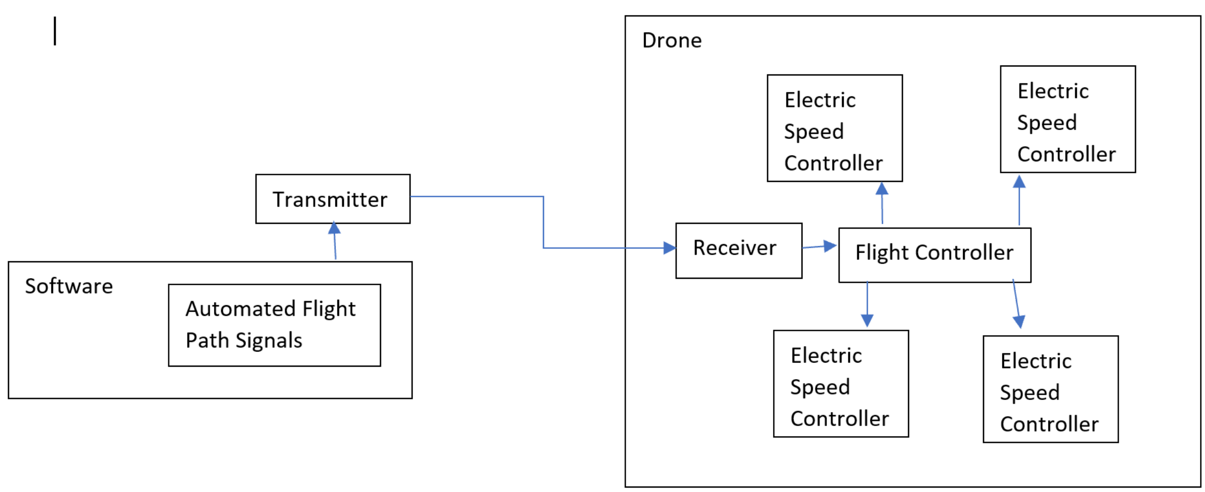

Fig. 3.1 Drone light show architecture

4. Scenarios and Use Cases

User Scenario

The user: An individual, or organization, interested in better environmental options to audience entertainment. An individual with a low budget to entertain people or themselves.
The environment: Outside, big event centers, etc.
The scenario: A user discovers that fireworks are not actually a good impact on the environment but require something else that is just as captivating in entertainment, as fireworks. They discover the low cost drones and realize they can provide all the perks of fireworks while staying on a lower budget and are even able to reuse these drones thus, helping the environment.

Use Case(s)

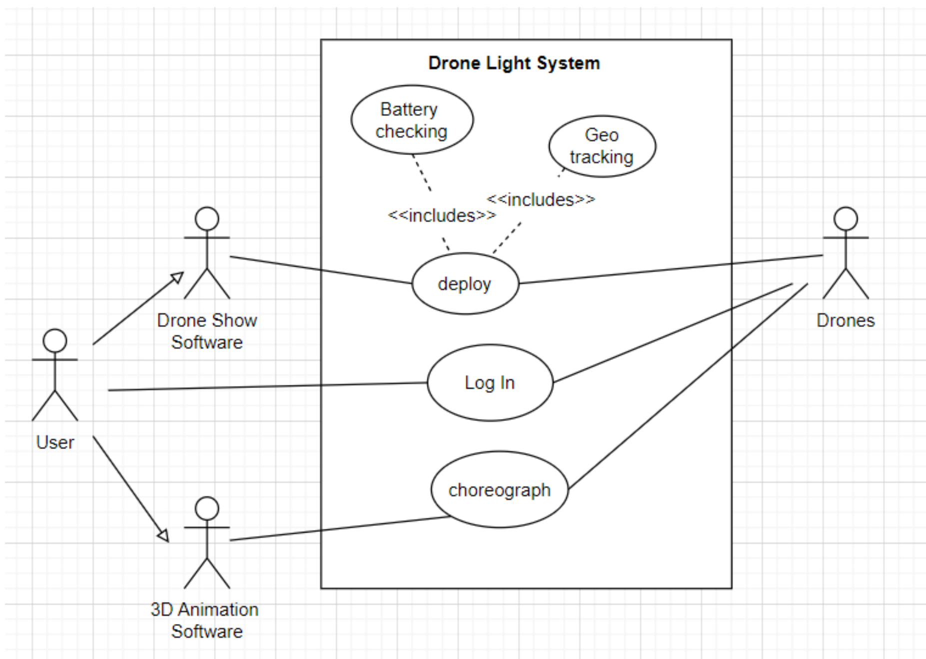

Fig 4.1 Use Case Diagram

5. Stakeholder Requirements and Traceability Matrix

The main outcome of the system is to develop a low-cost drone light show for individual entertainment purposes in order to eliminate noise and air pollution accumulated from fireworks. In order to successfully develop the system, the stakeholders interested in the proposed system must be identified along with their requirements. The primary stakeholders of this system would be individuals that would like to use drones for independent recreational purposes, along with event and entertainment organizations that will be bringing in this type of clientele. Their main priority is to have a safe and low cost experience for their guests, if the system is not able to meet these requirements then these stakeholders will opt for other alternatives. An example of these recreational purposes could include but is not limited to birthday parties, weddings, gender reveals etc. The secondary stakeholders of the system would be the viewers and audiences at the events where the drones are being used. The system should be able to give these viewers an enjoyable and entertaining experience.

