

Engineering and Project Management

by Ayoob Mohammed Azhar

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Project Proposal
(Semi-autonomous power line inspection
drone)

Engineering & Project Management
(ACDA5025)

Electrical and Electronic Engineering

Ayoob Mohammed Azhar (2400571)

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Introduction and background research

In the UK, drones/UAVs (Unmanned Aerial Vehicles) have become more commonly used by infrastructure operators to inspect important infrastructure in areas that are difficult or dangerous to reach, such as bridges, railways, power lines, and wind turbines. Power lines span diverse environments, from rural to urban areas, which require regular inspection to maintain a safe, reliable and efficient electrical grid.

Traditionally, power line inspection involves using manual labour-intensive techniques such as ground-based visual checks and helicopter patrols. However, ground-based visual checks involve workers walking along power line routes while using binoculars and infrared thermal imaging cameras, which is inefficient in high mountain areas and other difficult terrain, as well as in adverse weather conditions that are all difficult and time-consuming for workers to reach. Whereas, helicopter patrols, although faster, are more expensive, cause noise disturbances and are still affected by weather and operational conditions.

The deployment of autonomous drone inspections by the National Grid in collaboration with the CAA (Civil Aviation Authority) demonstrates the practical implementation of this technology in the UK power infrastructure sector [1].

Problem statement

Conventional methods to inspect power lines, such as ground-based inspections and helicopter patrols, are often slow, expensive and can put workers and operators at risk, especially in remote or difficult terrain and adverse weather conditions. Therefore, there is a need for a drone system with human monitoring that is safer, more efficient than conventional methods and complies with the UK CAA BVLOS (Beyond Visual Line of Sight) regulations for reliable operation.

Literature review

One similar project that is published in Science Direct demonstrates an autonomous UAV framework designed for power line inspection, integrating cloud-based data processing, onboard sensing and navigation algorithms. The system uses publicly available data to identify neighbouring pylons, and onboard processing allows cable detection. Additionally, the framework includes a cable following algorithm that helps with cable inspections, validated under a simulation environment. Their framework uses a dual-sensing approach that uses both LiDAR and vision systems to improve the reliability of the detection. LiDAR is used for distance measurement and alignment, whereas the vision system assists with detailed inspection and feature recognition. [2]

Another similar project that is published in MDPI proposes an autonomous power line inspection system that integrates autonomous path planning, flight control, and cloud-based data processing. Their system allows UAVs to create inspection routes based on grid data and carry out inspection activities while uploading pictures in real time. Their vision-based detection uses deep learning algorithms (i.e., AI), such as YOLO based models, to enhance fault detection. This allows AI detection of faults and analysis of inspection data, such as structural defects and foreign objects. Their system shows autonomy through pre-existing inspection data and a structured environment. [3]

An IEEE paper presents an autonomous drone system for power line inspections that integrates autonomous navigation, AI fault detection, and an inductive energy harvesting technology on one platform. The system is built on Robot Operating System (ROS) to coordinate navigation, cable inspection, cable following and autonomous landing for recharging. The system integrates a dual-LiDAR navigation with a built-in camera-based fault detection using deep learning models like YOLO. This allows for real-time onboard image analysis for fault classification while detecting and avoiding objects. They demonstrate real-world autonomy by validating the system in outdoor environments under ideal and various weather conditions of up to 30 kts of wind speeds. [4]

Literature Gap:

The reviewed papers demonstrate the significant progress made in autonomous power line drone inspection systems, such as cloud-based data processing, autonomous navigation, path planning, cable following and AI fault detection. However, when it comes to practical deployment in the UK, there is a gap in achieving BVLOS compliance to operate reliably and in compliance with regulations. Additionally, the AI fault detection relies on datasets that have a narrow range of faults, and there is also an improvement that can be made to consider the severity of faults.

Aim and Objectives

Aim

This project aims to design a semi-autonomous (with human monitoring) drone as an innovative, safer and more efficient way for inspecting UK power lines with AI-assisted fault detection, autonomous navigation, and reliable operation under CAA BVLOS regulations.

