IC 201P – Design Practicum

Fire Extinguishing spray mechanism on drone

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Certificate

This is to certify that the work contained in the project report entitled “Fire Extinguishing spray mechanism on drone”, submitted by Group 46 to the Indian Institute of Technology Mandi, for the course IC 201P – Design Practicum, is a record of bonafide research works carried out by him under our direct supervision and guidance.

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Signature and Date

Dr. Jagadeesh Kadiyam

Signature and Date

Acknowledgements

I would like to take this opportunity to express my heartfelt gratitude to all those who have contributed to the successful completion of this college project.

Firstly, I extend my sincere thanks to our esteemed mentors **Dr. Amit Shukla** and **Dr. Jagadeesh Kadiyam**, who provided us with the guidance and support throughout the project. Their valuable insights, constructive criticism, and unwavering encouragement were instrumental in shaping our ideas and turning them into a tangible reality.

I would also like to extend my gratitude to our teaching assistant **Prashant Rana** who was always available to clarify our doubts and provide us with the necessary resources. Their dedication and commitment to our project were invaluable in helping us achieve our objectives.

I would also like to appreciate my team members **Bhavay Aggarwal, Chinta Bhanushri, Prem Shankar, Soham Chongder, Bhavy Rahangdale** and **Shashank Dwivedi** for their exceptional collaboration, hard work, and commitment to the project. Each one of us brought unique skills and perspectives to the table, and our combined efforts resulted in a project that exceeded our expectations.

Lastly, I would like to thank the college administration for providing us with the necessary infrastructure, facilities, and resources.

Thank you all for your contributions, support, and encouragement throughout this project. Your guidance and support have been invaluable in helping us achieve our goals, and we couldn't have done it without you.

Abstract

The overall goal of the project would be to design and develop a subsystem in a fire extinguisher drone that can quickly and effectively suppress fires in remote or hard-to-reach areas. The drone would be equipped with a fire extinguisher system that can be remotely controlled, allowing it to quickly reach the source of the fire and extinguish it before it spreads.

The project would involve several stages, including understanding the drone design and its limitations of use, testing of the fire extinguisher system, and integration of the system with the drone. The drone would also need to be equipped with a camera to allow for real-time monitoring which upon integration with the ML model will help control extinguishing parameters.

The fire extinguisher drone would have a wide range of potential applications, including in industrial settings, wildfire suppression, and emergency response situations. By providing a rapid and effective response to fires, the drone could help to prevent the loss of life and property damage that often occurs as a result of fires.

Overall, the project would aim to improve fire safety and emergency response capabilities by developing an innovative and effective technology that can help to prevent and mitigate fires in a variety of settings.

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Chapter 1

Introduction

Background and Scope of Problem

Fire departments are seeing large benefits from the use of drones during structure fires and search and rescue missions. In the case of a structure fire, when first arriving on the scene, the drone can be deployed to assess the scene, before the firefighters are put in harm's way.

When equipped with a thermal camera, the drone can show operators where the hotspots are, and also have the ability to see through smoke and in low light conditions.

The thermal camera can then allow operators to monitor crew members and conditions, improving efficiency and safety. The drone can also be equipped with a spotlight to assist firefighters in dark or low light conditions. After the smoke has cleared, drones can also aid in the critical work of assessing the damage, whether it be from a fire or other natural disasters. Drones allow firefighters to quickly and effectively scout out dangerous fires, observe and monitor a large blaze and the surrounding area and more.

Design Philosophy

Our design is inspired from the term simplicity where we have kept everything fit to our requirements keeping the aesthetic look of drone.

Problem Statement

Building a subsystem for fire extinguisher drone that can control the flow rate of fire extinguishing material based on the amount of fire.

Beneficiaries

Beneficiaries from the fire extinguishing drone are:

- Firefighters who have difficulty in entering the above floors of high rise buildings.
- MNC's which can use drones in case of fire emergency in high rise buildings.

Organization of this Report

The report is organized in such a way that it gives you the clear pictures of how we will develop this subsystem.

