Term Project

Development of Smart Drones for Fire Fighting

By *Pranav Chowdhary*
Chowdhary.p@northeastern.edu
+16175865904

Submission Date: 11/29/2021

EMGT5220: Engineering Project Management, Fall 2021
Northeastern University

Instructor: Prof. George Kontopidis

Table of Contents

1. Purpose

The average response time of the fire fighting department is between 5 to 15 minutes. During this time a small fire goes from destructive to extremely catastrophic. To avoid such situations fire-fighting drones can be deployed in swarms. These drones can assess the area hit by fire, map the area as well as look for the best possible and efficient ways to put out the fire. Majorly, they can start extinguishing by pouring out a rapid stream of water to contain the fire until the crew arrives to take over with a plan because of the data provided by the drones or 'Frones' (Fire+Drones). This solves the problem that the fire will not get a chance to grow as much that it gets difficult to extinguish it. The other such drones being built/ developed by companies are mostly focused on aspects other than pouring water. Talking about benefits, the crew will not have to put their lives in danger. In addition, as the response time will be reduced with the drones, water usage will minimize along with fewer mob casualties.

2. Objective

There are a lot of companies that make drones, but only a handful of them develop drones equipped for fire fighting. Thus, a product i.e., drone will be developed along with the software that provides the drone with the features to cater to the fire department's crew.
This product will be available and sold to the fire departments of various counties and the management companies of the buildings. It is a completely autonomous drone, but can also be controlled by authorized and certified personnel.

3. Scope

This project in a start-up will aim to develop and patent a drone design with the capabilities to extinguish a fire and provide a 3-D mapping of the affected area. Along with that a heat-sensing camera, an AI algorithm will be embedded into the software to check and provide the data to efficiently put out the fire. Apart from the drone design, proprietary software will be developed that will run the drone and make use of the hardware efficiently. The manufacturing of the drone is not done in house, it will be outsourced to a company which makes it out of scope.

4. Funder/Investor

Angel investors or venture capital firms will be the funders for this project. Qualcomm Ventures are the frontrunners because of their involvement in drones' technologies such as their in-house developed microprocessor called Flight Pro. In short term, the company will undergo multiple rounds of seed funding to develop the software and the drone design. Once the product is ready, it will be sold in bulk to the fire departments of each county. This will provide the investors their initial return on investment. Being a start-up the project itself is the company, hence in the long term the drones will be sold with the basic features in the software and a SaaS based model will be implemented. Customers will pay for the features they want to include in the software. This will majorly be executed for the management companies of commercial and residential buildings. In addition to that market expansion phase will roll out along with it to diversify in drone use cases. Lastly, a much higher return on investment is possible through IPO events.

Cash Flow:

The image below shows the flow of cash from investors to the company, then back to the company and then the investors as their return. The investors put out the seed money in round A. The first phase involves the use of money for the development of the drone design as well as the software that will be used to run it. The second phase will include expenditures on marketing and promotions of the product, before the official launch announcement, which will be sometime during the manufacturing process. The third phase will involve expenditure on sales team, and thus this is where the cash inflow will start. Sale of the drones will bring the ROI to the stakeholders. In addition, market expansion, IPO event and pushing towards SaaS based model will bring out the further profits to the company.

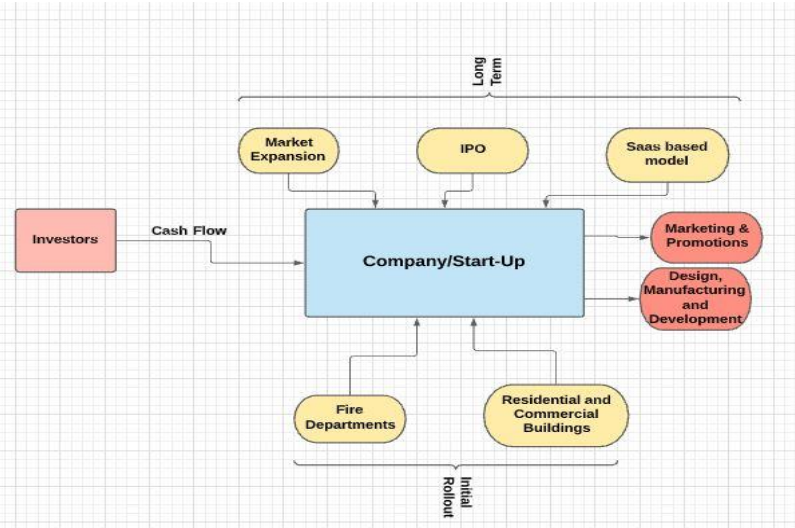


Figure 1- Cash Flow

5. Critical Success Factors

- The board of chief members of the company must keep a close relationship with the PM and provide regular feedback to satisfy the vision and aim.
- The market is accepting of the new technology. Due to early launched than the advent of the technology, the people do not support the product. Hence, the people and the market should be ready for the change in fire extinguishing technology.
- Rigorous testing and quality checks must be passes. This will allow the drone to with stand any weather conditions especially when carrying the extinguishing liquid weight.
- The light weight structure is supportive of the hardware (cameras', sensors etc) and can handle the any conditions.

6. Assumptions

- The investors must not back out of the deal as almost a half of it is going to be used for expansion one the initial product is launched. In addition to it, the government does not fall off the contract as initial chunk of revenue is going to come from the fire departments of various counties.
- The drone is capable of carrying the extinguishing liquid weight, which is >200lb.
- Firemen are efficient in using the technology and enough training is provided in order to control the drone swiftly if necessary.
- Quality is manufacturing is not compromised at all as even a slight disintegration may cause leaks disabling the drone to fly properly especially when carrying the extinguishing liquid weight.

7. Technical Approach

The company will be designing & fabricating a drone as well as developing a software. For the drone, a PCB board will be designed on Qualcomm's Flight microprocessor to match the project's purpose. The outer shell or the housing of the drone will be designed in-house. Possible manufacturing techniques will either be 3D printing or non-conventional manufacturing techniques for utmost accuracy, which will be outsourced. Several sensors and heat & RGB cameras will be fitted. In terms of software, AI algorithms will be deployed, leveraging the supervised, unsupervised, and reinforcement learning ML techniques.

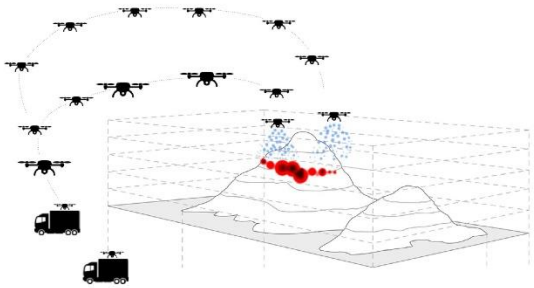


Figure 2 – Use Case of drones during emergency

8. Organization

As the company is a start-up, thus a fairly simple organizational structure is used. The CEO being the head of the company oversees all the operations. PM is also the CTO and most of the work involves Engineering and Technical Expertise. All the Engineers are supervised directly by the PM. In addition to this, CM&SO, Operations Manager and COO handle their own departments and eventually report to CEO.