Objectives

1. To test the AI fault detection software that can identify typical power line faults from the drone inspection data, with an operator who reviews the detection result, demonstrated in simulation, followed by real-world testing.
2. To integrate a multi-sensor gimbal system that includes an RGB camera, thermal camera, and LiDAR. This should be capable of operating in simulation, followed by real-world testing.
3. To validate the complete drone prototype under real-life flight conditions, by assessing whether the complete hardware, control and sensing system meets the required performance criteria.
4. To achieve the BVLOS compliance that allows the reliable and safe operation of the drone. This will be done after completing the testing stage and then sending all the testing details and related documents to CAA.

Device specifications and block diagram

Device specification

Name	Semi-autonomous power line inspection drone
Purpose	To safely, efficiently, and reliably inspect power lines semi-autonomously (with human monitoring).
Inputs	• Drone operator instructions. • Main sensors' input data (RGB, thermal camera, and LiDAR). • Flight controller input (that includes the IMU, barometer, magnetometer, accelerometer, and so on)
Outputs	• Inspection data (includes high resolution images, real-time video stream, thermal images, and 3D LiDAR maps. • Drone telemetry (includes drone speed, GPS coordinates, sensor status, and battery management) • AI fault detection reports.
Key features	• Follows pre-planned power line routes and navigates autonomously using LiDAR. • Along with RGB and thermal cameras, it uses an AI program to assist with detecting faults (such as overheating components, damaged power line hardware, and vegetation intrusion). • EMI shielding. • Geo-fencing feature (doesn't fly in no-fly zones). • Return to home feature (failsafe mode that returns the drone to the take-off location). • Parachute mode (failsafe mode for emergency landing).
Performance/Range	30-45 minutes of flight time
Communication	SATCOM (Satellite Communications) and 4G/5G cellular network
Power	LiPo battery packs. They are hot swappable which allows them to be replaced with new ones without powering off the drone.
Payload capability	Multi-sensor gimbal carrying a 4K RGB camera, thermal camera and LiDAR
Physical size and weight	15 kg, MTOW (Maximum Take off Weight). 4-6 kg, payload
Estimated price	£15,000 to £20,000

Block diagram

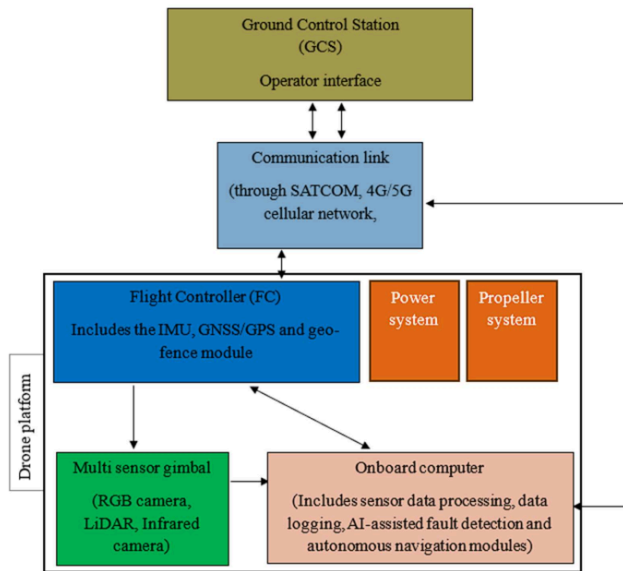


Figure 1: Block diagram

Figure 1 shows the block diagram operation of the drone system. The process starts at the GCS, where the operator sends low-level flight commands to the drone's FC via the communication link. The communication link uses SATCOM (Satellite Communication) and 4G/5G cellular network. The FC then processes the operator signals alongside real-time sensor data to control motor speeds and maintain the drone's stability. The power system powers all the electronic components, and the propeller system keeps the drone flying. The FC sends back live telemetry data, such as drone speed, GPS coordinates, and battery management, to the GCS. The FC sends data such as command and geolocation data for the multi-sensor gimbal to capture high-resolution inspection data at precise locations along the power lines. The multi-sensor gimbal sends real-time data from the sensors to the onboard computer, enabling autonomous navigation, real-time AI fault detection, and storing the inspection data for future analyses. The FC also provides data to the onboard computer concerning the position and altitude so that it can geolocate the exact coordinates of the faults it finds. The onboard computer sends back to the FC to let it know the right navigation plan so that it can avoid obstacles as it controls the drone. The live inspection data and fault alerts are sent from the onboard computer to the GCS for monitoring. The GCS can also send high-level data to the drone's onboard computer, such as instructions for prioritising a certain category of faults.