Chapter 2

Market Research

Existing Market Products

Firefighting drones have become increasingly popular in recent years due to their ability to reach inaccessible areas and quickly extinguish fires. Several types of firefighting drones are currently available on the market, each with its unique features and capabilities.
The DJI Matrice 300 RTK and the DJI Mavic 2 Enterprise Dual are two popular drones designed for firefighting.
But none of the existing products have automatic controls. In our project we will be integrating the camera with an extinguishing subsystem so that manual operation is reduced to a minimum extent. Moreover our project design would be modular so it could be used for both tanker based and tethered connection based model.

None of the existing products in the market have automatic controls. In our project we will be integrating the camera with an extinguishing subsystem so that manual operation is reduced to a minimum extent. Moreover our project design would be modular so it could be used for both tanker based and tethered connection based model.

Comparison with existing technology

The integration of automatic controls into our project's camera and extinguishing subsystem will bring numerous benefits. It will allow for more efficient and faster response times to fires, reducing the potential for extensive damage and loss of life. The reduction in manual operation also reduces the risk to firefighters, who can be placed in dangerous situations when manually operating firefighting equipment.

The modularity of our design means that it can be easily adapted for use in different contexts. The tanker-based model will be useful for firefighting in areas without a readily available water supply, such as remote rural areas. The tethered connection model, on the other hand, will be useful in urban areas where there is easy access to water sources.

Overall, our project aims to provide a more advanced and efficient approach to firefighting. With the integration of automatic controls and modularity, we believe that our design will greatly improve the safety and effectiveness of firefighting operations.

Problems with the existing fire extinguishers drones

There are several problems with existing fire extinguishing drones, including:

1. <u>Limited capacity</u>: Most existing fire extinguishing drones have limited capacity and can only carry a small amount of water or fire retardant. This limits their effectiveness in extinguishing large fires. Tethered connection can solve this problem.

2. <u>Limited range</u>: The range of existing fire extinguishing drones is limited by their battery life and communication range. This makes them less effective in extinguishing fires in remote or inaccessible areas.

3. <u>Limited accuracy</u>: Existing fire extinguishing drones may have limited accuracy in targeting fires, especially in windy conditions. This can lead to wasted resources and ineffective firefighting efforts. Usage of high quality motor and other subparts can improve this to a certain extent.

4. <u>Limited adaptability</u>: Many existing fire extinguishing drones are designed for specific types of fires or environments, and may not be easily adaptable to different situations. Usage of the best type of extinguishing agent can help in this matter.

5. <u>Limited autonomous capabilities</u>: Some existing fire extinguishing drones require human operators to control them, which can limit their effectiveness

and increase the risk to human operators in dangerous situations. Through our automation model we have solved this problem in a simple way.

Addressing these challenges will be critical in developing more effective fire extinguishing drones that can improve the safety and effectiveness of firefighting operations. Through our model we solved most of the existing problems related to firefighting drones.

Chapter 3

Conceptual Design

Ideation

Initially we decided to create a drone that has the capabilities to extinguish fires . Our goal was to maximize the range and variety of fires extinguished while using the most efficient material to do so in the process. We enlisted all types of extinguishing materials and also the types of nozzles, pipes, etc. We wrote a code for the optimization function. We then decided to integrate a camera to our subsystem.

After seriously considering the various agents that we can use for extinguishing fire , we find foam to be the most suitable one. Along with this we decided to conserve the material by automating it to stop and start depending on the presence of fire. The switching mechanism was also of PWM type integrated within the pump, so can be used later on to control the flow. We finalized on a 220 PSI , 10L/min diaphragm pump to spray out our foam and a conduit of 1.3m of PVC and also a tank of 10L capacity.

