POLITEKNIK BANTING SELANGOR

THERMOVISION PRO

NAME	MATRIC NO.
MUHAMMAD AMIRUL DANIAL B. MAZRUL	24DAM22F1009
AMAR ZULHADI B. ZULKIFLI	24DAM22F1012
MUHAMMAD AIMAN DANIAL B MOHAMAD FAIZELI	24DAM22F1025

DEPARTMENT OF AIRCRAFT MAINTENANCE

SESSION 1 2024/2025

POLITEKNIK BANTING SELANGOR

THERMOVISION PRO

NAME	MATRIC NO.
MUHAMMAD AMIRUL DANIAL B. MAZRUL	24DAM22F1009
AMAR ZULHADI B. ZULKIFLI	24DAM22F1012
MUHAMMAD AIMAN DANIAL B MOHAMAD FAIZELI	24DAM22F1025

A REPORT SUBMITTED TO DEPARTMENT OF AIRCRAFT MAINTENANCE IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR A DIPLOMA ENGINEERING IN AIRCRAFT MAINTENANCE

SUPERVISOR:

MRS. ROSMAWAR BINTI HUSSIN

REPORT ENDORSEMENT

This report entitled ***"ThermoVision Pro"*** is being submitted, reviewed, and endorsed to fulfill the conditions and requirements of report writing as specified.

Checked by:

Supervisor's Signature : ROSMAWAR

Supervisor's Stamp : ROSMAWAR BINTI HUSSIN
PENSYARAH
JABATAN PENYENGGARAAN
PESAWAT POLITEKNIK BANTING

Date : 25 November 2024

Endorsed by:

Project Coordinator's Signature :

Project Coordinator's Stamp : KHAIRUL IZWAN BIN ISMAIL
Pensyarah
Jabatan Penyenggaraan Pesawat
Politeknik Banting Selangor

Date : 3rd December 2024

CERTIFICATION OF PROJECT ORIGINALITY & OWNERSHIP

THERMOVISION PRO

SESSION 1 2024/2025

NAME	MATRIC NO
MUHAMMAD AMIRUL DANIAL BIN MAZRUL	**24DAM22F1009**
AMAR ZULHADI BIN ZULKIFLI	**24DAM22F1012**
MUHAMMAD AIMAN DANIAL BIN FAIZELI	**24DAM22F1025**

"We hereby declare that this report is the result of our own work, except excerpts that we have outlined its sources, and this project will be the ownership of polytechnic.

SIGNATURE: WRITER 1

SIGNATURE: WRITER 2

SIGNATURE: WRITER 3

Endorsed by,

ROSMAWAR

(SUPERVISOR'S SIGNATURE)

ROSMAWAR BINTI HUSSIN
PENSYARAH
JABATAN PENYENGGARAAN
PESAWAT POLITEKNIK BANTING

SUPERVISOR'S STAMP

DATE: 25 November 2024

ACKNOWLEDGEMENT

We would like to use this opportunity to express our sincere gratitude to our parents for their sacrifices, full support, and encouragement in helping us complete this end-of-semester project at Politeknik Banting Selangor.

We owe a debt of gratitude to our project manager, Mrs. Rosmawar Binti Hussin, for her unwavering guidance, support, and encouragement in seeing the project through to completion of our report. Every time we are working on a project and feeling down or uninspired, her enthusiasm and knowledge have motivated and inspired others. She always extends a helping hand and provides motivational words when we truly need them, enabling us to complete our work and overcome any challenges.

We are really grateful to our lecturers from the aircraft maintenance division for allowing us to utilize the workshop to complete the project. We also value their assistance in providing us with guidance, recommendations, and project monitoring to ensure the timely and effective completion of our projects. As the project was being finished, many concepts were created.

Once more, a big thank you to the team for their excellent collaboration in putting this into action. They continue to pour money, time, and energy into this cause until it is successful without ever realizing what hopelessness is. In fact, any kind of cooperation, whether direct or indirect, from certain parties is really appreciated by our organization. We extend our sincere gratitude to all those who participated directly, especially Politeknik Banting Selangor.

ABSTRACT

ThermoVision Pro integrates advanced thermography and computer vision to monitor and evaluate defects in various aircraft components. This innovative system combines thermography testing with artificial intelligence (AI) to detect and analyze defects such as delaminations, disbonds, and water ingress. Thermography captures heat patterns, while AI processes these images to identify and describe these issues with high accuracy and speed. ThermoVision Pro offers visual feedback and detailed defect descriptions through advanced image processing.

The system analyzes thermal images and generates descriptions of defects, explaining their nature and impact. This assists inspectors and maintenance personnel in understanding results and making informed decisions. ThermoVision Pro enhances aircraft safety, reliability, and cost-effective maintenance by automating inspections.

The user-friendly application enables efficient data capture, storage, and visualization of inspection results. AI analytics provide real-time insights, helping users interpret results quickly. The intuitive interface ensures accessibility, even for users with limited technical expertise, making the inspection process more efficient. ThermoVision Pro revolutionizes aircraft inspection, providing fast, accurate, and automated defect detection. Its advanced features and ease of use improve operational performance and extend the aircraft's lifespan. ThermoVision Pro sets new standards for aircraft maintenance and inspection, enhancing safety and efficiency in aviation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

AI	Artificial Intelligence
NDT	Non-Destructive Testing
AMM	Aircraft Maintenance Manual
UT	Ultrasonic Testing
ECT	Eddy Current Testing
MPT	Magnetic Particle Testing
MPI	Magnetic Particle Inspections
RT	Radiographic Testing
VT	Visual Testing
AE	Acoustic Emissions testing
DAU	Data Acquisition Unit
MSX	Multi-Spectral Dynamic Imaging
UI	User Interface

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In the aviation industry, ensuring the integrity and reliability of aircraft components is paramount for both safety and performance. Non-Destructive Testing (NDT) plays a critical role in this process, enabling maintenance teams to inspect components for hidden defects without damaging the parts themselves. Among various NDT methods, thermography also known as thermal imaging has gained prominence for its ability to capture and analyze the heat distribution patterns on the surfaces of aircraft components. Thermography allows maintenance engineers to detect anomalies such as cracks, dents, and other structural inconsistencies that may not be visible to the naked eye but could impact the performance of vital systems, particularly aircraft engines. These engines, which undergo extreme temperatures and mechanical stresses, require rigorous inspection and maintenance to function reliably. By using thermography, teams can detect thermal variations that reveal signs of wear, potential structural weaknesses, or early indications of failure.

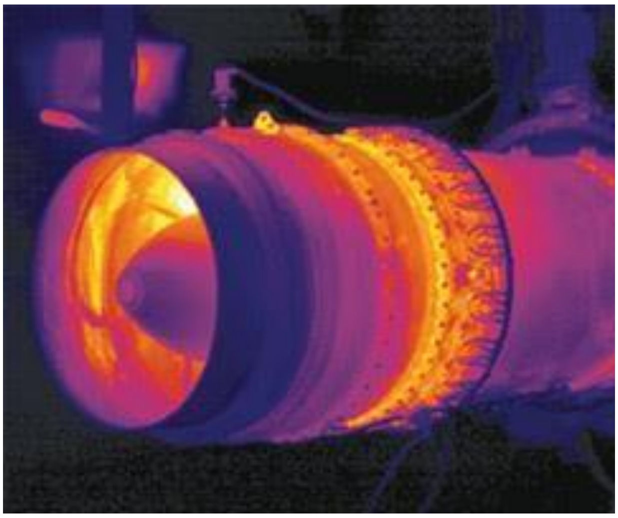


Figure 1.1: Thermography testing on the aircraft engine.

In recent years, the advancement of Artificial Intelligence (AI) has further transformed defect detection in various industries, including aviation. AI-driven algorithms can process vast amounts of data more rapidly and with greater precision than traditional methods, identifying subtle patterns that indicate potential issues. When applied to thermographic data, AI models can analyze thermal images to identify areas that deviate from normal temperature distributions, suggesting defects. These algorithms learn from each inspection, improving their accuracy and diagnostic capabilities over time. This combination of thermography and AI represents a significant step forward in predictive maintenance, as AI can enhance the ability to detect issues earlier and with greater accuracy, potentially preventing costly repairs or unexpected failures.

This final year's project aims to harness the power of both thermography and AI to improve defect detection specifically for aircraft engines. By integrating thermal imaging with advanced AI algorithms, this project aspires to develop a robust, efficient system capable of rapidly analyzing thermographic data to locate and highlight defects. The objective is to create a solution that not only improves accuracy and speed in identifying engine-related issues but also reduces the downtime associated with aircraft maintenance, thereby lowering operational costs for airlines and maintenance teams. Furthermore, the system's data-driven approach aligns with the aviation industry's ongoing shift towards predictive maintenance strategies that prioritize early defect detection and proactive intervention.

However, combining thermography with AI poses its own set of challenges. Developing AI models for thermal analysis requires substantial data to ensure reliable results, which can be difficult to obtain in the specialized context of aviation. Additionally, interpreting thermal data with AI requires careful calibration to account for varying conditions and component types within the engine, as any misinterpretation could lead to either missed defects or false positives. Despite these challenges, the potential benefits are substantial. By providing earlier warnings of structural or mechanical issues, this technology can contribute to prolonging the life of engine components and enhancing the overall safety and reliability of aircraft. As the aviation industry increasingly adopts data-driven solutions, this project represents a forward-thinking approach that supports safer, more efficient, and cost-effective maintenance practices.

This thesis explores the development and application of ThermoVision Pro, a system that integrates thermography and AI to address these challenges and opportunities. By evaluating the system's effectiveness in real-world scenarios and its potential implications for aviation maintenance practices, this research contributes to the broader field of aviation engineering and supports ongoing advancements in NDT technology. Through the implementation of ThermoVision Pro, the project seeks to set new standards in aircraft engine inspection, establishing a foundation for future innovations in predictive maintenance and AI-driven defect detection.