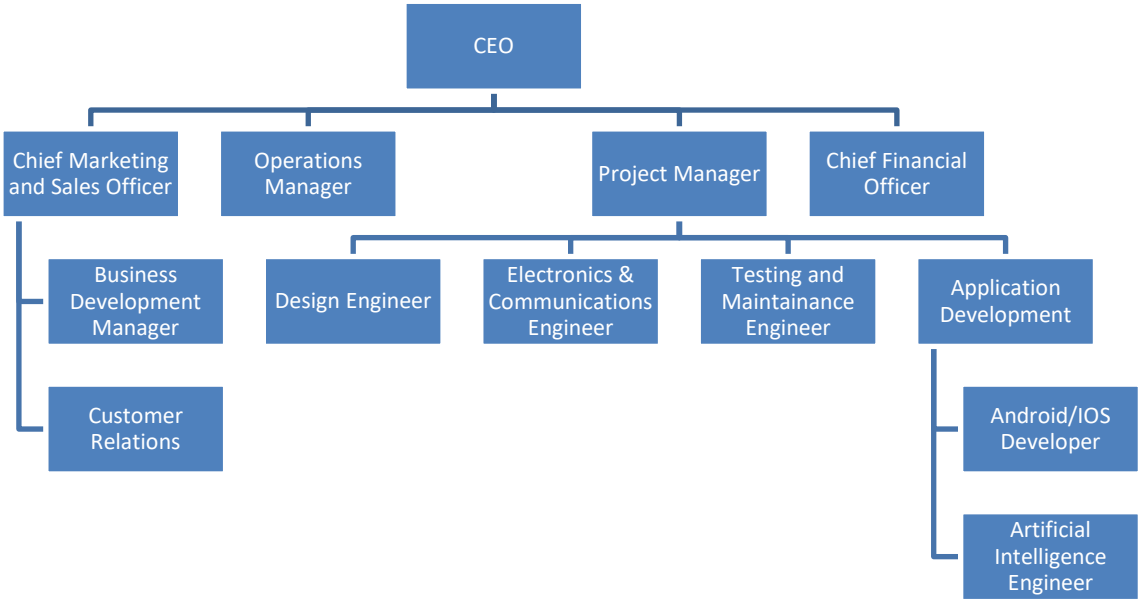


Figure 3 - Project Organization

9. Project Plan

a. Work Breakdown Structure (WBS)

It shows a complete breakdown of all the tasks to be achieved during the project to reach to the final goal.
Legend: DE – Design Engineer
E&CE – Electronics and Communication Engineer
AD – Android Developer
AID – Artificial Intelligence Engineer
TE – Testing and Maintenance Engineer
BDM – Business Development Manager
OM – Operations Manager
CR – Customer Relations

Task	Responsibility	Time (Weeks)	Dep.	Resources
1) Design Development				
a) Decide the Material	DE	1		
b) Check for Constraints	E&CE	1		
c) Design Propeller, Body	DE	2	1b	
2) Hardware Design & Development				
a) PCB Design	E&CE	5	2b	
b) Selection of components to be fit on the drone body	E&CE	2	1b	
c) Develop a firmware and upload it on PCB	E&CE	4	2b	
d) Build a working prototype to test flight	TE	**Milestone**	2c	
Milestone 1 – Successful testing of the prototype flight				
3) Application Development				
a) Design Drone Control Interface (DCI)	AD	6		
b) Design User Interface (UI/UX)	AD	6	3a	
c) Set up DCI with UI/UX	AD	1	3a,3b	
d) Test application in conjunction with the hardware	TE	**Milestone**	3c	
Milestone 2 – Successful testing with application able to handle the hardware				
4) Algorithm Development				
a) Collect Data and Develop a Reinforcement Learning Model	AID	4		
b) Training the Model	AID	2	4a	
c) Embed the model within the DCI	AD	1	4b,3c	
5) Prototype Testing				
a) Real world testing and pass the checks	TE	1	4c	
Milestone 3 – Real world testing with safety parameters and all AI, Hardware and Software functions				
6) Marketing				

a) Create campaigns for Commercial and Residential Buildings	BDM	3	7a	
b) Set-Up Cross Market Pitches	BDM	1	7a	
7) Operations				
a) Deal with Manufacturing	OM	24	5a	It is outsourced
b) Quality checks with each shipment	OM	1	7a	A basic quality check to be informed of any major issue.
8) Sales				
a) Create a Team	CR	2	7a	
b) Formulate a Script	CR	1	8a	

Table 1 - WBS

b. Resource Plan and Responsibilities (RACI)

RACI gives out the tasks and the personnel associated with them. In any project, a PM as well all the members must know what task is to be approached by whom to avoid confusion and have better efficiency without any roadblocks.
Legend: DE – Design Engineer
E&CE – Electronics and Communication Engineer
AD – Android Developer
AID – Artificial Intelligence Engineer
TE – Testing and Maintenance Engineer
BDM – Business Development Manager
OM – Operations Manager
CR – Customer Relations
CEO – Chief Executive Officer
CFO – Chief Financial Officer
CM&SO – Chief Marketing and Sales Officer

Tasks	Responsible	Accountable	Consulted	Informed
Decide the Material	DE	PM	PM	CEO
Check for Constraints	E&CE	PM	PM	CEO
Design Body, propeller	DE	PM	PM	CEO
PCB Design	E&CE	PM	PM	CEO
Selection of components to be fit on the drone body	E&CE	PM	PM	CEO & CFO
Develop firmware and upload it on PCB	E&CE	PM	PM	CEO
Build a working prototype to test flight	TE	PM	PM	CEO
Design Drone Control Interface (DCI)	AD	PM	PM	CEO
Design User Interface (UI/UX)	AD	PM	PM	CEO
Set up DCI with UI/UX	AD	PM	PM	CEO
Test application in conjunction with hardware	TE	PM	PM	CEO
Collect Data and Develop a Reinforcement Learning Model	AID	PM	PM	CEO

Training the Model	AID	PM	PM	CEO
Embed the model within the DCI	AD	PM	PM	CEO
Real World testing and pass checks	TE	PM	PM	CEO
Create campaigns for Commercial and Residential Buildings	BDM	CM&SO	CM&SO	CEO, PM & CFO
Set-Up Cross Market Pitches	BDM	CM&SO	CM&SO	CEO, PM & CFO
Deal with Manufacturing	OM	PM	PM	CEO & CFO
Quality Checks	OM	PM	PM/CFO	CEO
Create a Team	CR	CM&SO	CM&SO	CEO, PM & CFO
Formulate a Script	CR	CM&SO	CM&SO	CEO, PM & CFO

Table 2 - RACI

c. Financial Plan

The financials/budget of the project is $200,000 upon verifying the overheads. These are mentioned below with the expenditure per month and according to the tasks involved. A bulk of the money goes into manufacturing over 3 months which is outsourced to a company.