Types of Fires

Types of fires	**Fuel source**	**Examples**
Class A	Ordinary combustibles	Wood, paper, cloth, plastic
Class B	Flammable liquids and gasses	Gasoline, propane, oil, solvents
Class C	Electrical	Electrical panels, wiring, appliances
Class D	Combustible metals	Magnesium, titanium, sodium

Fire extinguishing materials

SL No	Element	Density	Types of fire	Limitations	Advantages
1	Water	1 kg/m3 and is nearly free	A	• add Anti - freezing additives(KCl,MgCl,etcl) • Corrosion inhibiting additives(alkyl phosphate, alkyl carbonate,sodium silicate ,potassium chromate) • Accessories conservation Preservatives to prevent the growth of algae and fungi(Rachit Salt , Ammonium compounds) • Sometimes vapourise near core of fire	• Readily available • Lowest Cost(even with additives) • No special tank needed
2	Wet Water	≈1 kg/m3 and is ≈₹6/kg(approx calculator from a product on IndiaMart)	A, B	• Same as above	• Can reach core of fire • Can extinguish B type of fire • Successfully extinguishes Buna rubber fire and wood house fires as opposed to normal water
3	Foam	1001 ± 2 kg/m3 and is ₹50/kg (as per IndiaMArt) [AFFF foam]	A,B	• Inefficiency in Extinguishing fire on one side • As it contains large quantity of water , so all problems with water also happen here • zero -effectiveness and impact in extinguishing fires solvents	• cooling effect is good, that heavy foam used to extinguish fires, wood, rubber, paper, plastic ... etc. • The heavy duty foam succeed in extinguishing fires, houses,halls and warehouses • high density foam allow large coverage areas.
5	Carbon Dioxide	1.87 kg/m3 and is ₹15/kg (as per IndiaMart)	A,B,C,D,E	• Not quite good with liquids and solids that catch fire	• Especially good for E type fires • Is able to isolate the oxygen so extinguishes all types of fire • Cheaper than Foam • Highly compressible

SL No	Element	Density	Types of fire	Limitations	Advantages
6	Hydrocarbon halides	1590 kg/m3 and is ₹99/kg (as in IndiaMart) [Tetrabromo Bisphenol A]	A,D,E	• They break down due to the impact of heat to the drugs and toxic compounds such as phosgene and others . • Expensive	• Used to extinguish the fires of electricity and also used successfully to extinguish the fires of goods, machinery, precious and valuable
7	Dry Powder	1.9-2.6kg / m3 and is ₹180/kg (as in IndiaMart) [ABC Dry Chemical powder]	A,B,C {special chemicals for wider range are also available}	• Fearing caking powder or ossification during transport and storage in addition to elongated sealing materials anti caking or ossification , such as magnesium stearate	• Experience has shown the U.S. in the field of fire that 9 kg of dry powder is equivalent to (150) liters of liquid foam, or 45 kg of carbon dioxide in effectiveness.

Types of Nozzles

Nozzle Type	Fire type	Description	Advantages
Fog Nozzle	Class A	Creates a fine mist that helps to cool the fire and disperse the extinguishing agent more effectively	Can be used for direct attack or exposure protection
Smooth Bore Nozzle	Class B	Has a straight, smooth outlet that produces a solid stream of water or other extinguishing agent.	Can penetrate burning liquids and gasses more effectively than a fog nozzle
Combination Nozzle	Class A and B	Can switch between a straight stream and a fog pattern	Versatile and can be used in a wide range of firefighting scenarios

Piercing Nozzle	Structure fires	Has a pointed tip that can penetrate materials like roofs or walls to reach fires that are difficult to access	Can be used for roof ventilation or direct attack through walls

Chapter 4

Embodiment and Detailed Design

Product Architecture

The subsystem consists of several components, including a fire extinguishing agent tank, a spray nozzle, a pump, and a control system. The fire extinguishing agent can be a liquid or a powder, depending on the type of fire being extinguished.