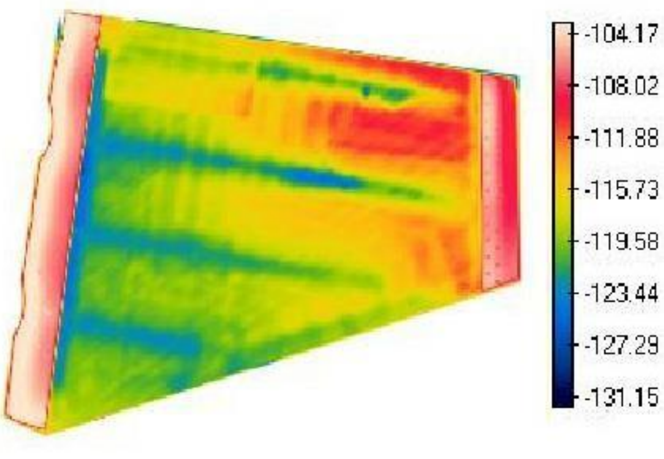


Figure 1.2: Aircraft rudder flap with internal reinforcement elements and structures

1.2 PROBLEM STATEMENTS

The aviation industry is heavily dependent on the reliability and safety of its aircraft components. Non-Destructive Testing (NDT) methods, such as thermography inspection, are essential for maintaining these standards. Thermography inspection uses infrared imaging to detect anomalies in materials, making it a popular choice due to its speed and accuracy. However, the current methods face several challenges that limit their efficiency and effectiveness. This project aims to innovate thermography inspection by integrating Artificial Intelligence (AI) to address these challenges and improve the overall process.

1.2.1 Manual Data Collection and Analysis

One of the main challenges in thermography inspection is the manual collection and analysis of data. Inspectors must manually capture thermal images and analyze them to identify potential defects. This process is time-consuming and prone to human error, which can lead to missed defects or false positives. The reliance on manual interpretation also limits the scalability of thermography inspection, as it requires highly trained personnel to perform the analysis.

1.2.2 Limited Detection of Subsurface Defects

Thermography inspection is effective in detecting surface-level anomalies, but it struggles with identifying subsurface defects. These defects, such as delaminations, disbonds, and water ingress, can significantly impact the structural integrity of aircraft components. The current thermography techniques often require multiple inspections using different methods to detect these subsurface issues, which increases the inspection time and cost.

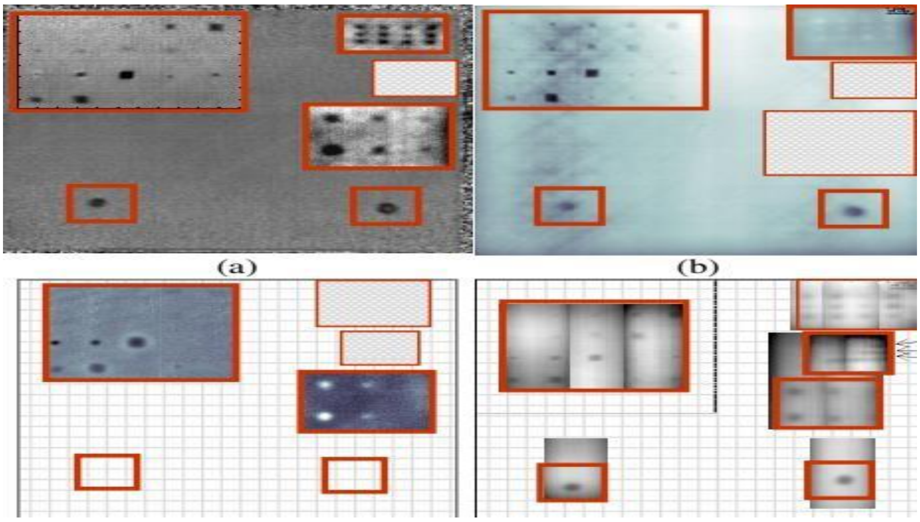


Figure 1.3: Limited Detection of Subsurface Defects

1.2.3 Inconsistent Inspection Results

The accuracy of thermography inspection can vary depending on several factors, including the inspector's experience, environmental conditions, and the quality of the equipment used. Inconsistent results can lead to uncertainty in the assessment of aircraft components, potentially compromising safety. The lack of standardized procedures and guidelines for thermography inspection further exacerbates this issue, making it difficult to achieve reliable and repeatable results.

1.2.4 High Costs and Resource Requirements

Thermography inspection requires specialized equipment and trained personnel, which can be costly for aviation companies. The need for frequent inspections to ensure the ongoing safety and performance of aircraft components adds to the overall expense. Additionally, the downtime required for inspections can disrupt operations and lead to financial losses. Finding ways to reduce the costs and resource requirements of thermography inspection is essential for the industry.

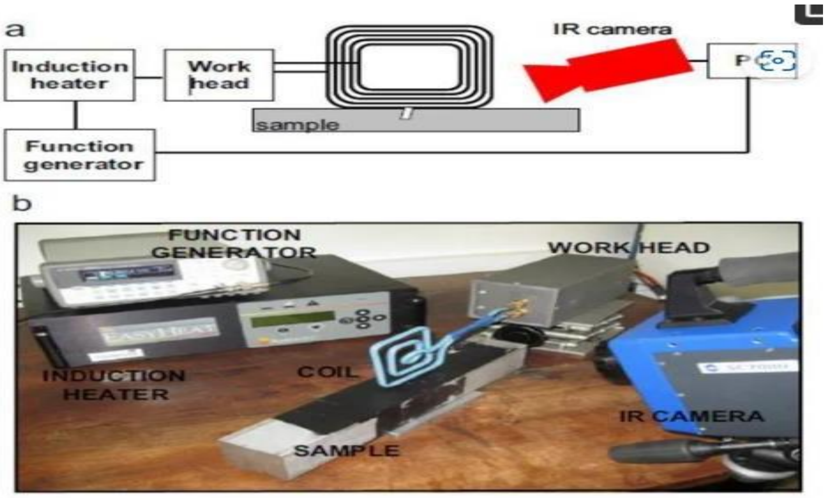


Figure 1.4: High-Cost Material and A Lot of Tools/Machine

1.2.5 Integration with Other NDT Methods

Thermography inspection is often used in conjunction with other NDT methods, such as ultrasonic testing and eddy current testing, to provide a comprehensive assessment of aircraft components. However, integrating these methods can be challenging due to differences in data formats, analysis techniques, and equipment requirements. The lack of seamless integration can result in inefficiencies and increased complexity in the inspection process.

1.2.6 Proposed Solution: AI-Enhanced Thermography Inspection

To address these challenges, this project proposes the development of an AI-enhanced thermography inspection system. By leveraging AI algorithms, the system can automate the data collection and analysis process, reducing the reliance on manual interpretation and minimizing human error. AI can also improve the detection of subsurface defects by analyzing thermal patterns and identifying anomalies that may not be visible to the naked eye.

The integration of AI can standardize the inspection process, ensuring consistent and reliable results regardless of the inspector's experience or environmental conditions. Additionally, AI can optimize the inspection process by identifying the most critical areas to inspect, reducing the overall time and cost of inspections. The system can also facilitate the seamless integration of thermography with other NDT methods, providing a comprehensive and efficient assessment of aircraft components.

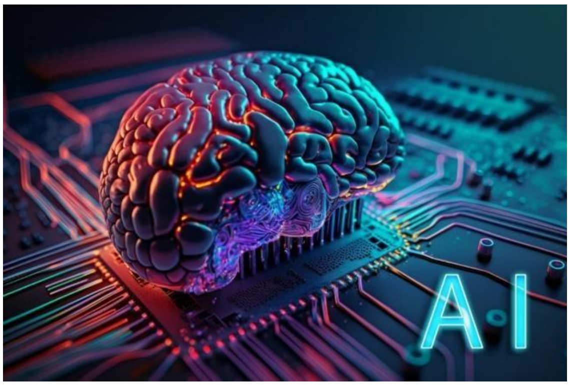


Figure 1.5: AI-Enhanced Thermography Inspection

The aviation industry faces several challenges in thermography inspection, including manual data collection and analysis, limited detection of subsurface defects, inconsistent results, high costs, and difficulties in integrating with other NDT methods. By incorporating AI into thermography inspection, this project aims to address these challenges and enhance the efficiency, accuracy, and reliability of the inspection process. The development of an AI-enhanced thermography inspection system has the potential to significantly improve the safety and performance of aircraft components, benefiting the aviation industry as a whole.

Figure 1.6: Traditional way Inspection using Thermography Testing.

1.2 PROJECT OBJECTIVES

1.3.1 General Project Objectives

1. **To develop a device that uses the concept of thermography testing and AI to detect defects such as delaminations, disbonds, water ingress, and other anomalies in aircraft components.**

   The primary objective of this project is to create a sophisticated device that leverages thermography testing combined with artificial intelligence to identify various defects in aircraft components. This includes not only engine defects but also issues like delaminations, disbonds, and water ingress, which can compromise the structural integrity and safety of the aircraft. By integrating AI, the device will enhance the detection capabilities, providing more accurate and reliable results. This innovation aims to streamline the inspection process, making it more efficient and less dependent on manual interpretation, thereby reducing the likelihood of human error. This directly addresses the problem of manual data collection and analysis, as well as the challenge of detecting subsurface defects.

2. **To provide visual feedback and defect descriptions using image processing and natural language generation**

   Another key objective is to develop a system that offers clear visual feedback and detailed descriptions of detected defects. Utilizing advanced image processing techniques, the system will analyze thermal images to highlight areas of concern. Additionally, by incorporating natural language generation, the system will generate easy-to-understand descriptions of the defects, explaining their nature and potential impact. This feature is designed to assist inspectors and maintenance personnel in quickly understanding the inspection results, facilitating prompt and informed decision-making. This objective addresses the issue of inconsistent inspection results by providing standardized and easily interpretable feedback, regardless of the inspector’s experience or environmental conditions.

3. **To develop a user-friendly and intuitive app that allows efficient data capture, storage, and visualization of inspection results, as AI analytics explains.**

   The final objective is to create an application that is both user-friendly and intuitive, enabling efficient data capture, storage, and visualization of inspection results. The app will be designed to work seamlessly with the thermography device, allowing users to easily collect and store data during inspections. AI analytics will be integrated to provide real-time insights and explanations, helping users to quickly interpret the results. The app will also feature a clean and intuitive interface, ensuring that even those with limited technical expertise can use it effectively. This objective aims to enhance the overall user experience, making the inspection process more accessible and efficient. It addresses the high costs and resource requirements by reducing the need for specialized training and equipment, and it also tackles the integration challenges by ensuring compatibility with existing systems and data formats.