Monthly Budget ($)								
		Months						
Task ID	**Task**	**1 (Nov)**	**2 (Dec)**	**3 (Jan)**	**4 (Feb)**	**5 (March)**	**6 (April)**	**Totals**
1a	Decide the Material	500						**500**
1b	Check for Constraints	100						**100**
1c	Design Propeller, Body	1000	200					**1200**
2a	PCB Design	200	2800					**3000**
2b	Selection of components to be fit on the drone body	750						**750**
2c	Develop a firmware and upload it on PCB	600	1500					**2100**
2d	Build a working prototype to test flight		1000	4500				**5500**
3a	Design Drone Control Interface (DCI)	600	600					**1200**
3b	Design User Interface (UI/UX)	400	400					**800**
3c	Set up DCI with UI/UX		300					**300**
3d	Test application in conjunction with the hardware		800					**800**
4a	Collect Data and Develop a Reinforcement Learning Model	1400						**1400**
4b	Training the Model	1000	2000					**3000**
4c	Embed model within DCI		300					**300**
5a	Real world testing and pass the checks		4500	500				**5000**
6a	Create campaigns for Commercial and Residential Buildings					700	150	**850**
6b	Set-Up Cross Market Pitches					250	50	**300**
7a	Deal with Manufacturing			40000	40000	40000		**120000**
7b	Quality checks with each shipment					100	150	**250**
8a	Create a Team					50	350	**400**
8b	Formulate a script						100	**100**
Monthly Total		**6550**	**14400**	**45000**	**40000**	**41100**	**800**	**147850**

Table 3 - Budget

d. PERT Chart

It shows the tasks to be performed and how they interact with each other, ie. the dependencies of one task to another. In addition, the start date and the end dates have been given for each task to allow the project to have a smooth timeline.

Pert Chart Reference

Task ID	Task	Dep.	Time	Start Date	End Date
1a	Decide the Material		1	11/1/2021	11/8/2021
1b	Check for Constraints		1	11/1/2021	11/8/2021
1c	Design Propeller, Body	1b	4	11/9/2021	12/7/2021
2a	PCB Design	2b	4	11/23/2021	12/20/2021
2b	Selection of components to be fit on the drone body	1b	2	11/9/2021	11/23/2021
2c	Develop a firmware and upload it on PCB	2b	4	11/24/2021	12/22/2021
2d	Build a working prototype to test flight	2c	4	12/23/2021	1/20/2022
Milestone - 1					
3a	Design Drone Control Interface (DCI)		6	11/1/2021	12/13/2021
3b	Design User Interface (UI/UX)		6	11/1/2021	12/13/2021
3c	Set up DCI with UI/UX	3a, 3b	1	12/14/2021	12/21/2021
3d	Test application in conjunction with the hardware	3c	1	12/22/2021	12/29/2021
Milestone - 2					
4a	Collect Data and Develop a Reinforcement Learning Model		4	11/1/2021	11/29/2021
4b	Training the Model	4a	2	11/30/2021	12/14/2021
4c	Embed model within DCI	4b, 3c	1	12/22/2021	12/29/2021
5a	Real world testing and pass the checks	4c	1	12/30/2021	01/06/2022
6a	Create campaigns for Commercial and Residential Buildings	7a	3	04/04/2022	04/25/2022
6b	Set-Up Cross Market Pitches	7a	1	04/04/2022	04/11/2022
7a	Deal with Manufacturing	5a	12	01/07/2022	04/01/2022
7b	Quality checks with each shipment	7a	1	04/04/2022	04/11/2022
8a	Create a Team	7a	2	04/04/2021	04/18/2021
8b	Formulate a script	8a	1	04/19/2021	04/26/2021
Market Launch					