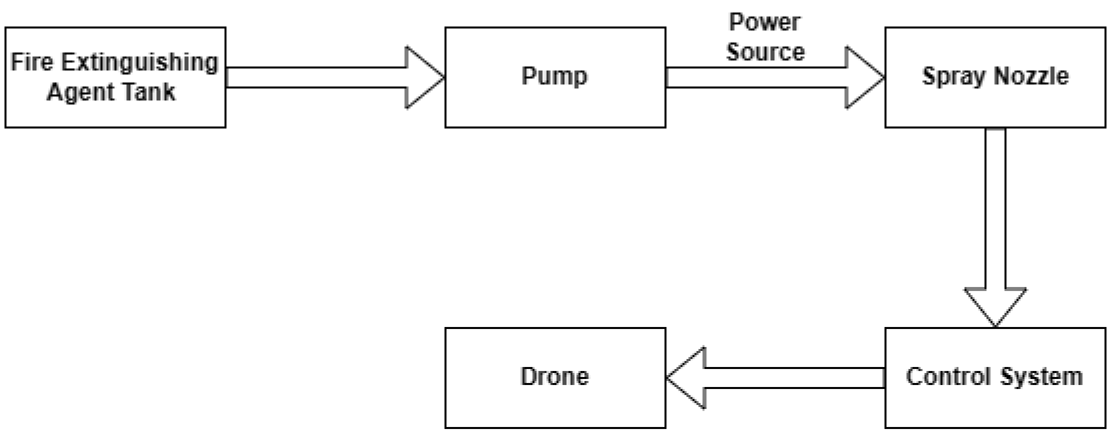


Figure 1:Block Diagram of product architecture

Working Principle:
The subsystem carries a fire extinguishing agent, such as water or foam, in a tank mounted on the drone. The pump pressurizes the agent and sends it to the spray nozzle, where it is sprayed onto the fire in a fine mist or stream. The control system manages the flow rate and direction of the spray, ensuring maximum effectiveness in extinguishing the fire.

The pump used in the subsystem can be either a positive displacement pump or a centrifugal pump. Positive displacement pumps provide a constant flow rate and are well-suited for spraying a consistent amount of extinguishing agent on a fire. Centrifugal pumps, on the other hand, are more suited for high flow rates and can be used to deliver a large amount of extinguishing agent quickly. The choice of pump depends on the requirements of the specific application.

The spray nozzle used in the subsystem can be either a fixed or an adjustable nozzle. Fixed nozzles provide a consistent spray pattern and are ideal for extinguishing fires in a specific area. Adjustable nozzles, on the other hand, allow for changes in the spray pattern and can be used to extinguish fires in different areas.

The control system used in the subsystem manages the flow rate and direction of the spray. It can be programmed to follow a specific path or be controlled remotely by an operator. The control system can also be equipped with sensors that monitor the fire and adjust the flow rate and direction of the spray accordingly.
Our subsystem would be automated as it will start spraying the extinguishing material as soon as fire is detected in the camera mounted on the drone.

Feasibility of the Design Concept:
The design concept of a fire extinguishing spray subsystem on a drone is highly feasible and has numerous advantages. Drones are able to quickly and effectively reach hard-to-reach areas, such as forests or high-rise buildings, where fires can be difficult to extinguish using traditional firefighting methods. Additionally, drones can be flown close to the fire, allowing for better accuracy and control over the spray.

The fire extinguishing spray subsystem on a drone can also be operated remotely, reducing the risk to human firefighters. This is especially important in situations where the fire is too dangerous for firefighters to approach. The system can be operated by an operator who is a safe distance away from the fire, providing a higher level of safety and control.

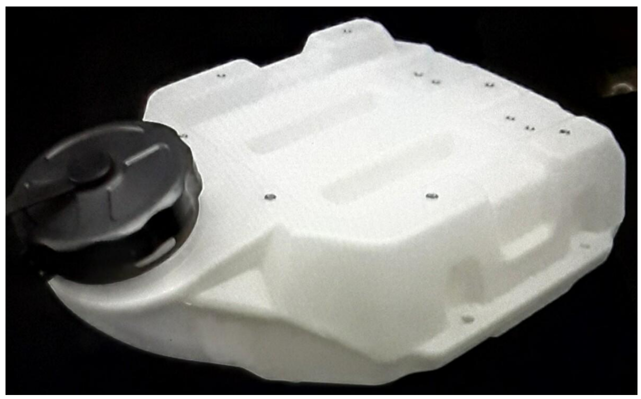
Overall, the fire extinguishing spray subsystem on a drone is a highly effective and feasible design concept for fighting fires. With its ability to reach hard-to-reach areas quickly and safely, it has the potential to greatly improve the efficiency and safety of firefighting operations.