Project Plan

Work Breakdown Structure

1. Initialisation
 - 1.1. Research similar projects, and plan for the project
 - 1.2. Inspection site planning
 - 1.3. Contact CAA and prepare initial documents
2. Design
 - 2.1. Develop the AI fault detection program
 - 2.2. Design the electrical schematics
 - 2.3. Design the CAD drawing
3. Procurement
 - 3.1. Acquire all the drone software (such as flight and simulation software)
 - 3.2. Select components
 - 3.3. Ordering components
4. Prototyping and implementation
 - 4.1. Drone hardware assembly
 - 4.2. AI fault detection program integration
5. Testing and Evaluation
 - 5.1. Simulation testing
 - 5.2. Real-world testing
 - 5.3. Submit BVLOS application to CAA
6. Project completion
 - 6.1. Final presentation and handover

The monitoring will be done on a shared logbook among the team members managed by the project manager throughout the project timeline. Note: this is not shown on the Gannt chart or critical path analysis.

Gantt chart

The project timeline is estimated to be 8 months and 1 week as shown in Figure 2 (the Gantt chart) below.



Critical path analysis

Tasks	Dependencies
1. Initialisation	
1.1 Research	none
1.2 Inspection site planning	none
1.3 Prepare CAA initial documents	1.2, and 1.1
2. Design	
2.1 AI fault detection program	1.1
2.2 Electrical schematics	1.1
2.3 CAD drawing	2.2 and 1.1
3. Procurement	
3.1 Acquire software	1.1
3.2 Select components	2.2 and 1.1
3.3 Ordering components (and delivery)	2.2 and 1.1
4. Prototyping and implementation	
4.1 Drone hardware assembly	3.3, 2.3, 2.2 and 1.1
4.2 AI program integration	2.1, and 1.1
5. Testing and Evaluation	
5.1 Simulation testing	4.2, 3.1, 2.3, 2.2, 2.1 and 1.1
5.2 Real world testing	5.1, 4.2, 4.1, 3.3, 3.1, 2.3, 2.2, 2.1 and 1.1
5.3 Getting BVLOS compliance	5.2, 5.1, 1.3, 1.2 and 1.1
6. Project completion	
6.1 Final presentation and handover	all

Figure 3 below shows the critical path analysis after tabulating the dependencies of each task shown in Table 1.

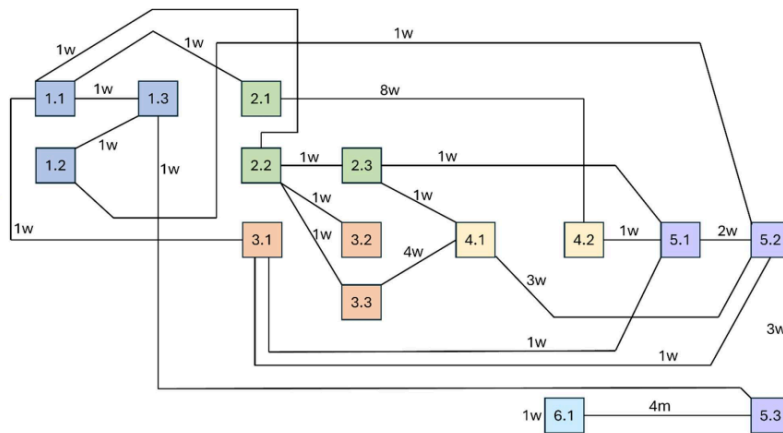


Figure 3: Critical path analysis

Where 'w' is week, and 'm' is month. The critical path here is identified to be from Task 1.1 → 2.1 → 4.2 → 5.1 → 5.2 → 6.1. This helps to identify the longest chain of dependent tasks that should be completed on time to prevent the entire project from being delayed.