Table 4 - PERT

Pert Chart Using Gantt-Project

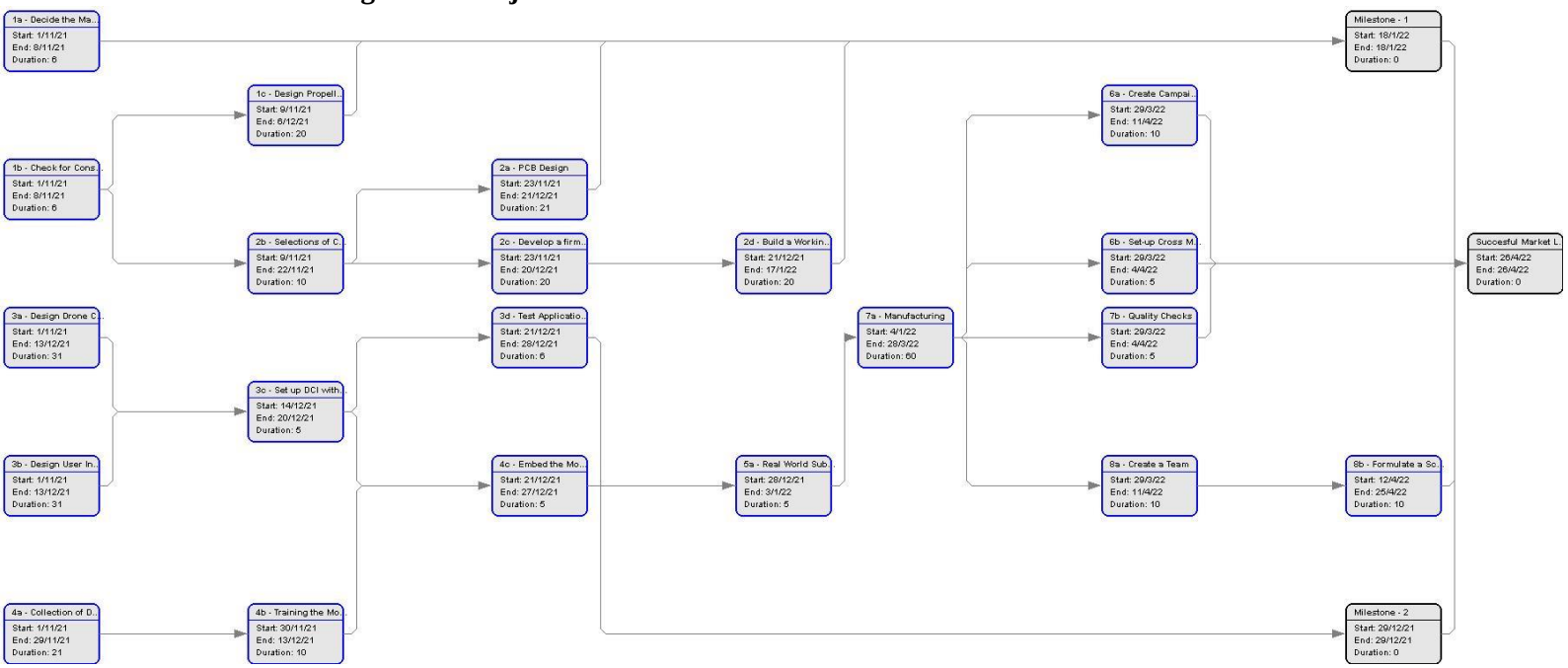


Figure 4 - PERT Chart using Gantt-Project

Pert Chart using WBS

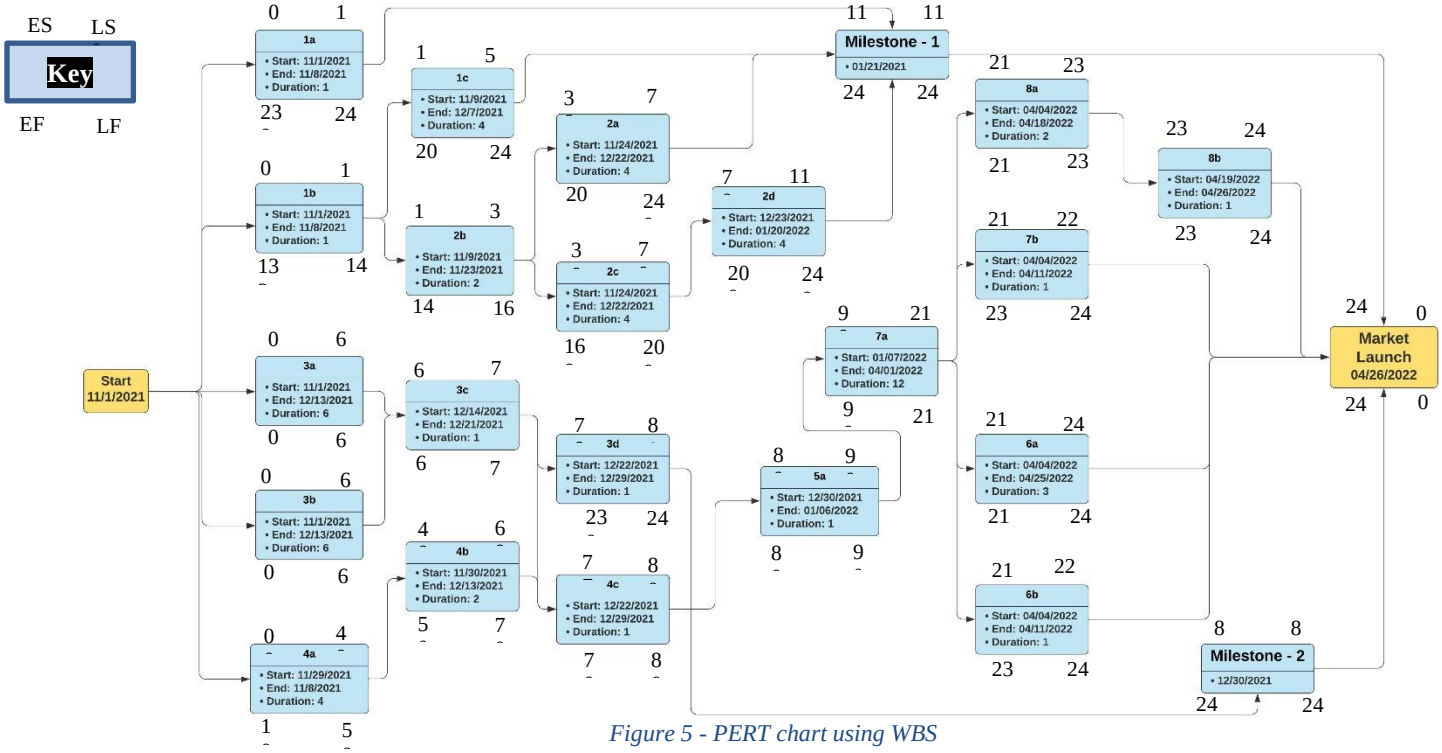
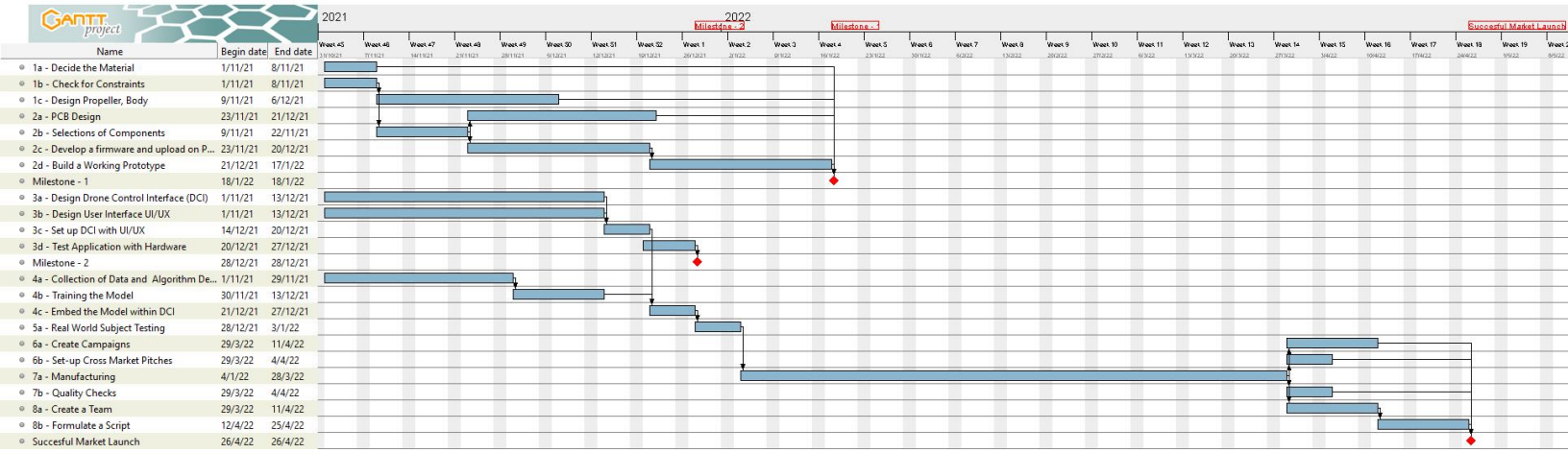


Figure 5 - PERT chart using WBS

e. Gantt Chart

It gives out the timeline of the project. It is a reflection of the PERT chart but with respect to time. The maximum time is taken up by manufacturing, while a lot of work is being done during the first few months. Hence, that time is pressurized and time-intensive.