System-level design

<u>Function of each subcomponent which interacts with each other</u>

a. Fire Extinguishing Agent Tank:

The fire extinguishing agent tank stores the fire extinguishing agent. It is connected to the pump through a flexible hose, allowing the pump to draw the extinguishing agent from the tank for pressurization.



b. Pump:

The pump is connected to the fire extinguishing agent tank and pressurizes the agent for spraying through a flexible hose. In a tethered setup, the hose is connected to a power source on the ground. In an untethered setup, the pump is powered by the drone's onboard battery.

c. Spray Nozzle:

The spray nozzle is connected to the pump through a pipe and sprays the fire extinguishing agent onto the fire. In a tethered setup, the pipe is connected to the drone, allowing for greater flexibility in directing the spray. In an untethered setup, the nozzle is mounted directly onto the drone and can be directed using the drone's flight controls.

<u>Different fire extinguishing nozzles</u>

Nozzle Type	
Fog Nozzle	
Smooth Bore Nozzle	

Combination Nozzle	
Piercing Nozzle	

d. Control System:

The control system manages the flow rate and direction of the spray, whether for tethered or untethered use. It is programmed to follow a specific path and controlled remotely by an operator. In a tethered setup, the control system is operated using a tethered controller on the ground. In an untethered setup, the control system is integrated into the drone's onboard control system.

e. Power Source:

The power source provides the necessary power to operate the subsystem, whether for tethered or untethered use. In a tethered setup, the power source is located on the ground and connected to the pump and control system through a power cable. In an untethered setup, the power source is onboard the drone, such as a battery or fuel-powered generator.

Design configuration

The design configuration of the fire extinguishing drone project involves careful analysis of the product architecture, selection of appropriate components, preliminary design, optimization, and modular design.

The analysis of the product architecture helps to understand the functional requirements, operating environment, and dimensional constraints of the drone. Based on this analysis, the design team has selected the components needed to build the drone. In this case, the project utilizes a Heavy Duty Diaphragm Pump Operated with a 12v Battery, nozzle pipe(3m long with ¾" diameter), and a camera.

The preliminary design is developed based on the selected components, taking into account the specified requirements and dimensional constraints. The design team ensured that the shape and general dimensions of the drone are optimized for the project requirements.

In the optimization stage, the preliminary design underwent a series of iterations to ensure that it can be manufactured efficiently and cost-effectively. The design team carefully considered material selection, part sizing, and manufacturing processes during this process.

Once the design is finalized, the drone will undergo testing to ensure that it meets the specified functional requirements and operates as expected.

Shape and dimensions of components

a. Fire Extinguishing Tank- 10 L plastic tank
b. Extinguishing Material- Foam
c. Pump- Pump used in the project is 12v DC Water Pump Battery Sprayer Motor Double High Performance 12V Dc 220 Psi.It is capable to provide 220 PSI Pressure with 10.3 Bar Cut off and the open Flow is 10 Litre Per Minute.
d. Spray Nozzle- Orifice Diameter: 5.15 mm , size: ¾" , spray angle: 15 deg.
e. Control System-
f. Connecting pipes and hoses- A CPVC(Chlorinated Polyvinyl Chloride) pipe of diameter ¾" is being used for the connections.

Detailed design

- **Electrical/Electronics aspect:** The approximate distance between our point of pump exit and the base of the fire is 7.5m (5m +2.5m)

The bare minimum outlet speed required is about 5.42m/s. For it to work in all types of air conditions we take it to be 8m\s for further calculations to calculate the outlet diameter.

Volume discharge rate by pump =10 L/min =1/6000 m^3/sec
Desired exit velocity= 8 m/sec to get range of 2.5 m through nozzle
Now we know Volume = Area ✕ Exit Velocity
therefore, $Area = \frac{Volume}{Exit\ Velocity}$
so, Area=1/48000 m^2
therefore, diameter = 5.15m.

- **Software part:** YOLO (You Only Look Once) algorithm is being used in the fire detection model of the drone.

  YOLO is a state-of-the-art real-time object detection system. It is a popular neural network algorithm used in computer vision for object detection tasks such as object recognition and tracking in real-time video streams.