Figure 1.7: To Develop a User-friendly and Intuitive App

1.3.2 Specific Individual Project Objectives

1.3.2.1 Product Structure of ThermoVision Pro

1. **Develop a User-Friendly and Intuitive Application:** The primary objective of this project is to create a user-friendly and intuitive application that simplifies the process of thermography inspection. This app will be designed to facilitate efficient data capture, storage, and visualization of inspection results. By incorporating AI analytics, the app will provide real-time insights and explanations, making it easier for users to interpret the data. The goal is to reduce the reliance on manual data collection and analysis, thereby minimizing human error and improving the accuracy of inspections. This objective directly addresses the challenge of manual data collection and analysis, making the inspection process more efficient and reliable.

2. **Ensure Portability and Ease of Use:** Another key objective is to develop a portable thermography inspection system that is easy to carry and operate. The system will be designed to require minimal tools and equipment, making it convenient for inspectors to use in various environments. By focusing on portability, the project aims to reduce the logistical challenges and costs associated with thermography inspections. This objective addresses the high costs and resource requirements of current inspection methods, providing a more cost-effective and practical solution for the aviation industry.

3. **Integrate Seamlessly with Existing Systems:** The project aims to ensure that the new thermography inspection system can seamlessly integrate with existing NDT methods and data management systems. This involves designing the product structure to be compatible with various data formats and analysis techniques used in the aviation industry. By facilitating easy integration, the system will enhance the overall efficiency of the inspection process and reduce the complexity involved in using multiple NDT methods. This objective addresses the integration challenges, making the inspection process more streamlined and cohesive.

4. **Standardize and Optimize the Inspection Process:** Finally, the project seeks to standardize and optimize the thermography inspection process. By leveraging AI, the system will provide consistent and reliable results, regardless of the inspector's experience or environmental conditions. The app will include standardized procedures and guidelines to ensure repeatable and accurate inspections. Additionally, AI will help in identifying the most critical areas to inspect, optimizing the inspection process and reducing the overall time and cost. This objective addresses the issues of inconsistent inspection results and the integration challenges with other NDT methods, providing a streamlined and efficient solution for the aviation industry.

1.3.2.2 Software / Programming of ThermoVision Pro

The software component of ThermoVision Pro is designed to streamline and enhance the thermal inspection process through a series of sophisticated, AI-driven analysis and data management functions. This software has been developed with specific objectives to maximize efficiency, accuracy, and usability in aircraft maintenance environments. Below are the primary objectives and functionalities of the ThermoVision Pro software:

Thermal Camera Activation and Interface Control: The software initiates and manages the thermal camera interface, allowing users to activate the camera directly from the app. This integration ensures seamless user interaction with the hardware, enabling quick and efficient start-up for on-site inspections.

Image Capture and Real-Time Data Processing: The application enables inspectors to capture thermal images of aircraft components directly within the app. Each image is instantly processed to extract temperature data across the component's surface. This rapid data acquisition supports real-time inspection workflows, reducing the time required for initial data gathering.

Defect Detection and Temperature Analysis Using AI Algorithms: One of the core functionalities is the application of AI algorithms to analyze captured thermal images. The AI is trained to detect temperature variations indicative of potential defects, such as delaminations, disbonds, or surface cracks. By analyzing these patterns, the software can automatically identify areas that deviate from expected thermal norms, providing a preliminary diagnosis of potential structural issues.

Automated Defect Classification: Following defect detection, the AI classifies identified issues based on pre-defined categories, such as crack type, location, and severity. This categorization provides a structured analysis, allowing inspectors to prioritize maintenance actions based on defect type and criticality.

Display and Visualization of Inspection Results: The results of the analysis are displayed on the LCD, providing visual feedback to the inspector. This interface includes highlighted thermal hotspots and defect annotations, allowing inspectors to see detailed information about each detected anomaly. Additionally, the software presents a summary of temperature readings and classified defects, aiding in decision-making during the inspection process.

Data Storage and Management for Future Reference: The software includes a data storage feature, enabling the secure saving of inspection data, including captured thermal images, AI analysis results, and diagnostic information. This data is stored for future reference, supporting longitudinal tracking of component condition over time and providing a valuable dataset for predictive maintenance.

The software's modular programming design emphasizes efficiency and reliability, with a focus on AI-driven automation to support a comprehensive defect detection and analysis process. By leveraging real-time data and a user-friendly interface, the ThermoVision Pro software enhances the ability to identify critical defects quickly and accurately, optimizing the overall maintenance workflow in aviation environments.

1.3.2.3 Accessories & Finishing

1. Installing the Product: Setting up ThermoVision Pro starts with securely assembling all its main parts to ensure everything fits together for safe, long-lasting performance. Start by mounting the thermal camera, Raspberry Pi, LCD screen, and any other key modules in their designated places inside the main casing. Each piece should be carefully positioned—not only for stability but also so they are accessible if you need to make future adjustments. Position the thermal camera to capture clear thermal images and ensure the Raspberry Pi has a secure spot for handling data processing. Once the core parts are in place, connect the power supply unit, making sure it is stable yet accessible for any power-related adjustments down the line. This careful installation lays a solid foundation for ThermoVision Pro to operate smoothly and efficiently.

2. Cable Management: Managing the cables well is essential to keep the device organized, reduce electrical interference, and make maintenance easier. Begin by routing each cable along the inner walls of the casing, allowing them to stay close to the frame so they do not tangle or get in the way. Keeping power and signal cables separate reduces the chances of interference, which can sometimes disrupt data accuracy. Plus, having well-placed cables helps with airflow, so the system stays cool and runs more reliably. Proper cable management not only keeps ThermoVision Pro neat and user-friendly but also makes future adjustments or repairs a breeze.

3. Modifying the LCD Case: For a streamlined design, part of the LCD case is cut to allow for better cable management. This modification creates a dedicated exit path for the cables so they can connect without cluttering the display or the device’s appearance. The cut section ensures that cables can fit securely without putting stress on the casing, making them easier to access if you ever need to replace or adjust them. This simple adjustment keeps the cables organized and extends the life of both the LCD screen and the cables.

4. Final Finishing Touches: With all the components in place, it is time for a final check to make sure everything is working as it should. Start by testing each component—confirm that every part operates as intended. Check that the cables connect correctly to the processor, ensuring stable power and data flow. Power on the LCD screen to confirm it displays properly, and double-check that every piece, from the thermal camera to the power supply, functions smoothly as part of the whole system. This final round of checks ensures that ThermoVision Pro is fully operational and ready for action.

1.4 PURPOSE OF PRODUCT

1.4.1 Automate the Data Collection and Analysis Process

The primary purpose of developing this thermography inspection device integrated with artificial intelligence is to automate the data collection and analysis process. In the aviation industry, manual data collection is often time-consuming and prone to human error, which can lead to missed defects or false positives. By leveraging AI, the device can provide more accurate and reliable results, ensuring that potential defects such as delaminations, disbonds, and water ingress are detected efficiently. This automation enhances the precision of inspections and speeds up the process, allowing for more frequent and thorough checks, which is crucial for maintaining the safety and reliability of aircraft components.

1.4.2 Enhance Portability and User-Friendliness

Another significant purpose of the product is to enhance portability and user-friendliness. Traditional thermography inspection methods often require bulky equipment and specialized training, which can be logistically challenging and costly. By developing a lightweight and intuitive device, the project aims to reduce these barriers, making advanced inspection technology more accessible and practical for everyday use in the aviation industry. This portability ensures that inspections can be conducted more flexibly and efficiently, even in remote or difficult-to-access areas of the aircraft. The ease of use also means that less specialized training is required, which can significantly reduce operational costs and improve the overall efficiency of maintenance operations.

1.4.3 Provide Real-Time Insights and Explanations

The integration of AI analytics within the device allows for real-time insights and explanations, facilitating quicker and more informed decision-making during inspections. This feature is particularly beneficial in maintaining the structural integrity and safety of aircraft components, as it ensures that any detected anomalies are promptly and accurately assessed. Real-time feedback helps inspectors to immediately understand the severity and nature of defects, enabling faster corrective actions and reducing the downtime of aircraft. This capability is essential for enhancing operational efficiency and ensuring continuous airworthiness. Moreover, the AI-driven insights can help in predicting potential future issues, allowing for proactive maintenance, and further enhancing the safety and reliability of the aircraft.

1.4.4 Standardize the Inspection Process

The development of an intuitive application that interfaces with the thermography device aims to standardize the inspection process, providing consistent and reliable results regardless of the inspector's experience or environmental conditions. Standardization is crucial in the aviation industry, where consistency in maintenance practices directly impacts safety and regulatory compliance. The app will feature a clean and intuitive user interface, making it accessible to users with varying levels of technical expertise. By ensuring that all inspections follow the same rigorous standards, the project helps to eliminate variability and improve the overall quality of maintenance operations. This standardization also facilitates better record-keeping and data management, which are essential for regulatory audits and continuous improvement of maintenance practices.

1.4.5 Improve Cost Efficiency and Integration with Existing Systems

Lastly, the project seeks to enhance the overall efficiency and effectiveness of thermography inspection by ensuring seamless integration with existing NDT methods and data management systems. This integration reduces the complexity and inefficiencies often associated with using multiple inspection techniques, thereby optimizing the entire inspection process. By making it easier to incorporate thermography into existing workflows, the project aims to provide a comprehensive and cohesive solution for aircraft maintenance. This holistic approach not only improves the accuracy and reliability of inspections but also supports the broader goal of maintaining high safety standards in the aviation industry. Additionally, the integration with existing systems ensures that the new technology can be adopted without significant disruptions, making it a practical and scalable solution for the industry. This focus on cost efficiency is particularly relevant in today's aviation industry, where reducing operational costs while maintaining high safety standards is a top priority.

1.6 SCOPE OF PROJECT

1.5.1 General Project Scopes

This project aims to enhance the safety and reliability of aviation by developing a system to detect delamination defects in the skin structure of aircraft. Delamination, if undetected, can lead to serious issues. Therefore, we will employ methods such as ultrasonic testing and thermography to identify and analyse delamination in composite aircraft skins. Our goal is to be precise in addressing these problems to prevent future in-flight failures and ensure the safety of everyone on board.