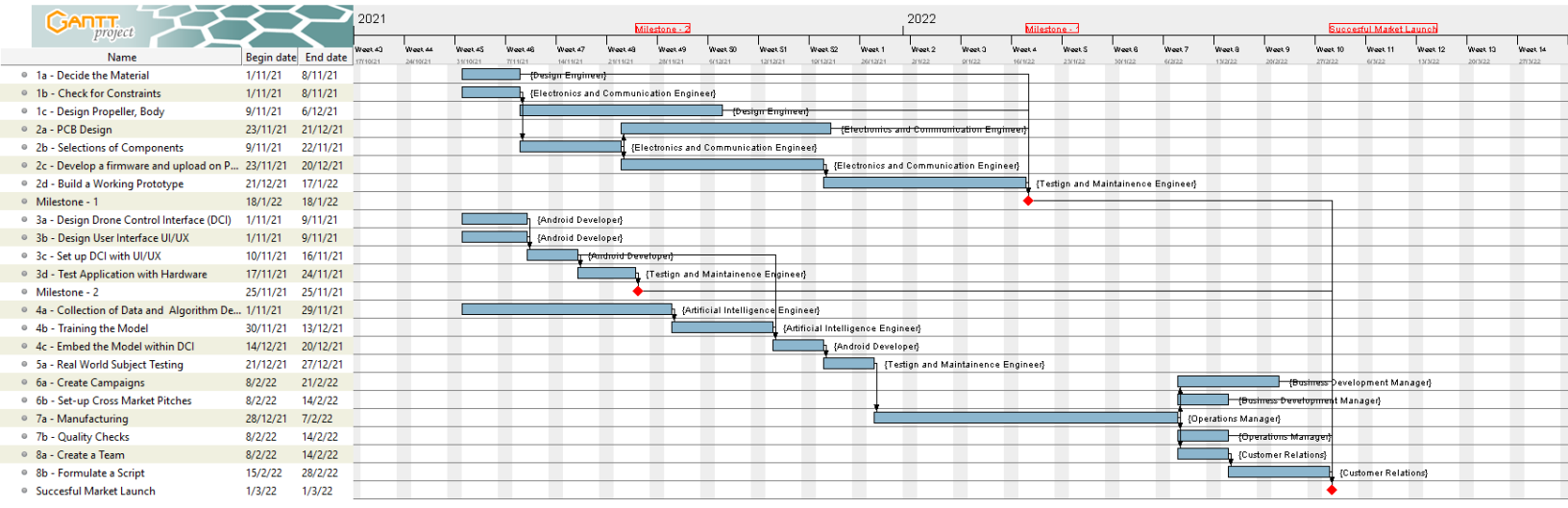


Name	Begin date	End date
1a - Decide the Material	1/11/21	8/11/21
1b - Check for Constraints	1/11/21	8/11/21
1c - Design Propeller, Body	9/11/21	6/12/21
2a - PCB Design	23/11/21	21/12/21
2b - Selections of Components	9/11/21	22/11/21
2c - Develop a firmware and upload on P...	23/11/21	20/12/21
2d - Build a Working Prototype	21/12/21	17/1/22
Milestone - 1	18/1/22	18/1/22
3a - Design Drone Control Interface (DCI)	1/11/21	13/12/21
3b - Design User Interface UI/UX	1/11/21	13/12/21
3c - Set up DCI with UI/UX	14/12/21	20/12/21
3d - Test Application with Hardware	20/12/21	27/12/21
Milestone - 2	28/12/21	28/12/21
4a - Collection of Data and Algorithm De...	1/11/21	29/11/21
4b - Training the Model	30/11/21	13/12/21
4c - Embed the Model within DCI	21/12/21	27/12/21
5a - Real World Subject Testing	28/12/21	3/1/22
6a - Create Campaigns	29/3/22	11/4/22
6b - Set-up Cross Market Pitches	29/3/22	4/4/22
7a - Manufacturing	4/1/22	28/3/22
7b - Quality Checks	29/3/22	4/4/22
8a - Create a Team	29/3/22	11/4/22
8b - Formulate a Script	12/4/22	25/4/22
Succesful Market Launch	26/4/22	26/4/22

Figure 6 - Gantt Chart

Gantt Chart after Crashing

To crash the project two critical paths were identified and hence as per the budgeting shown in the above table cost for each week was taken for each task. As the tasks in the critical were brought down to the minimum time in which they could be done the cost increased. The tasks with the duration of 1 week were denied for crashing, hence all other tasks were considered in the critical path along with the least cost per week. The project was accelerated by 6 weeks with a cost of approximately $60,000.



Name	Begin date	End date
1a - Decide the Material	1/11/21	8/11/21
1b - Check for Constraints	1/11/21	8/11/21
1c - Design Propeller, Body	9/11/21	6/12/21
2a - PCB Design	23/11/21	21/12/21
2b - Selections of Components	9/11/21	22/11/21
2c - Develop a firmware and upload on P...	23/11/21	20/12/21
2d - Build a Working Prototype	21/12/21	17/1/22
Milestone - 1	18/1/22	18/1/22
3a - Design Drone Control Interface (DCI)	1/11/21	9/11/21
3b - Design User Interface UI/UX	1/11/21	9/11/21
3c - Set up DCI with UI/UX	10/11/21	16/11/21
3d - Test Application with Hardware	17/11/21	24/11/21
Milestone - 2	25/11/21	25/11/21
4a - Collection of Data and Algorithm De...	1/11/21	29/11/21
4b - Training the Model	30/11/21	13/12/21
4c - Embed the Model within DCI	14/12/21	20/12/21
5a - Real World Subject Testing	21/12/21	27/12/21
6a - Create Campaigns	8/2/22	21/2/22
6b - Set-up Cross Market Pitches	8/2/22	14/2/22
7a - Manufacturing	28/12/21	7/2/22
7b - Quality Checks	8/2/22	14/2/22
8a - Create a Team	8/2/22	14/2/22
8b - Formulate a Script	15/2/22	28/2/22
Succesful Market Launch	1/3/22	1/3/22

Figure 7 - Gantt chart after crashing

Resource Loading

The engineers are added to the software as per the tasks in RACI. But due to overlapping of tasks with the same engineer, it can be seen that Electronics & Communication Engineer, Android Developer are overworked.

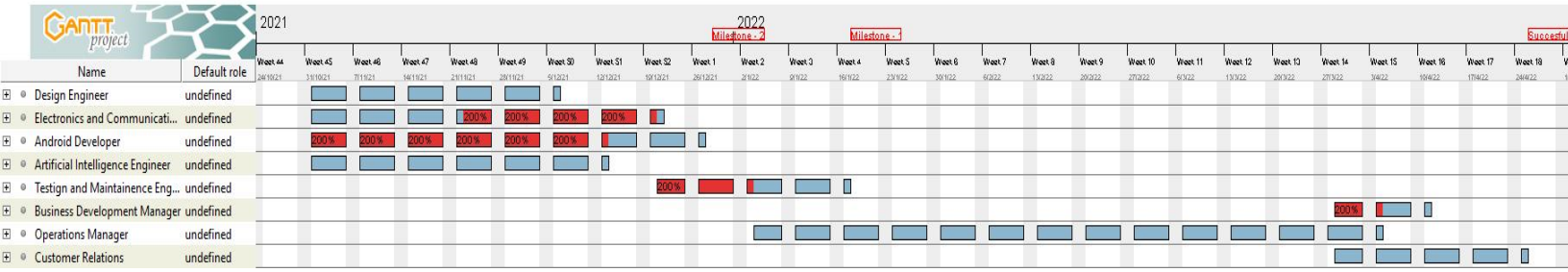


Figure 8 - Resource Loading

Resource Leveling

On changing the dependency of task 2c on 2a, it was possible to remove the overloading for Electronics and Communication Engineer but it increased the timeline. On the other hand, along with Android Developer, UI/UX developer is added along with Android Developer to take the load off.