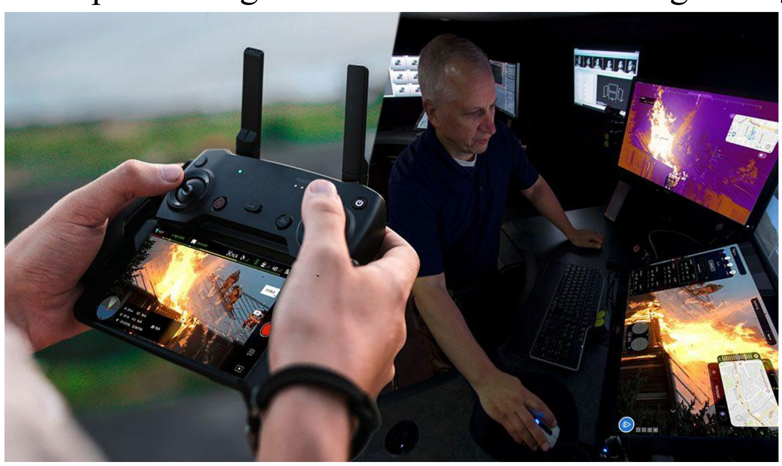
  The YOLO algorithm works by dividing the input image into a grid of cells and predicting a set of bounding boxes and class probabilities for each cell. It also predicts the confidence scores for each of the predicted bounding boxes, indicating the likelihood of an object being present in that region. The YOLO algorithm then selects the bounding box with the highest confidence score and the corresponding class prediction as the final detection.

  The reason we chose YOLO over other object detection algorithms is its speed. Since YOLO only requires a single forward pass through the neural network, it can achieve real-time object detection at high frame rates.

  The YOLO algorithm in the project is trained with a huge dataset of fire images to improve the accuracy and is easily able to bifurcate between fire and other surrounding objects.

<u>Yolo detected fire image</u>

The above image describes the output of the trained model using YOLO. This helps the automation system locate the fire location which then helps us align the drone at the perfect angle for much better fire extinguishing.



<u>Aligning the Drone to the detected location</u>

When the location is detected it becomes easy for the user to align the drone and the agent can be sprayed without much wastage.

- **Mechanical Aspects:**
  There are several mechanical aspects that are included in the project related to a fire-extinguishing drone. Some of these aspects are:

  a. <u>Design and fabrication of the drone body and frame</u>: This would include the shape, size, and weight of the drone, as well as the materials used for its construction. It would also cover the fabrication process, including any challenges or modifications made during the construction.

c. Design and testing of the fire-extinguishing system: This would include the design of the nozzle, the type of fire extinguishing agent used, and the integration of the system with the drone. It would also cover the testing process for the fire-extinguishing system, including any modifications made to improve its efficiency.

d. Power system and battery selection: This would include the selection of the battery and its specifications, as well as the design and integration of the power system into the drone.

e. Safety features and considerations: This would include any safety features incorporated into the drone design, such as emergency shut-off mechanisms and safety protocols for handling the fire-extinguishing agent.

7. Tethered design considerations:The drone subsystem is designed to be used in a tethered mode, which would be incorporated into the design at later stages.

Chapter 5

Fabrication and Assembly

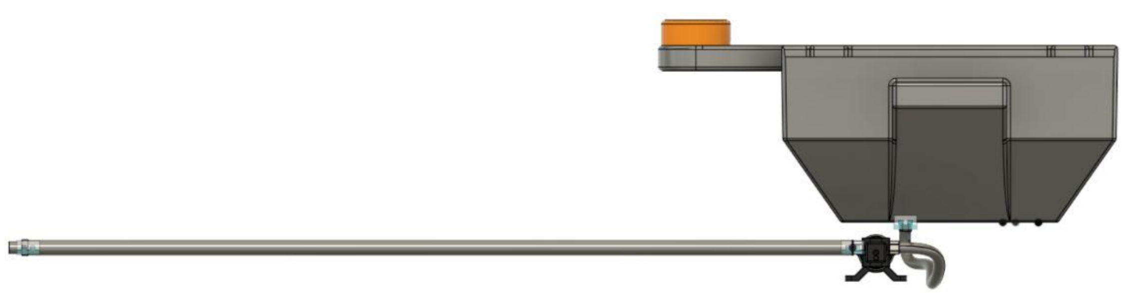
The fabrication plan shall be discussed in this chapter. Following points must be included.