Milestones

- Project initiation completed
- Design finalisation approved
- Procurement completed
- Hardware/software integration completed, and drone prototype ready
- Testing stage completed and reviewed
- Getting BVLOS compliance
- Project closure

Deliverables

- Report of risk management strategy detailing risks and risk mitigation methods
- Pictures of the inspection site for testing
- Gantt chart and cost-benefit analysis
- Details of environmental, societal and ethical concerns
- Electrical schematic and CAD drawing of the drone
- Device specifications
- Vendor documents
- Final hardware prototype of the drone
- Simulation test results
- Real-world flight test results
- List of all the resources used
- Project presentation

Human resources

- Project Manager/Electronics Engineer
- Software (AI) Engineer
- Embedded engineer
- Mechanical engineer
- Drone operator

Total estimated cost for employees = £120,000

Components (hardware and software) list

- Multirotor frame
 - Motors
 - Propellers
 - Landing gear
 - Flight controller
 - GNSS/GPS module
 - Detect-and-avoid system
 - Geofencing module
 - LiDAR sensor
 - RGB camera
 - Thermal camera
 - AI processing unit (NVIDIA Jetson Orin Nano)
 - Gimbal to hold the sensors/camera
 - LiPo battery pack
 - Power distribution board
 - Voltage regulation
 - Battery monitoring system
 - Fail-safe method (parachute)
 - Industrial grade memory card
 - Communication link components
-
- UgCS software for flight planning (enterprise yearly subscription))
 - NVIDIA Isaac sim for simulation and AI testing (free/open source)
 - ROS 2 for the operating system (free/open source)
 - AutoCAD/AutoCAD Electrical (yearly subscription))

Total estimated cost = £10,000

Cost-benefit analysis

Costs:

1. High costs for hiring experienced team members
2. High component costs that include hardware and software
3. BVLOS compliance approval waiting time

Benefits:

1. Improves efficiency and productivity, as a drone can cover a longer range in a shorter time compared to time-consuming conventional inspection methods.
2. Reduces equipment/vehicle cost, such as expensive helicopter inspections.
3. Reduces labour cost as only one or two people will be needed for the inspection operation.
4. Improves the safety of workers as they won't have to be exposed to hazardous conditions.
5. Reduces downtime, as drones can inspect the power line without shutting down the grid.

Net Benefit = Total Benefits – Total Costs = 5 – 3 = 2

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Total Benefits}}{\text{Total Costs}} = \frac{5}{3} = 1.67$$

Therefore, the benefits outweigh the costs.

Risk management strategy

Identified risks

1. Communication link failure, causing loss of control and communication with the drone.
Likelihood = 3, Impact = 5. Risk score = 15
2. BVLOS compliance approval delay, preventing the drone from inspecting long distances.
Likelihood = 3, Impact = 4. Risk score = 12
3. AI fault detection doesn't perform well in real-world testing, failing to detect key faults.
Likelihood = 4, Impact = 4. Risk score = 16
4. EMI interference from high voltage lines, corrupting sensor data or disrupting the flight controller. Likelihood = 3, Impact = 5. Risk score = 15
5. Adverse weather conditions, delaying real-world testing or preventing the drone from operating reliably in those conditions. Likelihood = 4, Impact = 3. Risk score = 12
6. Privacy breach, accidentally capturing identifiable private property or people. Likelihood = 2, Impact = 4. Risk score = 8
7. Team member unavailability, leading to a lack of progress or missing deadlines. Likelihood = 3, Impact = 3. Risk score = 9

8. Drone crash during real-world testing, causing hardware damage and a significant schedule delay. Likelihood = 2, Impact = 5. Risk score = 10
9. AI program integration issue, preventing AI fault detection reports from being sent to the operator. Likelihood = 3, Impact = 4. Risk score = 12
10. Component delays or discontinuation, leading to a delay in drone hardware assembly. Likelihood = 3, Impact = 3. Risk score = 9