A key aspect of this project is the creation of a comprehensive training toolkit for maintenance personnel and engineers. This toolkit will include written and video instructions, hands-on activities, and full-scale simulated defect examples. These resources will allow users to practice identifying delamination using the non-destructive testing (NDT) techniques we develop. Additionally, we aim to educate users on the importance of regular inspections and maintenance of aircraft skin structures to prevent defects.

Furthermore, we plan to design a mobile application to facilitate data collection and analysis during inspections. Users will be able to input inspection results, visualize the condition of the aircraft skin, and generate detailed reports on its state. This app will streamline the inspection process and support maintenance staff in making informed decisions.

This project seeks to set new standards for detecting delamination in aircraft skin structures through rigorous testing and evaluation of the proposed NDT methods. We aim to advance technologies that improve training efficiency and provide modern resources to enhance the overall safety and reliability of aircraft operations. By ensuring that maintenance personnel are well-equipped to identify and address potential defects, we hope to contribute to safer and more dependable flying experiences.

1.5.2 Specific Individual Scope

1.5.2.1 Product Structure of ThermoVision Pro

1. **Development of the Thermography Inspection Device:** The project will involve the design and development of a portable thermography inspection device integrated with AI capabilities. This device will be engineered to detect a range of defects in aircraft components, including delaminations, disbonds, water ingress, and other structural anomalies. The scope includes selecting appropriate sensors, developing AI algorithms for defect detection, and integrating these components into a compact, user-friendly device. The device will be designed to be lightweight and easy to carry, ensuring it can be used efficiently in various inspection environments within the aviation industry. This aspect of the project directly addresses the problem of manual data collection and analysis, aiming to enhance the accuracy and reliability of inspections.

2. **Creation of a User-Friendly Application:** The project will also involve developing an intuitive application that interfaces with the thermography inspection device. This app will facilitate efficient data capture, storage, and visualization of inspection results. It will feature a clean and intuitive user interface, making it accessible to users with varying levels of technical expertise. The application will leverage AI analytics to provide real-time insights and explanations of the inspection data, helping users quickly interpret the results. This component of the project aims to standardize the inspection process, ensuring consistent and reliable results regardless of the inspector’s experience or environmental conditions. It also addresses the high costs and resource requirements by reducing the need for specialized training and equipment.

3. **Integration and Testing:** The scope includes integrating the thermography inspection device and the application with existing NDT methods and data management systems used in the aviation industry. This involves ensuring compatibility with various data formats and analysis techniques, facilitating seamless integration into current workflows. The project will also cover extensive testing of the device and application in real-world scenarios to validate their performance and reliability. This phase will address the integration challenges identified in the problem statement, ensuring that the new system can be effectively incorporated into existing inspection processes. Additionally, the project will include developing standardized procedures and guidelines to optimize the inspection process and reduce the overall time and cost.

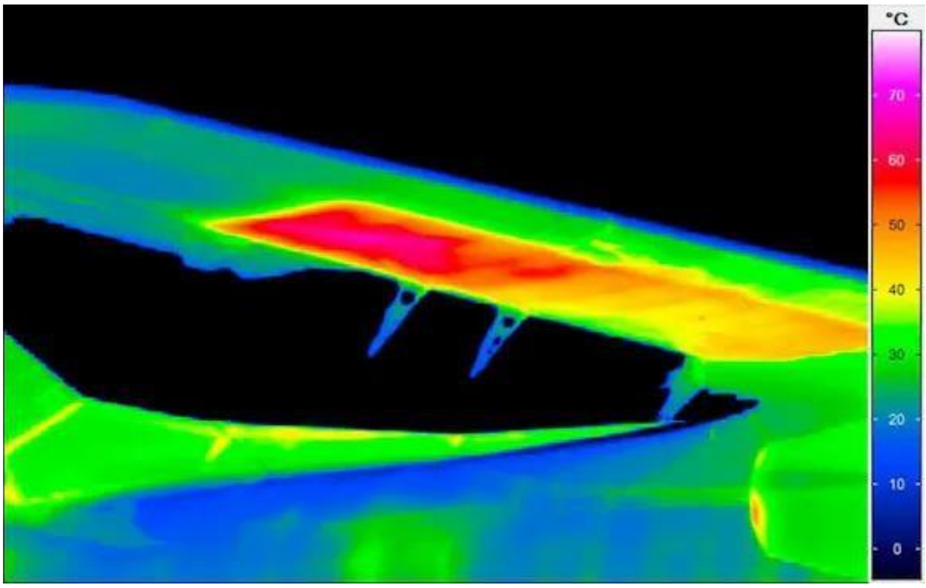


Figure 1.8: Integration and Testing of Thermography Testing

1.5.2.2 Software / Programming of ThermoVision Pro

The scope of ThermoVision Pro*'s* software component encompasses several critical functions designed to enhance the defect detection process through a user-friendly and efficient platform. The software integrates thermal imaging and artificial intelligence (AI) to enable real-time analysis, accurate defect identification, and comprehensive data management. Key aspects of the software's scope are outlined below:

Thermal Image Acquisition and Preprocessing: The primary function of the software is to capture thermal images from the AMG8833 thermal camera and preprocess them for analysis. Preprocessing includes optimizing image resolution, enhancing image clarity, and normalizing temperature data to reduce environmental noise. This process ensures that only high-quality images are analyzed, which is essential for accurate defect detection and reliable temperature readings. Effective image preprocessing minimizes errors in AI analysis, allowing the system to identify defects with greater precision.

AI-Driven Defect Detection and Temperature Analysis: The core feature of the ThermoVision Pro software is its ability to analyze thermal images using AI algorithms. The software is programmed to detect temperature variations in real time and identify anomalies indicative of potential defects, such as delaminations, disbonding, and surface cracks. The AI algorithms are trained on a dataset of thermal images, enabling the system to recognize complex thermal patterns and classify defects based on their temperature characteristics. This AI-powered approach not only accelerates the detection process but also improves the accuracy of defect identification by reducing human error.

User Interface for Real-Time Visual Feedback and Decision Support: The software is equipped with an intuitive interface that displays real-time feedback from the thermal camera, highlighting areas where defects have been detected. This visual feedback includes heat maps and temperature readings that allow inspectors to assess the severity and location of identified issues. Through a user-friendly interface on the LCD, the software enables inspectors to view defect annotations, confirm findings, and make informed decisions quickly. This real-time feedback system enhances usability, making it easier for inspectors to interpret thermal data accurately and efficiently.

Data Storage and Retrieval for Historical Record Keeping: The *ThermoVision Pro* software incorporates a data storage system that securely saves thermal images, analysis results, and diagnostic data from each inspection. This feature facilitates long-term tracking of component condition and supports predictive maintenance by allowing historical comparisons. Store data can be retrieved for subsequent inspections, providing valuable insights into the wear patterns and degradation of aircraft components over time. By maintaining a comprehensive inspection history, the software aids maintenance teams in proactive decision-making and trend analysis, supporting the aviation industry's shift toward data-driven maintenance strategies.

1.5.2.3 Accessories & Finishing of ThermoVision Pro

1. Installing the Product**:** The main goal of the ThermoVision Pro project is to bring together several key components to create a fully functional and reliable system. This starts by securely mounting the thermal camera, Raspberry Pi, LCD screen, and other important parts in the right spots inside the casing. Each component is positioned carefully, not just for stability, but to ensure everything is easy to access in case future adjustments or maintenance are needed. The thermal camera is placed where it can capture the best thermal images, and the Raspberry Pi is set up to handle all the data processing. The power supply unit is also positioned securely, ensuring it's stable but still easy to reach if adjustments are necessary.

2. Cable Management**:** Another important part of this project is making sure that all the cables are neatly organized. Proper cable management helps keep the system running smoothly by preventing tangles and reducing the risk of accidental disconnections. By routing the cables along the inside of the casing and keeping them out of the way, the device stays neat and functional. The cables for power and signals are kept separate to avoid any electrical interference that could affect performance. Organized cables also help the system stay cool by allowing better airflow, preventing overheating, and ensuring the components last longer. Good cable management makes ThermoVision Pro easier to use and maintain overtime.

3. Modifying the LCD Case**:** Part of the scope of this project is making a small but important modification to the LCD case. This involves cutting a section of the case to make space for better cable management. This simple adjustment helps ensure that the cables can be routed neatly without getting in the way of the LCD screen. It also helps keep the setup more organized and ensures that the cables are protected from wear and tears. By making this small change, we help the system stay functional and easy to maintain, while ensuring the components are safely connected

4. Final Finishing Touches: The final step of the project is making sure everything works as it should. This means testing each part to ensure that the system is ready for use. First, check that the cables are properly connected to the processor and that the LCD screen powers on and displays correctly. Then, confirm that all other components, such as the thermal camera and power supply, are functioning together as a seamless system. These final checks make sure that ThermoVision Pro is fully operational, with every part working together as planned.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL LITERATURE REVIEW

2.1.1 Demand in Aviation

AI Integration in Malaysian Aviation Malaysia's aviation industry is poised to benefit significantly from AI integration. With the government's support through initiatives like the New Industry Master Plan (NIMP 2030), there is a clear trajectory towards adopting AI to improve various aspects of aviation, including maintenance and safety. The Malaysian Investment Development Authority (MIDA) has highlighted the role of high-value manufacturing and global services, aiming to create 3,000 smart factories by 2030, which will include AI-enabled aviation facilities. (Symphony solution,2017)

Thermography's Role in Maintenance In line with global trends, thermography is gaining traction in Malaysia for aircraft maintenance. Technology's ability to detect defects without disassembly aligns with the industry's need for quick and reliable inspection methods. This is particularly relevant as Malaysia's aviation sector grows, with increased passenger traffic and cargo volume, necessitating more efficient maintenance protocols.