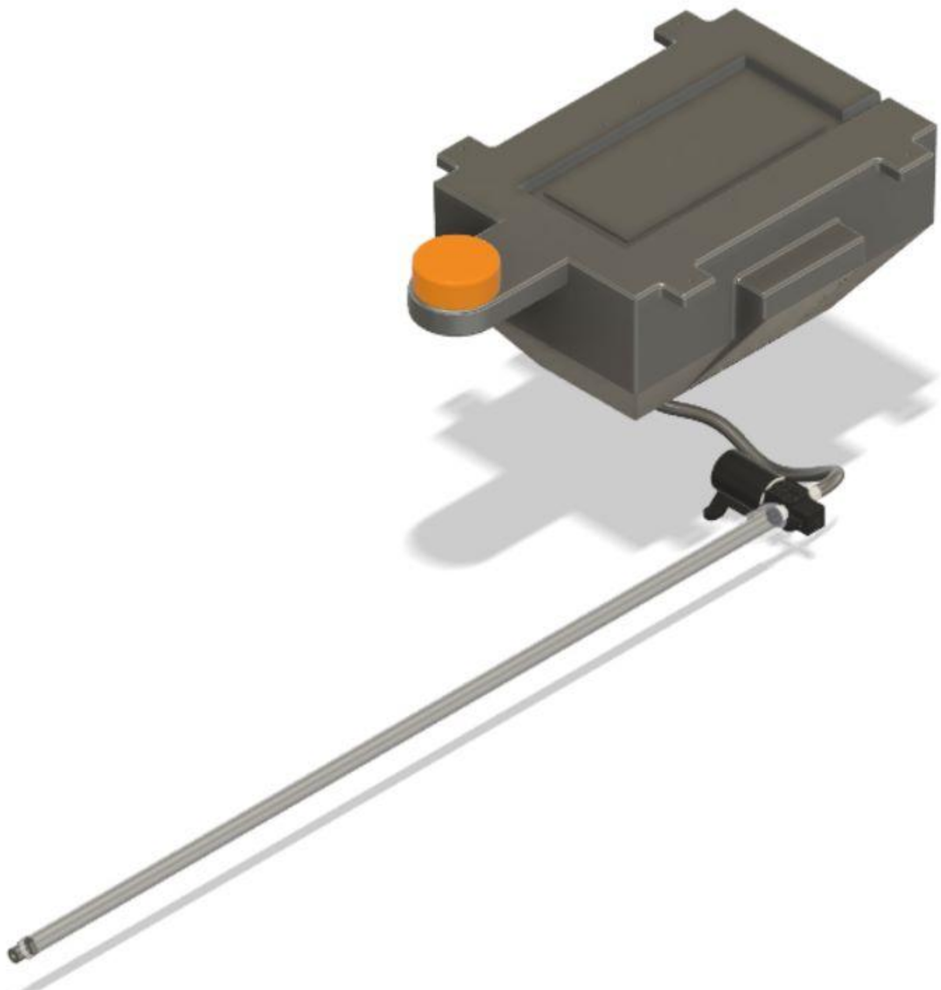
Bill of Materials (BOM)

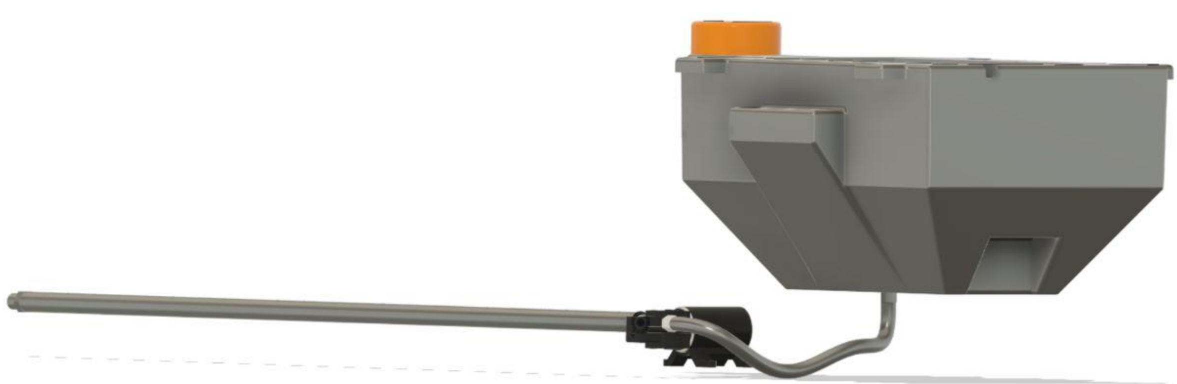
SL No	Material	Cost(Rs)
1.	Diaphragm Pump	Rs1,249
2.	Tank	Rs18,500
3	PVC pipe(5m)	Rs230
4.	nozzle	Rs150
	Total	Rs20,129