Risk matrix

	Impact				
Likelihood	Negligible (1)	Marginal (2)	Moderate (3)	Major (4)	Catastrophic (5)
Almost Certain (5)					
Likely (4)			n.o 5	n.o 3	
Moderate (3)			n.o 7 and 10	n.o 2 and 9	n.o 1 and 4
Unlikely (2)				n.o 6	n.o 8
Rare (1)					

Figure 4: Risk Matrix

Figure 4 above shows the identified risks plotted on a 5x5 Risk Matrix based on the risk scores calculated (likelihood and impact). It shows that the project is mainly a high risk project.

Risk mitigation methods

1. Use a reliable communication link. Carry out pre-flight communication link checks. Have additional communication methods in place. Include a failsafe method, such as a return to home command.
2. Have a strict checklist during the testing stage and ensure all the required safety, operational and compliance documents are completed carefully and properly checked before sending them off.
3. Train and test the AI program on various datasets to imitate real-world conditions and categorise them into the most common faults and visible faults.
4. Use EMI shielding methods to protect critical components and shielded twisted pair wiring where possible with proper grounding.
5. Monitor the weather forecasts weekly. Pre-plan and book the testing times within suitable timings.
6. Restrict testing areas to approved areas using geofencing and careful flight planning. Blur faces and private property, before the data is stored and transmitted
7. Keep tasks documented and shared in a central location so that all the team members have access to the current progress. Assign a backup team member for each critical path task.

8. Have a checklist and pre-inspect all hardware after assembly, and before the flight test. Have a strict testing protocol to ensure the testing passes in stages. In case of emergencies, ensure there is a proper fail-safe or emergency landing (such as a parachute landing).
9. Progressively integrate the module, testing each stage to ensure there are no faults in the final integration stage. Use version control to track changes.
10. Order early. Instead of relying on only one vendor, identify alternative components and backup suppliers.

Environmental and societal impact

The semi-autonomous drone used for power line inspections can contribute sustainably to the environment by replacing conventional inspection methods, which would produce a lot of carbon emissions, such as using helicopters. [5]

Considering the impact to the society, this project can reduce the need for workers to carry out inspections in difficult or dangerous locations, which improves their safety and lowers the risk associated with manual inspection. Additionally, the quick inspection process can help electricity grid companies identify faults at an early stage and take immediate action more quickly, which can improve the reliability of service for the public.

Ethical concerns

The proposed semi-autonomous drone system raises several ethical concerns related to its design, production, and use in the society. Because the drone is created for public infrastructure inspections, i.e. power line inspections, it may capture high-resolution videos/photos that include sensitive information about individuals, private properties and nearby homes without their knowledge or consent. [6]

Another concern is data security and integrity. Because the system relies on handling sensitive data, any unauthorised access, cyber-attacks, data breaches, misuse, or manipulation of data could lead to incorrect maintenance decisions, potentially compromising public safety. [6]

Moreover, there is also an issue regarding transparency. Although the drone is being used legally, people can see it as intrusive if they are unaware of its purpose or what it is recording. This implies that the project should be planned with transparency in mind, including clear information on the drone's intended purpose, the kind of data it will gather, and how it will be used. [6]

When considering the production of the device, building the drone requires a wide range of hardware and electronics components, such as the drone frame and circuit boards, all of which require additional material use and manufacturing processes. Therefore, an ethical production of this device should prioritise commercial off-the-shelf components where possible rather than unnecessary custom development, as this can reduce waste, and cost.