Challenges and Opportunities The integration of AI and thermography in Malaysia faces challenges similar to those globally, such as data acquisition and interpretation. However, the opportunities, especially in terms of cost savings and safety improvements, are driving demand. Malaysia's focus on becoming a hub for AI-enabled manufacturing suggests a fertile ground for such technologies in aviation maintenance. (ICAO, 2023)

Market Trends and Predictions the Malaysian aviation market is recovering post-pandemic, with a forecasted increase in passenger and cargo traffic. This recovery is creating a demand for more sophisticated maintenance technologies to ensure the safety and reliability of a growing fleet. AI and thermography are well-positioned to meet this demand, offering advanced solutions for defect detection. (Precedence research,2021)

Regulatory Considerations as Malaysia's aviation industry advances, regulatory frameworks will need to evolve to accommodate modern technologies like AI and thermography. Ensuring these technologies comply with national and international safety standards will be crucial for their widespread adoption. The Malaysian aviation authorities are likely to take cues from global best practices in this regard.

In summary, the demand for AI and thermography in the Malaysian aviation industry is driven by the need for enhanced safety measures, operational efficiency, and cost reduction. The country's commitment to technological advancement and supportive government policies provides a conducive environment for the adoption of these technologies. This literature review underscores the importance of continued innovation and regulatory adaptation to meet the evolving demands of Malaysia's aviation sector. (Infratec, 2018)

2.1.2 Types of Typical Non-Destructive Testing in aircraft

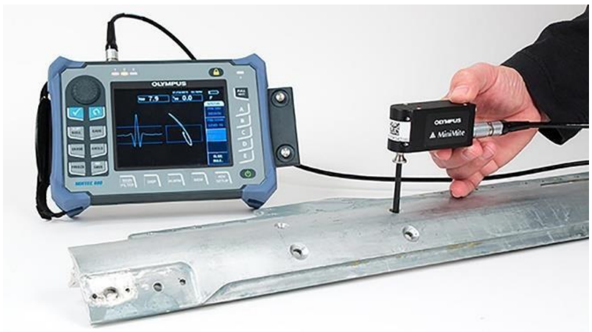
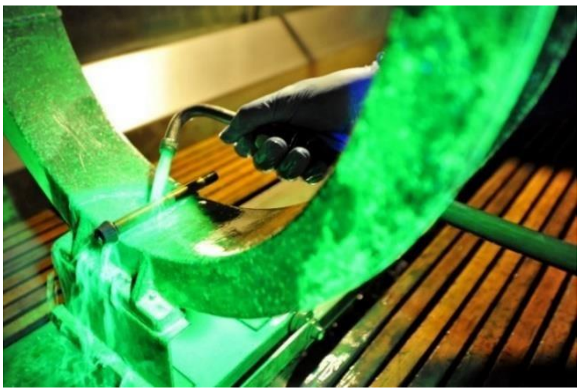
TYPES OF TYPICAL NON-DESTRUCTIVE TESTING IN AIRCRAFT	EXAMPLE
Ultrasonic testing in Non-Destructive Testing	
Eddy current testing in Non-Destructive Testing	
Magnetic particle testing in Non-Destructive Testing	

Table 2.1: Types of typical non-destructive testing in aircraft

2.1.3 Ultrasonic testing

Ultrasonic Testing (UT) is a widely used Non-Destructive Testing (NDT) method in the aviation industry, known for its ability to detect subsurface flaws within materials with high precision. This technique operates by sending high-frequency sound waves into a material and analyzing the reflected waves to detect internal discontinuities. When these ultrasonic waves encounter any flaw, such as a crack or void, they are reflected back to the sensor, producing signals that can be analyzed to identify the type and location of the defect. Due to its high sensitivity, ultrasonic testing can detect defects that are not visible to the naked eye, making it an essential tool for ensuring the structural integrity and safety of aircraft components.

In aviation, ultrasonic testing is commonly applied to inspect metal and composite materials, such as wings, fuselage, and landing gear. The ability to inspect these critical areas without disassembling the aircraft enhances efficiency and reduces maintenance downtime, which is crucial in the aviation sector. UT is effective in detecting various types of flaws, including cracks, delamination, and corrosion, as well as measuring thickness to detect any loss of material due to wear or degradation. The data obtained through ultrasonic testing enables maintenance teams to assess the condition of components accurately, predict potential failure points, and carry out preventive repairs, contributing to the overall safety and longevity of the aircraft.

Ultrasonic testing in aircraft maintenance has evolved with advancements in portable UT equipment and digital technologies, which have improved the precision, speed, and ease of conducting inspections. Technicians use handheld UT devices that can be easily maneuvered over different surfaces, providing real-time data and enabling on-site analysis. Furthermore, the integration of software with UT equipment has facilitated data storage, retrieval, and analysis, allowing technicians to compare current data with historical records for more informed maintenance decisions.

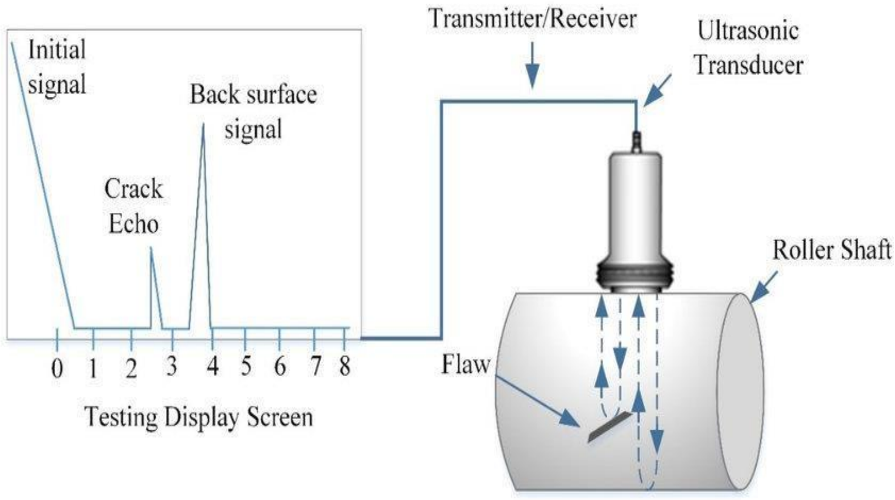


Figure 2.1: Typical of ultrasonic testing

2.1.4 Eddy current testing

Eddy Current Testing (ECT) is a Non-Destructive Testing (NDT) method commonly applied in the aviation industry, particularly effective for inspecting conductive materials like metals. ECT works by introducing an alternating current into a coil, generating a magnetic field that, when brought close to the surface of a conductive material, induces circulating electrical currents called eddy currents. These eddy currents flow through the material, and any interruptions caused by flaws such as cracks, corrosion, or changes in thickness disturb the flow, which can be detected by observing changes in impedance in the testing coil. This allows technicians to locate and analyze surface and near-surface defects without physically altering or damaging the component.

In aviation, ECT is widely used for the inspection of aircraft components made from aluminum, steel, and other conductive alloys, such as fuselage skin, wing structures, and engine components. It is particularly beneficial for detecting small cracks or corrosion around fasteners, bolt holes, and other stress-prone areas. Eddy current testing is fast, precise, and well-suited for applications where surface accessibility is limited but accurate inspection is required, making it invaluable for routine maintenance and inspection schedules.

Advances in ECT technology, including digital eddy current instruments and multi-frequency testing capabilities, have further enhanced its applications in aviation. These modern devices allow for real-time analysis, can filter out noise, and detect subtle variations in material properties, resulting in more detailed insights into component integrity. Additionally, with minimal setup time, eddy current testing is both time-efficient and highly effective, providing aviation maintenance teams with critical data needed to ensure the safety and longevity of aircraft components.

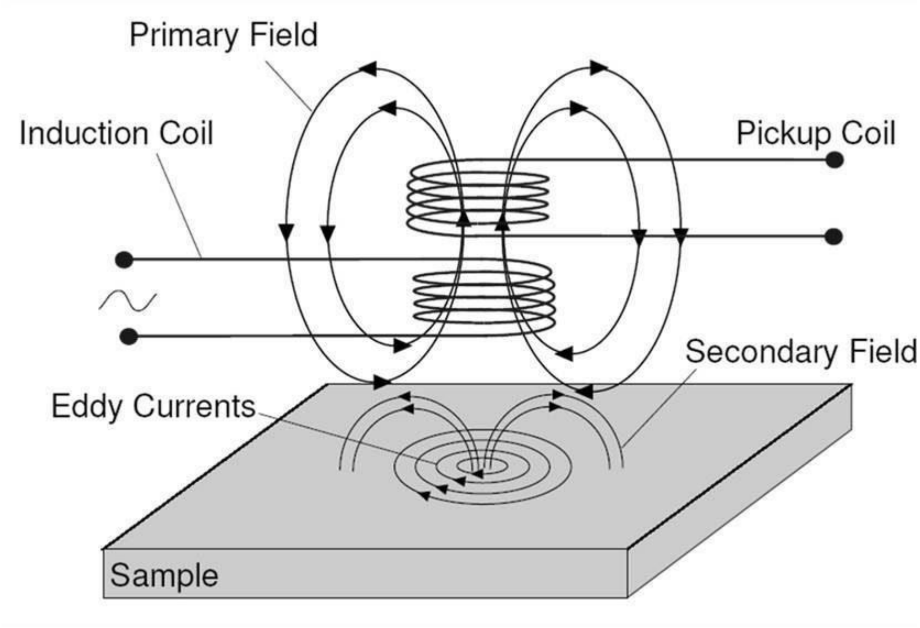


Figure 2.2: Typical of eddy current testing

2.1.5 Magnetic particle

Magnetic particle testing (MPT), also known as magnetic particle inspection (MPI), is a widely used non-destructive testing method for detecting surface and near-surface flaws in ferromagnetic materials such as iron, nickel, cobalt, and their alloys. In MPT, the component is magnetized, and magnetic particles—either in dry powder or wet suspension form—are applied to its surface. Flaws in the material disrupt the magnetic field, causing the particles to cluster and form visible indications, which trained inspectors can then interpret to identify the size, shape, orientation, and location of the flaws. This technique is advantageous for its speed, non-destructiveness, and effectiveness in identifying flaws, though it is limited to ferromagnetic materials and requires accessibility to the surface being inspected.