Drawing/Cad Model

CAD Models of tanker and nozzle sub-system







Manufacturing Process description

PVC pipe, diaphragm pump and tank were purchased and in order to integrate them we had to fabricate connecting pipes.

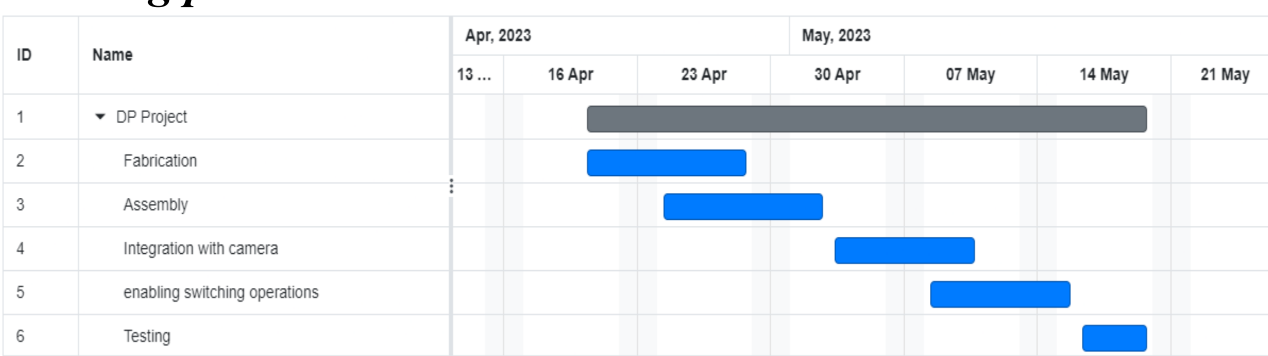
Assembly

The tank was connected to the inlet of the pump using the fabricated connecting pipes which in turn was connected to PVC pipe conduit and nozzle. The diaphragm pump is supplied with a 12V power supply controlled by a microcontroller integrated to the camera onboard the drone. This helps in automating the process and helps us to conserve our extinguishing material

Limitations and Challenges

1. The PVC pipe must be long enough(5m) in order to avoid the effect of downward thrust of blades of drone
2. At this length the PVC pipe may slack downwards
3. Drones cannot carry large amount of extinguishing materials

Scheduling plan



Contribution

Report: Bhavay Aggarwal and Soham Chongder
Logistics: Bhavy Rahangdale.
Cad Model Designing: Shashank Dwivedi
Yolo Code: Bhanushri Chinta and Prem Shankar

Conclusions

In conclusion, the development of a fire fighting drone is a significant technological advancement in the field of emergency response. The drone's ability to detect and suppress fires from the air can significantly reduce response time and minimize the risks to human life. The drone's capabilities are impressive, as it can detect fires in remote areas, navigate through challenging terrain, and deliver water or fire retardants with great accuracy.The fire fighting drone's potential applications are numerous, including in firefighting operations, search and rescue, and disaster response. The drone's versatility and agility make it an ideal tool for emergency responders, enabling them to respond quickly to fires in hard-to-reach locations, which would have previously required extensive manpower and resources.However, there are still some limitations and challenges associated with the technology, including regulatory and legal frameworks, technical limitations, and public perception of drones. Addressing these challenges will require collaboration between regulators, manufacturers, and end-users to ensure that the drone's capabilities are utilized to their full potential.

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[4]

https://bete.com/ (nozzle types)