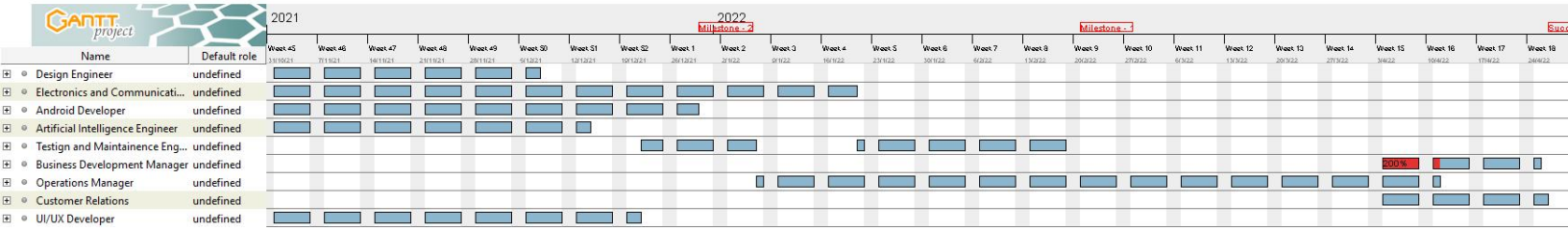


Figure 9 - Resource Leveling

Gantt Chart after Resource Leveling

Gantt Chart has widened a little bit and added to the timeline along with the cost of UI/UX Developer but with the overworking of engineers, it is better to adjust the load to avoid any delay.

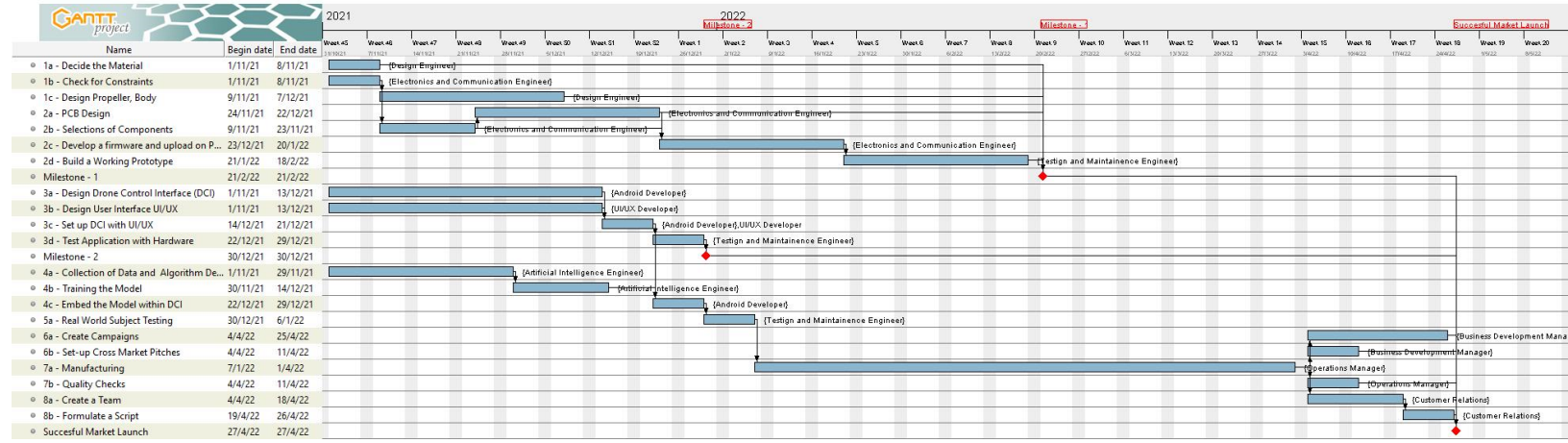


Figure 10 - Gantt chart after resource leveling

10. Risk Assessment

A. SWOT Analysis

➔ These depictions below show the risks involved in the project, thus as a project manager, I have a calculated plan to counter them and thereby handle the stakeholders.

Figure 11 - SWOT Analysis

B. 3x3 Risk Matrix

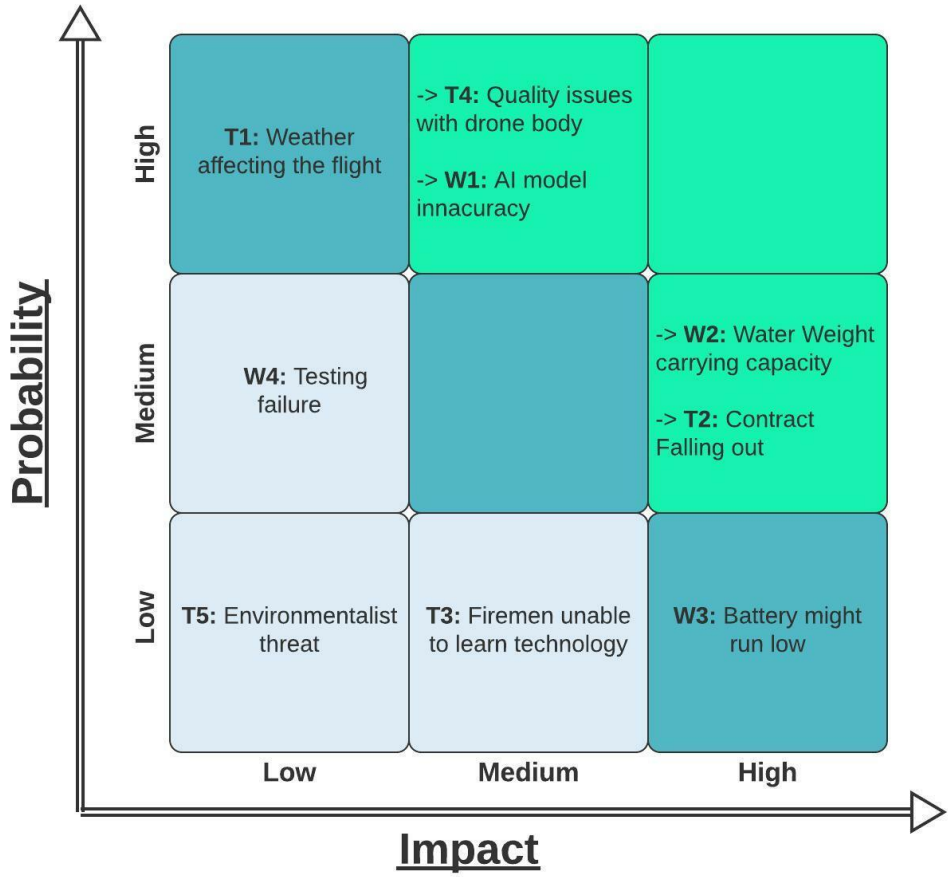


Figure 12 - 3x3 Risk Matrix

C. FMEA (Failure Mode and Effect Analysis)

The score is given out of 10 for each factor i.e severity (S), Likelihood (L), Inability to detect (D). Multiplying S, L, D gives RPN – Risk Priority Number. This allows us to get a better understanding of which risk is to be prioritized and according make a mitigation plan.
The number 1 – depicts least; 10 – depicts high