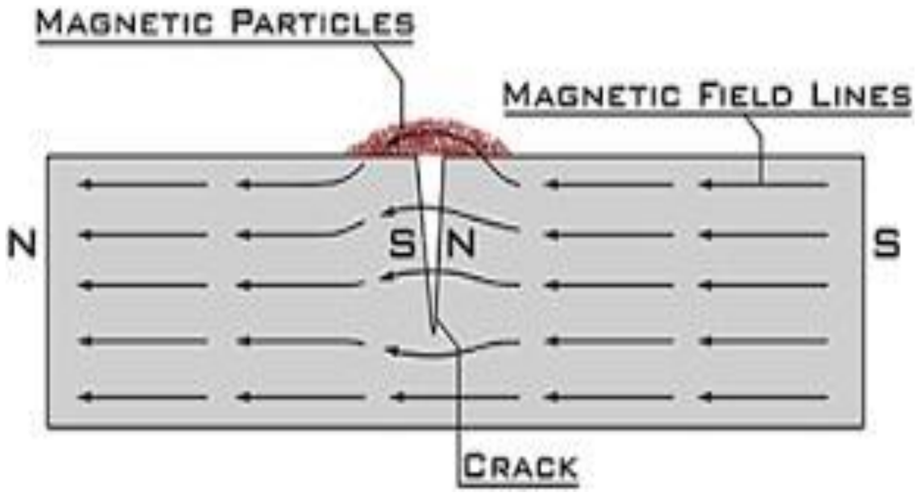


Figure 2.3: Typical of magnetic particle testing

2.1.6 Concept and theory of Non-destructive testing (NDT)

Non-Destructive Testing (NDT) is an indispensable facet of ensuring the safety and structural integrity of aircraft, relying on a diverse array of methods such as Ultrasonic Testing (UT), which utilizes high-frequency sound waves to meticulously detect internal flaws like cracks or voids, Eddy Current Testing (ECT), which harnesses electromagnetic induction to sensitively identify surface and subsurface defects primarily in conductive materials, Radiographic Testing (RT), a method involving the controlled penetration of materials by X-rays or gamma rays to unveil internal flaws through radiographic images, Visual Testing (VT), a foundational yet crucial inspection technique often enhanced by tools like borescopes to visually scrutinize every aspect of the aircraft's surface for any signs of damage, Electromagnetic Testing (ET), which encompasses a variety of techniques like magnetic particle testing and flux leakage testing to pinpoint surface and subsurface defects particularly in ferromagnetic materials by exploiting variations in magnetic fields, and Acoustic Emission Testing (AE), which monitors the structural integrity of aircraft by detecting stress-induced acoustic emissions, with these methods frequently amalgamated to ensure a comprehensive inspection coverage that safeguards the structural integrity and airworthiness of aircraft during both flight and ground operations, all while benefiting from ongoing advancements in sensor technology and data analysis to further enhance the precision, reliability, and efficiency of NDT for aircraft inspection.

2.1.7 ThermoVision in Non-Destructive Testing (NDT)

In recent years, infrared thermography has emerged as a powerful tool for non-destructive testing in various industries, including the aviation sector. ThermoVision, also known as infrared thermography, has gained significant attention in the aviation industry due to its ability to detect defects and anomalies in aircraft components without causing any damage. This non-destructive testing method employs the use of infrared cameras to capture the thermal radiation emitted by an object, and then analyzes the temperature distribution to identify potential issues.

Several studies have been conducted to explore the effectiveness of ThermoVision in non-destructive testing on aircraft. These studies have shown that thermography can be used to detect subsurface defects, voids, delamination, and corrosion in various aircraft components such as composite materials, metallic structures, and electrical systems. Additionally, the use of ThermoVision in maintenance and inspection processes has the potential to improve the overall safety and reliability of aircraft.

Furthermore, advancements in thermographic technology have led to the development of portable and handheld infrared cameras, making it easier for technicians and inspectors to conduct on-site testing and inspections. The implementation of ThermoVision in non-destructive testing on aircraft is expected to reduce downtime and maintenance costs, while also enhancing the efficiency of inspection procedures.

In conclusion, ThermoVision has demonstrated its capabilities as an effective tool for non-destructive testing in the aviation sector, offering numerous benefits in terms of safety, reliability, and cost-effectiveness. As technology continues to advance, it is likely that thermography will play an increasingly important role in the maintenance and inspection of aircraft in the future.

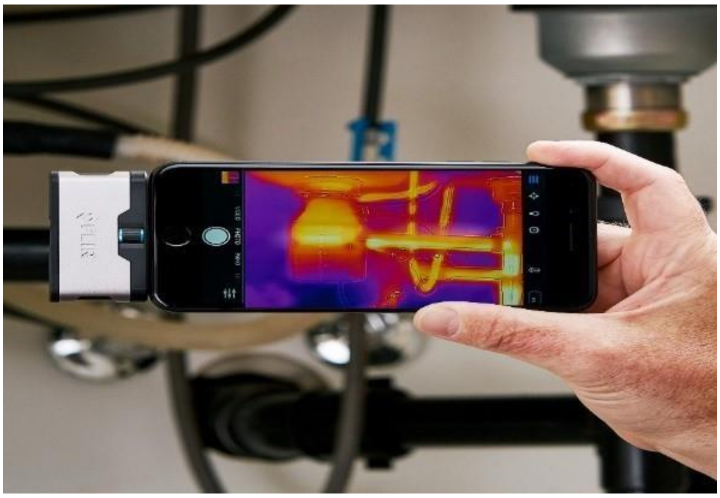


Figure 2.4: Technology in thermal camera

2.2 SPECIFIC LITERATURE REVIEW

2.2.1 Product Structure

2.2.1.1 Specific Components used in ThermoVision Pro: Design of Portable Thermal Imaging Tablets for Aviation Industry

Figure 2.5: The real-time visualization of thermal data provided by these screens.

The integration of thermal imaging technology into portable devices like tablets has revolutionized various sectors, particularly aviation. Marek Štumper et al. (2018) highlight how incorporating LCD display screens within the casings of these tablets significantly enhances the user experience, especially for aviation maintenance crews. The real-time visualization of thermal data provided by these screens allows for quick and precise identification of issues in aircraft systems. The design process focuses on achieving an optimal balance between the clarity of the display and the sensitivity of the thermal sensors, which is crucial for detecting even the slightest anomalies in aircraft components.

The evolution of thermal imaging technology, as detailed by Nguyen et al. (2021), has been instrumental in advancing aviation maintenance and safety. The miniaturization and improved efficiency of thermal sensors have enabled the development of portable devices that maintenance teams can conveniently use on the tarmac. This transition from bulky, stationary equipment to compact, handheld tools underscore the ongoing technological advancements that have made thermal imaging more accessible and practical for aviation applications. The portability and ease of use of these devices facilitate efficient inspection processes, thereby enhancing overall aircraft safety.

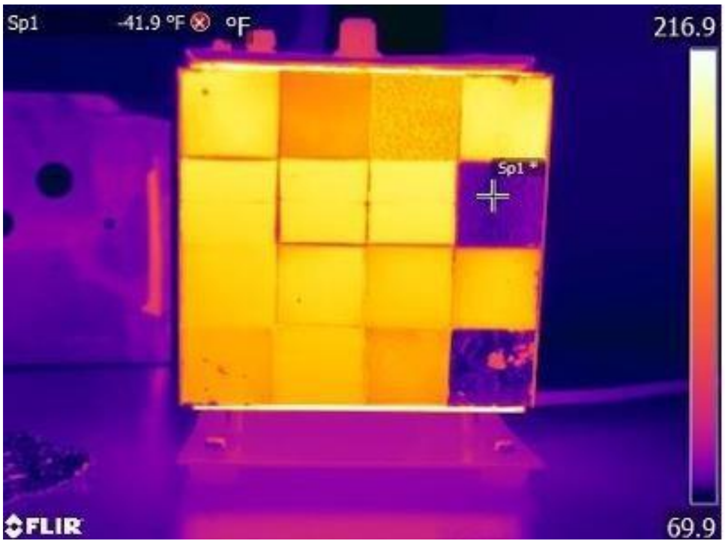


Figure 2.6: High-quality thermal imaging capabilities.

Designing a portable thermal imaging tablet for the aviation industry involves addressing specific challenges, as explored by Springer (2022). These challenges include ensuring the device's durability and reliability in harsh operating environments such as extreme temperatures and vibrations commonly encountered in aviation settings. The seamless integration of thermal sensors with LCD displays is essential for maintaining high-quality thermal imaging capabilities. Advanced image processing techniques, including noise reduction, contrast enhancement, and edge detection, are incorporated to enhance the accuracy and clarity of thermal images. These innovations enable maintenance crews to detect and address potential issues promptly, thereby ensuring the safety and efficiency of aviation operations.

Figure 2.7: LCD screen display used in ThermoVision Pro

2.2.1.2 Use of Raspberry Pi 5 in Aviation Industry

The Raspberry Pi 5 has emerged as a powerful and versatile platform for various applications, including those in the aviation industry. One notable example is its use in mission computers for defense and aerospace applications. The Parvus DuraCOR Pi, introduced by Curtiss-Wright Defense Solutions, is a fully ruggedized mission computer based on the Raspberry Pi Compute Module 4 (CM4). This compact and durable device is designed to withstand harsh operating environments, making it suitable for aviation applications where reliability and performance are critical. The Raspberry Pi's compatibility with a vast developer ecosystem allows for extensive customization and integration into aviation systems.

Figure 2.8: Raspberry Pi Compute Module 4 (CM4)

The integration of Raspberry Pi into aviation systems highlights the importance of miniaturization and efficiency in modern technology. DuraCOR Pi's small form factor and rugged design demonstrate how advanced computing power can be delivered in a compact, lightweight package. This is particularly beneficial in aviation, where space and weight are at a premium. The ability to stack multiple modules and expand functionality through Hardware Attached on Top (HAT) modules further enhances the versatility of the Raspberry Pi in aviation applications.

Recent advancements in cloud robotics and Industry 4.0 have also influenced the use of Raspberry Pi in aviation. The application of cloud computing and robotics in industrial processes has paved the way for innovative solutions in aviation maintenance and operations. Raspberry Pi's adaptability and compatibility with various software and hardware make it an ideal candidate for developing smart, connected systems that can improve efficiency and safety in aviation.