References

- [1] "Infrastructure inspections with drones made easier under new rules," UK Civil Aviation Authority, 15th October 2024. [Online]. Available: <https://www.caa.co.uk/newsroom/news/infrastructure-inspections-with-drones-made-easier-under-new-rules/>. [Accessed 22nd March 2026].
- [2] O. B. Schofield, N. Iversen, and E. Ebeid, "Autonomous power line detection and tracking system using UAVs," *Microprocessors and Microsystems*, vol. 94, p. 104609, Oct. 2022, doi: <https://doi.org/10.1016/j.micpro.2022.104609>.
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- [5] "Drones and ESG," Balmore Group, [Online]. Available: <https://thebalmoregroup.co.uk/drones-and-esg/>. [Accessed 26th April 2026].
- [6] "Ethical Considerations for Drone Use in Public Infrastructure Inspection," AAI Drones, [Online]. Available: <https://aai-drones.com/ethical-considerations-for-drone-use-in-public-infrastructure-inspection/>. [Accessed 25th April 2026].

Appendices

Appendix A: PREVENT training certificate



**AN INTRODUCTION TO
THE PREVENT DUTY
AS IT AFFECTS
HIGHER EDUCATION**

CERTIFICATE OF COMPLETION

THIS ACKNOWLEDGES THAT

Name: Ayoob Mohammed Azhar

HAS SUCESSFULLY COMPLETED THE INTRODUCTION TO PREVENT E-LEARNING

Date: 25/02/2026

Appendix B: Equality, Diversity, and Inclusion training certificate



This is to certify that
Ayoob Mohammed Azhar
successfully completed the
Equality & Diversity Briefing
course with a score of
91%
on
25th March 2026



Engineering and Project Management

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

83/100

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GRADING FORM: ENGINEERING PROJECT MGT

AYOOB MOHAMMED AZHAR

82.60**ENGAGEMENT WITH LITERATURE**

Marks for this section will be awarded for your engagement with literature evidenced through relevant, credible sources cited throughout your report



Engagement with a wide range of literature. The report uses relevant sources such as CAA guidance, ScienceDirect, MDPI, and IEEE papers. Literature gap is identified. It would have been better if more in-text citations should be added in the specification, risk, environmental, and ethical sections.

3.3**KNOWLEDGE AND UNDERSTANDING**

Marks for this section will be awarded for your identification and ordering of the tasks, identification of the risks to your project, identification of any environmental and societal impacts of the project.



Excellent, detailed knowledge and critical understanding. The report shows good understanding of the problems with manual and helicopter-based power line inspections. The device specification table is detailed and includes inputs, outputs, features, flight time, payload, and cost. The block diagram clearly explains the system structure and communication between major components. Some technical values, such as flight time, weight, communication system, and cost, need stronger justification. It is evident that the environmental and societal impacts of

16.3

solutions to broadly defined problems have been considered.

COGNITIVE AND INTELLECTUAL

Marks for this section will be awarded for your risk mitigation techniques and the ethical considerations for your project.



Excellent critical evaluation and analysis of concepts and principles of Engineering and Project management. The report shows analysis by comparing traditional inspection methods with drone-based inspection. The risk section is good, with clear risks such as communication failure, EMI, AI failure, and drone crash. Ethical concerns such as privacy, data security, and transparency are discussed well. It would have been better with more detailed cost-benefit analysis. It is evident that the need for quality management systems and continuous improvement has been recognised through the identification of system limitations, implementation of risk mitigation measures.

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PRACTICAL SKILLS

Marks for this section will be awarded for your use of the available tools and techniques in the identification of risks and milestones and in determining your minimum project duration.



Exceptional levels of application and deployment skills using appropriate methods and tools. The work breakdown structure is clear and follows a logical project sequence. A Gantt chart is included and gives an estimated project duration. The critical path analysis is included. The risk matrix and mitigation methods are practical and relevant to the project. It would have been better if task durations, responsible roles, quality checks, and deliverables were linked more clearly. The PREVENT and Equality, Diversity and Inclusion certificates are included in the appendices. It is evident that the responsibilities, benefits, and importance of supporting equality, diversity, and inclusion have been recognised.

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TRANSFERABLE SKILLS FOR LIFE

Marks for this section will be awarded for the structure, coherence, presentation and overall quality of your reports.



Can communicate professionally confidently and consistently. The report is well organised and follows a clear professional structure. Tables, diagrams, the Gantt chart, critical path, and risk matrix improve presentation quality. The report would have been better with conclusion

25