Stakeholders

Primary Stakeholders

- Event/Entertainment organizations
    - Organizations will be able to acquire the low cost drone light shows for their clients events

- Independent Clients
    - Individuals looking to have a low cost drone light show for their independent entertainment purposes

Secondary Stakeholders

- Viewers/Audience
    - Viewers of the low cost drone light show will benefit from an enjoyable and entertaining experience. This can possibly lead to their interest into using the light show for their own purposes, moving them to a potential primary stakeholder

Stakeholder Requirements

Functional Requirements

FR-1: The system should produce various light patterns using drones.
FR-2: The system should be able to fly the drones in the specific trajectory pattern according to the program developed.
FR-3: The system should be able to be monitored through a control system, such as an app or website.
FR-4: The system should produce various light patterns that can be seen from 100 meters.
FR-5: The system should produce a light show for at least 5 minutes.
FR-6: The system should stay within the specified coordinates during its flight path.
FR-7: The system should have the drones flight altitude to a minimum of 5ft.

Design Requirements

DR-1: The system should use drones with LEDS that have power consumption of less than 15W.
DR-2: The system all together should cost no more than $1500.
DR-3: The system should use drones that have a weight between 1000g to 1500g.

Operational Requirements

OR-1: The system should abide by all safety requirements and regulations of the device and venue.
OR-2: The system should keep the drone flight path within the venues maximum height.

Test Cases (Use Cases)

TC-1: LogIn
TC-2: Deploy
TC-3: Choreograph

TC-4: Battery Checking
TC-5: Geo Tracking

Traceability Matrix

Table 5.1: Traceability Matrix

Functional Requirement	**Design Requirement**	**Operational Requirement**	**Test Case**	**Priority**
Fr-1	Dr-1, Dr-2		Tc-2, Tc-3, Tc-4	Medium
Fr-2	Dr-3	Or-1, Or-2	Tc-2, Tc-3, Tc-4, Tc-5	High
Fr-3	Dr-2		Tc-1, Tc-2,	Medium
Fr-4	Dr-1		Tc-2, Tc-3, Tc-4	Low
Fr-5	Dr-1, Dr-2		Tc-2, Tc-3, Tc-4	Medium
Fr-6	Dr-3	Or-1, Or-2	Tc-2, Tc-3, Tc-4, Tc-5	High
Fr-7	Dr-3	Or-1, Or-2	Tc-2, Tc-3, Tc-4, Tc-5	Medium

6. Definition of Acceptance Tests

To demonstrate that this project has met the requirements outlined, we will be running a number of tests. These tests can change depending on the project if anything changes in its next stages.
Some of the acceptance tests that we will conduct are as follows:

Mobile Application
- Test 1: The user is able to log in to the application that is connected to the drone
- Test 2: The application displays a number of premade light show design that the drone can perform
- Test 3: The status of the drones can be displayed to the user. Ie. if they function.
- Test 4: The application successfully connects to the drone

Drones
- Test 5: The drones can be connected to the mobile application
- Test 6: The drones are functioning
- Test 7: The drones can perform premade light show design when the user clicks it from the mobile application
- Test 8: The drones are able to create to send and receive information from the mobile application

Lights/circuits
- Test 9: The circuit connected to the drones are functioning

- Test 10: The lights able to create a simple light show
- Test 11: The lights/circuit is durable
- Test 12: It is functional with the drone

7. Project Plan

The following project plan is for the capstone project for the fall term 2022. This plan outlines all the requirements that must be completed for this term.

Table 7.1: Project Plan

Task	**Days**	**Start**	**Finish**
Report R1	**23**	**09/26/2022**	**10/18/2022**
Background and Research	4	09/26/2022	09/29/2022
Design Process	4	09/30/2022	10/03/2022
Use Cases and Requirements	8	09/04/2022	10/11/2022
Acceptance Tests	3	10/12/2022	10/14/2022
Finalize Report	4	10/15/2022	10/18/2022
Report R2	**Estimated 25**	**10/15/2022**	**11/08/2022**
Concept Generation and Analysis	13	10/15/2022	10/27/2022
Conceptual System Design	9	10/28/2022	11/05/2022
Integration Tests and Project Costs	3	11/06/2022	11/08/2022
Presentation and Demo	**Estimated 25**	**11/07/2022**	**12/01/2022**
Design Prototype	5	11/07/2022	11/11/2022
Develop Prototype	15	11/12/2022	11/26/2022
Test Prototype	2	11/27/2022	11/28/2022
Fix Errors	3	11/29/2022	12/01/2022
Final Report	**Estimated 5**	**12/02/2022**	**12/06/2022**

8. Contribution Matrix

Table 8.1: Contribution Matrix

	Michelle	**Munazza**	**Rodaba**	**Nivetha**	**Tioluwanimi**
Problem Identification		yes			
Background and Research	yes		yes		yes
Design Process	yes		yes		
Scenarios and Use Cases					yes
Stakeholder Requirements				yes	
Acceptance Tests		yes			
Project Plan	yes	yes	yes	yes	yes

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