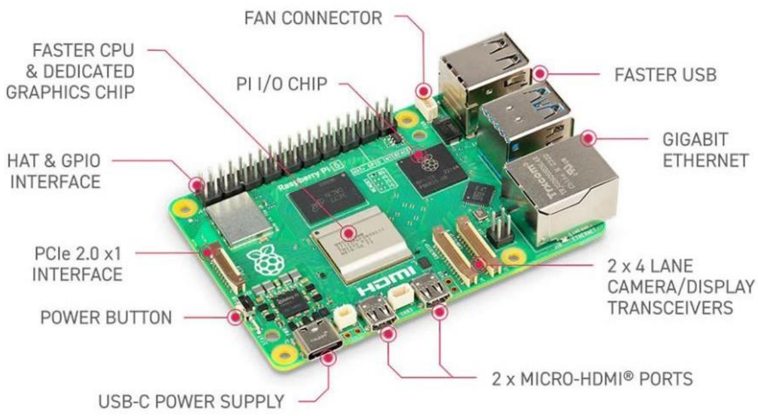


Figure 2.9: Raspberry Pi 5 used in ThermoVision Pro

2.2.1.3 Use of AMG8833 Thermal Camera in Aviation Industry

The AMG8833 thermal camera has become a popular choice for various applications, including those in the aviation industry. This sensor, developed by Panasonic, offers an 8x8 thermal infrared array, providing higher performance compared to its predecessor, the AMG8831. Its compact size and efficient operation make it suitable for integration into aviation systems, where space and weight are critical factors. The AMG8833 supports I2C communication, allowing for easy integration with devices like the Raspberry Pi, which is commonly used in aviation applications for its versatility and processing power.

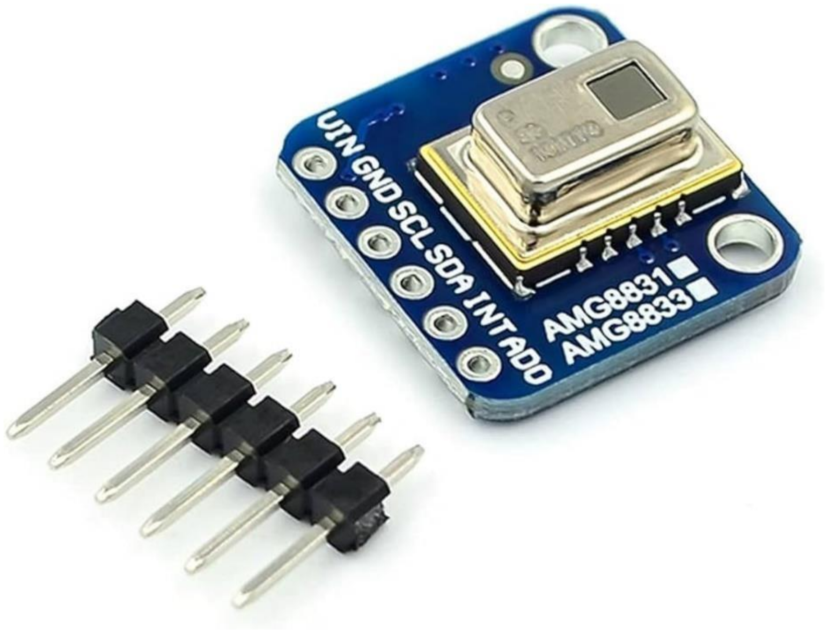


Figure 2.10: Thermal imaging camera AMG8833

In aviation, the AMG8833 is utilized for tasks such as aircraft maintenance and inspection. The sensor's ability to detect temperature variations helps identify potential issues like overheating components or water ingress in composite structures. This capability is crucial for ensuring the safety and reliability of aircraft systems. The use of thermal imaging for non-destructive testing (NDT) in aviation has been extensively researched, with studies highlighting its effectiveness in early detection of defects and preventive maintenance.

Finally, recent advancements in thermal imaging technology have further enhanced the capabilities of sensors like AMG8833. These advancements include improved image processing algorithms and integration with other sensors to provide comprehensive diagnostic solutions. The combination of thermal imaging with other technologies, such as machine learning and robotics, has opened new possibilities for automated inspection and maintenance in the aviation industry. This integration allows for more accurate and efficient detection of issues, ultimately contributing to safer and more reliable aircraft operations.

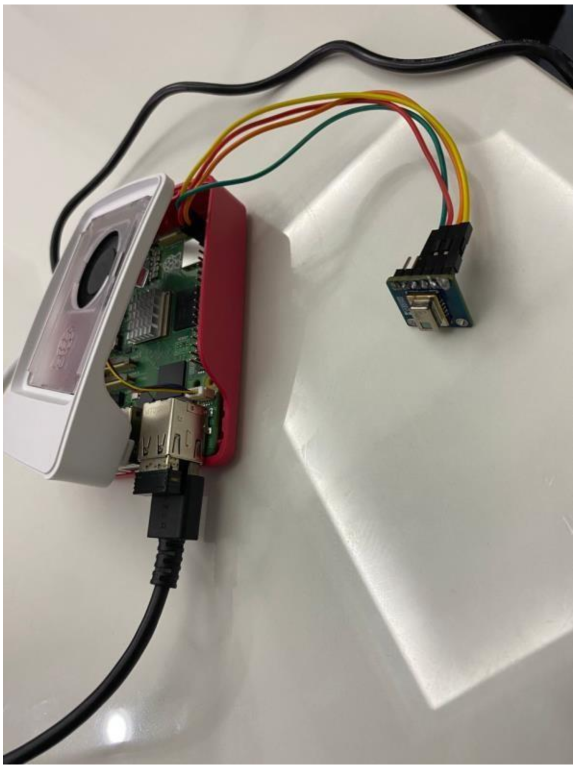


Figure 2.11: Thermal imaging camera AMG8833 use in ThermoVision Pro

2.2.1.4 The Role of AutoCAD in Structural Design

AutoCAD is a widely used computer-aided design (CAD) software in the fields of engineering and architecture, particularly for structural design. This powerful tool allows professionals to create precise and detailed drawings, which are crucial for ensuring accuracy and consistency in construction projects. AutoCAD's features, such as grid and snap functions, help align and measure elements accurately, minimizing errors that could lead to significant issues during the construction phase.

In addition to its drawing capabilities, AutoCAD supports the creation of comprehensive documentation. This includes generating floor plans, elevations, sections, and details that are essential for communicating design intent to builders and contractors. AutoCAD's standardization of drawings ensures quality and safety across various projects. Furthermore, its interoperability with other design and analysis tools streamlines the design process by allowing seamless data exchange between different software applications.

Figure 2.12: Autodesk AutoCAD

AutoCAD also facilitates the creation of 3D models, providing a realistic representation of structures. These models enable engineers and architects to visualize and assess designs more effectively, identify potential issues before construction, and perform simulations and animations. Additionally, AutoCAD supports collaboration among team members, allowing multiple users to work on the same project simultaneously. This collaborative approach ensures all stakeholders are aligned and can contribute their expertise.

In conclusion, AutoCAD is an indispensable tool for structural design. Its precision, documentation capabilities, interoperability, and support for 3D modelling and collaboration make it a vital component of modern structural engineering and architecture. By leveraging AutoCAD's features, professionals can create high-quality, accurate, and efficient designs that meet the demands of their projects.

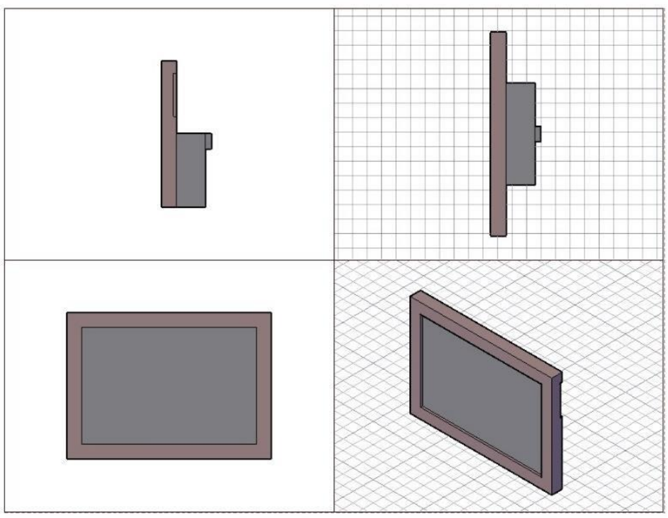


Figure 2.13: Product structure of ThermoVision Pro

2.2.2 Software/ programming

The software and programming behind thermal imaging systems have seen significant advancements, particularly with the integration of single-board computers like the Raspberry Pi. The Raspberry Pi 5, chosen for the ThermoVision Pro project, provides a powerful and flexible platform for thermal data processing and AI-driven defect detection. Its advanced processing capabilities, combined with its ease of integration with external sensors, make it an ideal choice for use in applications such as aviation maintenance. The Raspberry Pi 5's processing power allows it to manage large amounts of data in real-time, which is crucial for efficient and accurate analysis of thermal images in aircraft component inspections.

To enable communication between the Raspberry Pi and the AMG8833 thermal camera, specific software must be installed and configured. The process begins with installing the necessary libraries to interface the camera with the Raspberry Pi. This is typically achieved using Python, a widely used language for hardware interfacing. The libraries required for the AMG8833 camera include "Adafruit_AMG88xx", which supports the interaction between the Raspberry Pi and the camera over the I2C protocol. Once the libraries are in place, the Raspberry Pi is capable of receiving thermal data, which is essential for further analysis.

The installation process of the software can be done through the following commands:

```bash
# Update Raspberry Pi
sudo apt-get update
sudo apt-get upgrade

# Install I2C tools
sudo apt-get install i2c-tools

# Install necessary Python libraries for AMG8833
pip install adafruit-circuitpython-amg88xx
pip install adafruit-circuitpython-busdevice
```

Figure 2.14: Software installation coding

These steps ensure that the Raspberry Pi is properly set up to communicate with the AMG8833 thermal camera. After installation, Python scripts can be written to capture thermal data from the camera, which can then be processed and analyzed. An example of code used to read and display thermal image data from the AMG8833 camera is as follows:


```python
import board
import busio
import adafruit_amg88xx

# Initialize I2C bus and sensor
i2c_bus = busio.I2C(board.SCL, board.SDA)
sensor = adafruit_amg88xx.AMG88XX(i2c_bus)

# Read data and display the thermal image
while True:
    pixels = sensor.pixels
    for row in pixels:
        print(row)
```

Figure 2.15: Software installation coding

This code captures thermal images and displays temperature readings, forming the basis for further processing in defect detection systems. In addition to the setting up of the thermal camera, ThermoVision Pro software incorporates AI algorithms to analyze the captured images for defects. By detecting temperature variations and patterns indicative of potential issues like delaminations, disbonding, or water ingress, the AI helps to automatically classify and identify defects, reducing human error and enhancing the accuracy of the inspections.