S.No.	Threats/Risks Involved	Severity (S)	Likelihood (L)	Inability to Detect (D)	RPN = SxLxD	Risk Factor	Mitigation
1	Quality issues with the drone body	4	9	3	108	Medium	Creating KPIs during quality check.
2	Weather affecting the flight	3	8	6	144	Medium	Robust and sturdy material to be used for drone body.
3	AI model inaccuracy	5	6.5	2	65	Low	A large data set will improve accuracy.
4	Water weight carrying capacity	10	7	4	**280**	High	

5	Contract falling out	8	5	9	**360**	High	Analyzing and keeping the stakeholders informed will play a key role.
6	Testing failure	2	4	8	64	Low	
7	Firemen unable to learn the technology	6	3	8	144	Medium	Hold seminars and teaching lessons to overcome this barrier
8	Battery running out	9	2	9	162	Medium	Avoiding the over usage of hardware components will help. Avoiding heat-generating components.
9	Environmentalist threat	1	1	10	10	V. Low	

Table 5 - FMEA

11. Monitoring

As seen in the WBS and the PERT chart I have opted for the milestone approach. With the completion of the prototype, which contains the hardware and a basic body layout with the hardware attached to it. It includes cameras, sensors, etc. This gives the 1st Milestone. Subsequent milestones come when the software is ready to be deployed with the prototype to test the remote flight with the tablet and when the final subject testing is done. This way the project stays in a feedback loop.

In addition, the 50-50 rule will be the most appropriate as the milestones can be treated as phases. Therefore, these phases can be thought to be the points where I as PM can look at the earned value of the overall project. This way the cost and the schedule stay in check. As this rule assigns 50% value once the task is started, and 50% value once the task is done, the budget calculated at the starting of the project can be mapped with this estimate at completion through the 50-50 rule.

.

12. Summary

The smart drone is a necessity now for fire–fighting as other means like extinguishing cylinders are getting moot. Large fires need to be contained to conserve the environment as well and to protect the lives of firemen who are always in life-threatening situations.

The success of the project is the main focus to capture an empty void in the market.

The WBS has been developed with all the tasks required for the successful completion of the project. Along with 3 milestones, it follows a traditional/waterfall approach. Gantt chart and PERT chart deliver consistent results as per WBS and show a 5-month plan for market launch. AS per the budget allocation and the resource loading the total cost will go as high as $210,000 when crashed. Risk assessment is also carried out to understand the potential failure causes and thus mitigation plan is provided against each threat or weakness.

13. Appendix

a. Mind Map

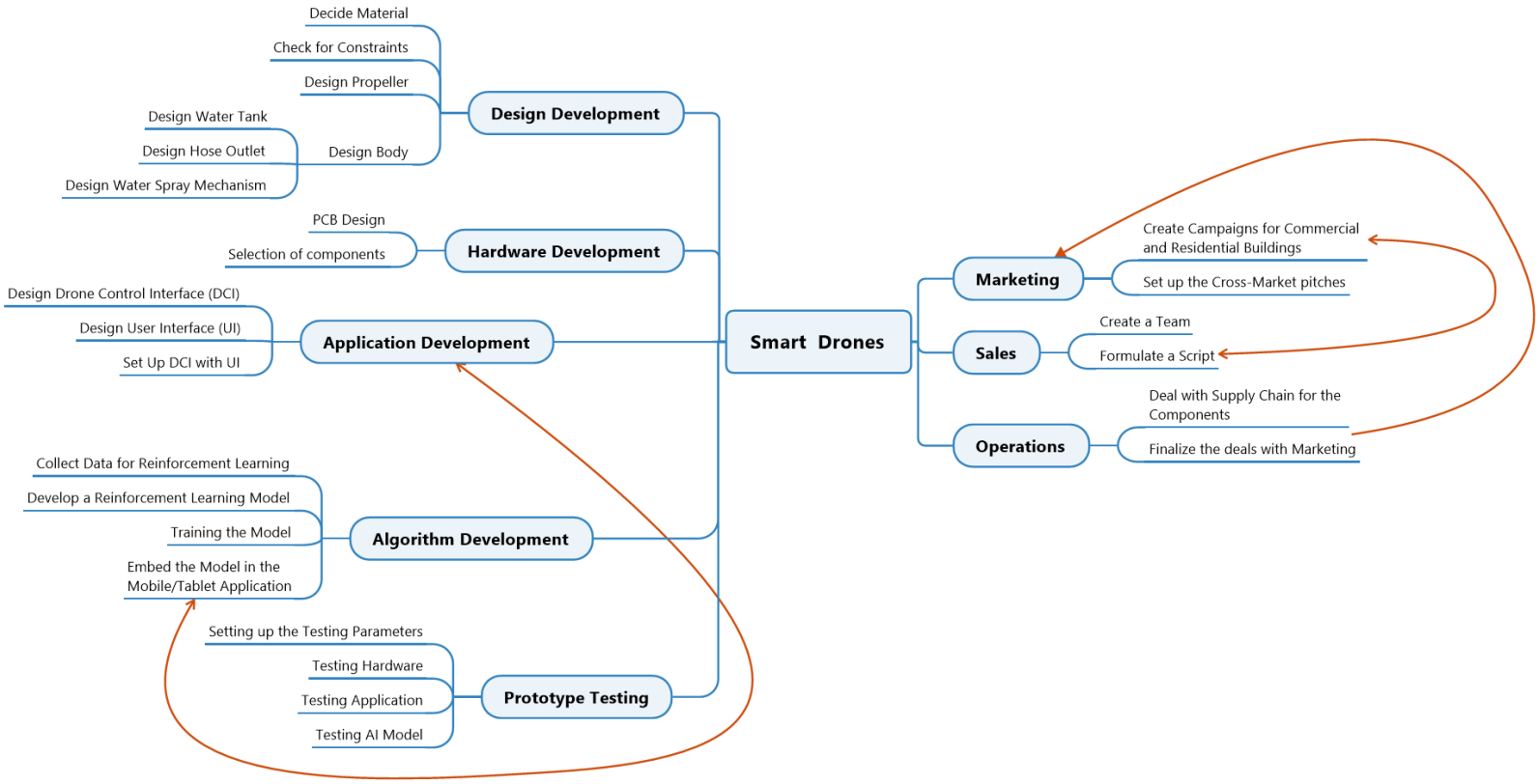


Figure 13 - Mind Map

b. Sequence Diagram

It shows the interaction between a fireman when they get a call for fire. The user interacts with the tablet having the software on it. The software further interacts with the drone to fulfill user demands and exchange the data to aid the fireman.

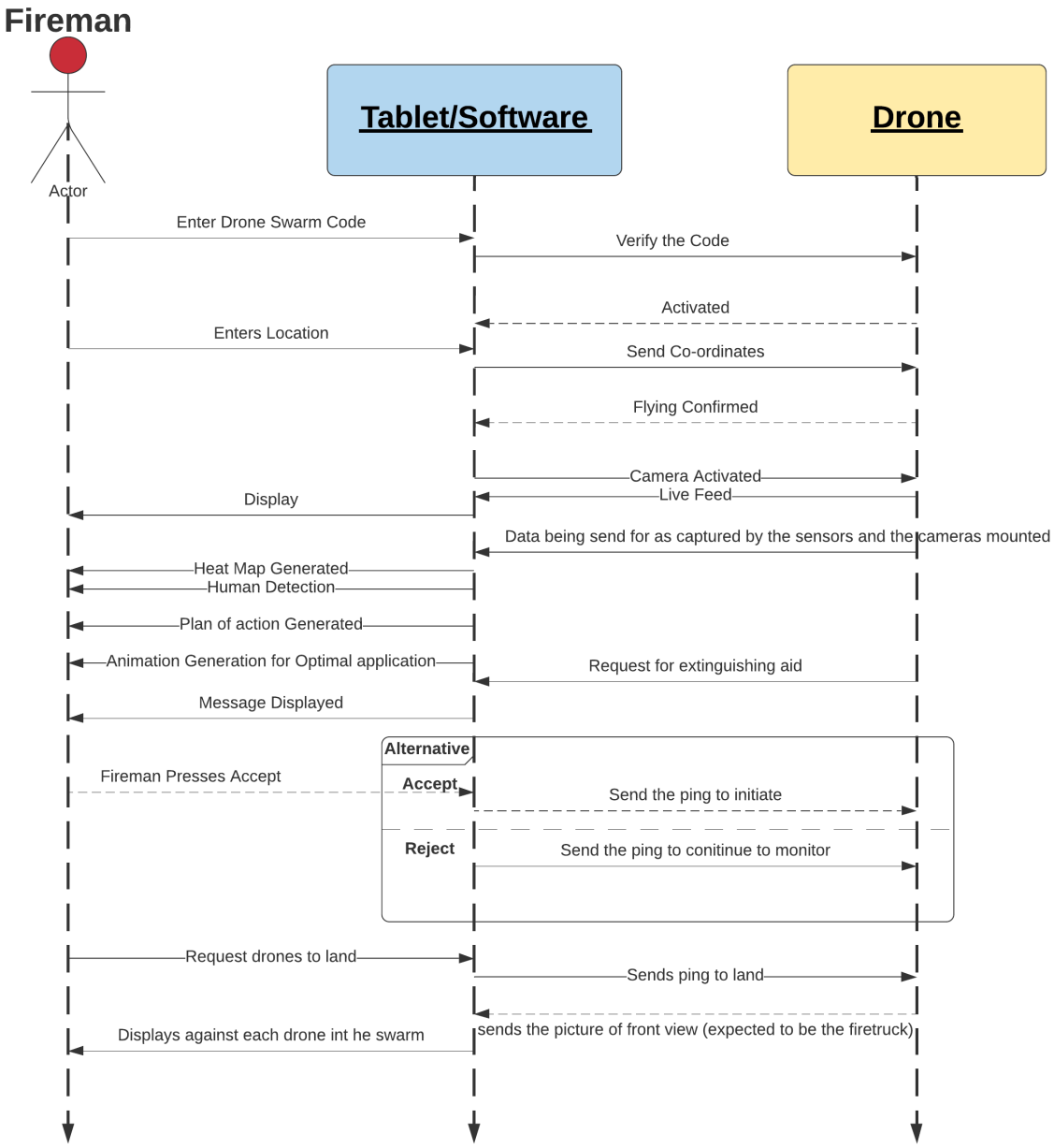


Figure 14 - Sequence Diagram

c. Component Diagram

This shows the software layers and what it includes. It has 3 layers with each of the layers containing the below-mentioned options on that page. The user can interact with them through the tablet.

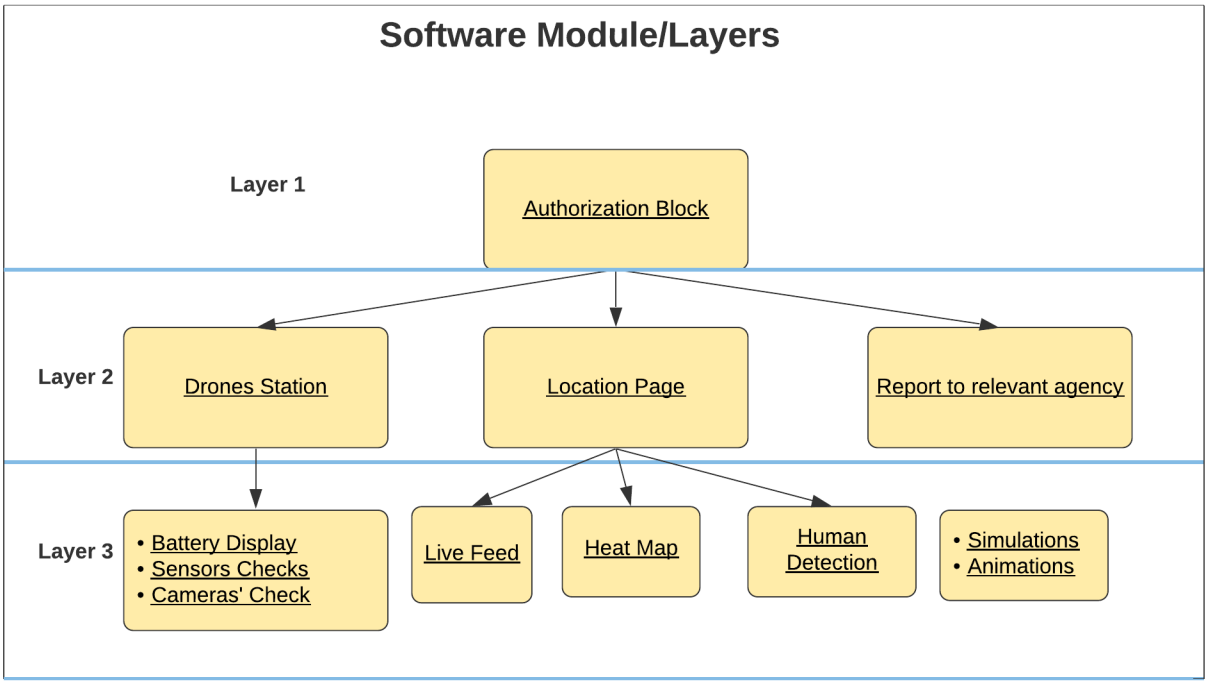


Figure 15 - Component Diagram

`

14. References

- https://dronelife.com/2021/04/28/drone-swarms-for-firefighting-the-future-of-fire-supression/
- https://pages.skydio.com/public-safety-drone-series.html
- https://developer.qualcomm.com/hardware/qualcomm-flight-pro
- https://www.cbinsights.com/research/drone-most-active-investors/
- https://scholar.google.com/
- https://ieeexplore.ieee.org/document/8533926