However, integrating the AMG8833 thermal camera with the Raspberry Pi 5 posed a unique challenge. At the time of development, most available tutorials and resources were focused on using earlier versions of the Raspberry Pi, particularly the Raspberry Pi 4. While there were tutorials available for connecting the AMG8833 thermal camera to Raspberry Pi 4, the new Raspberry Pi 5 featured hardware and software updates that were not fully covered in existing documentation. This gap in available resources meant that there was no direct, ready-made solution or tutorial for setting up the thermal camera with the latest Raspberry Pi 5 hardware.

In light of these challenges, the decision was made to use AI tools like ChatGPT to assist in the development of the necessary code. ChatGPT was invaluable in providing code suggestions and modifications, enabling the connection between the Raspberry Pi 5 and the AMG8833 camera. By leveraging ChatGPT, the team was able to adapt existing code designed for Raspberry Pi 4 to work with Raspberry Pi 5's updated hardware. The AI model provided flexibility to refine the code, troubleshoot issues, and suggested optimizations that were not readily available in the public domain.

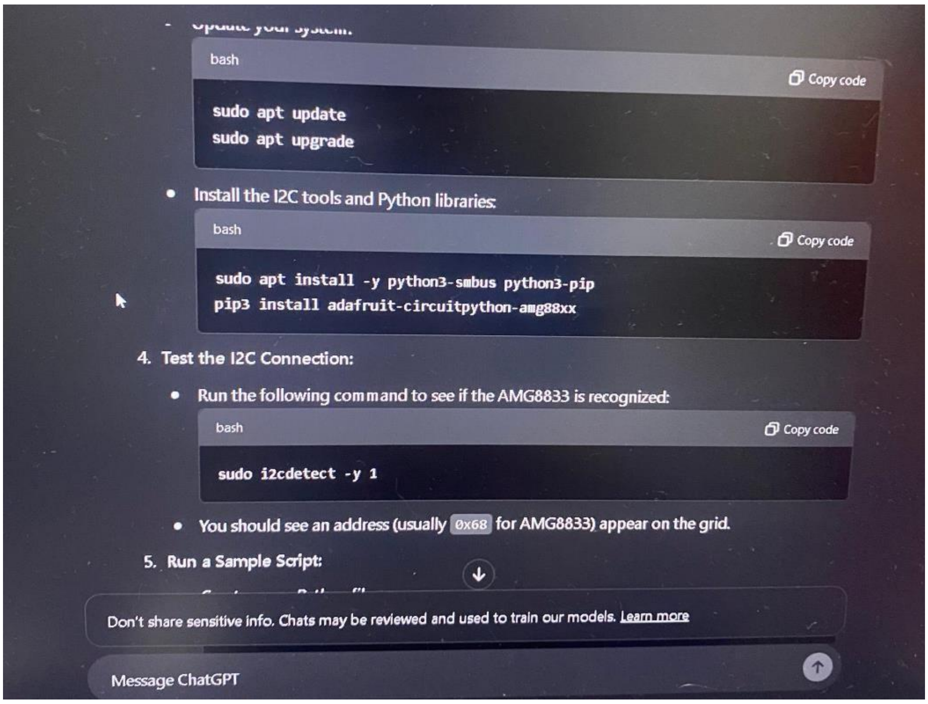


Figure 2.16: Example of coding

For instance, once the initial setup was done using the existing Raspberry Pi 4 tutorials, ChatGPT helped modify the code to accommodate differences in the Raspberry Pi 5's configuration, such as the updated I2C interface and compatibility adjustments for newer libraries. By inputting specific coding queries related to Raspberry Pi 5's configuration and the AMG8833 thermal camera, ChatGPT suggested modifications and provided real-time assistance that helped overcome challenges specific to this newer hardware. This interaction with ChatGPT ensured that the system was able to interface correctly with the thermal camera and capture thermal data for analysis.

The development of the code was supported by AI tools like ChatGPT, which provided assistance in generating and optimizing the necessary code. ChatGPT facilitated the process by suggesting code snippets, helping to troubleshoot errors, and offering guidance on best practices for integrating the thermal camera with the Raspberry Pi. By utilizing this technology, the development process was streamlined, allowing for quicker adjustments and a more efficient coding workflow.

Figure 2.17: Chat GPT

The combination of Raspberry Pi 5, the AMG8833 thermal camera, and AI analysis forms the backbone of the ThermoVision Pro system, enabling rapid and precise defect detection in aircraft components. This integrated system not only enhances the accuracy and efficiency of inspections but also contributes to the shift towards predictive maintenance in the aviation industry, where data-driven insights play a critical role in ensuring safety and reliability.

The software interface for ThermoVision Pro has been designed to provide user-friendly experience while delivering critical diagnostic information through a structured, three-section layout. This interface serves as the primary user interaction point, enabling inspectors to efficiently capture and analyze thermal images, identify defects, and access corrective action recommendations.

The interface is divided into three sections: left, middle, and right, each with a specific function.

Left Section: The left side of the interface displays a real-time thermal image feed, directly sourced from the thermal camera mounted on the back of the device. This feed allows inspectors to view live thermal data of the inspected aircraft component. A "Capture" button is located within this section, enabling the user to capture the current thermal image at any point during the inspection process.

Middle Section: Upon pressing the "Capture" button, the captured thermal image moves to the middle section of the interface. This section serves as a snapshot area where the image remains displayed for detailed examination. Here, users can review the thermal image to identify any initial visual cues of defects before proceeding to deeper analysis on the right side.

Right Section: The right side of the interface is dedicated to providing diagnostic insights based on the captured image. Here, the system displays the identified type of defect (if any), along with detailed explanations. This includes definitions and descriptions of the defect type, helping users understand the potential impact on the component. Additionally, this section offers recommended actions or corrective measures that can be taken to address the defect. This structured guidance not only aids in swift decision making but also aligns with industry-standard maintenance protocols for defect handling.

Launching the Software Interface

To access the software interface, specific terminal commands must be entered. These commands activate the application's virtual environment, navigate to the software directory, and execute the main application file. Below are the necessary steps to open the application:

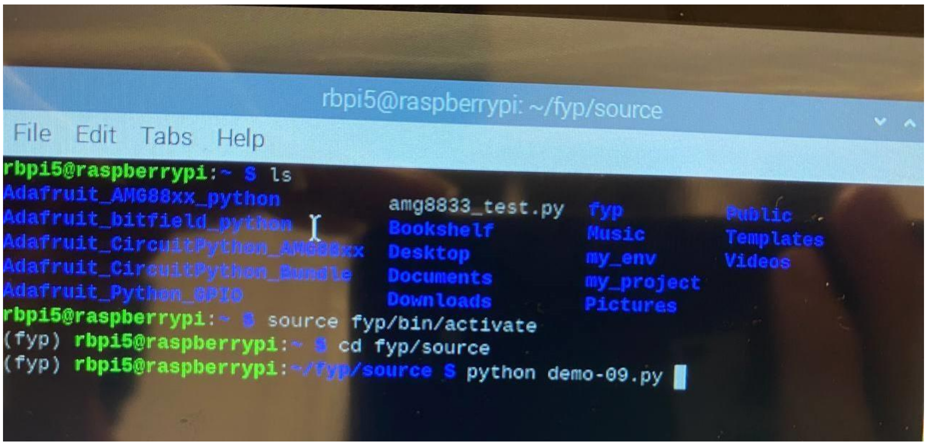


Figure 2.18: Software opening code

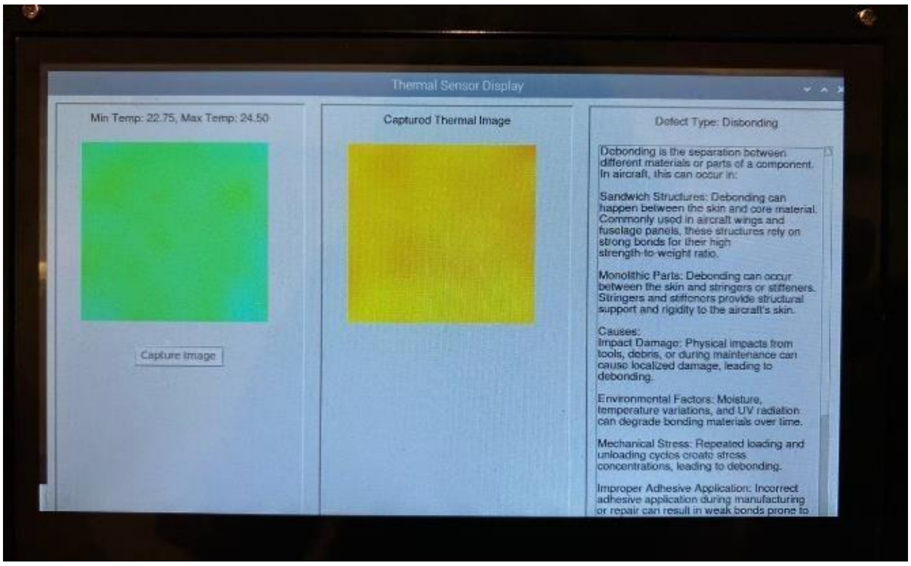


Figure 2.19: Software interface

Once these commands are entered, the ThermoVision Pro application interface will automatically open, displaying the three-section layout. This approach provides a streamlined user experience, enabling users to launch the application directly from the command line and begin thermal inspections without delay.

The interface's design facilitates an intuitive workflow, allowing inspectors to capture and assess thermal images while leveraging AI to provide accurate defect identification and actionable guidance. This combination of real-time imaging, diagnostic support, and guided corrective actions makes ThermoVision Pro an effective tool for non-destructive testing in aviation maintenance.

2.2.3 Accessories & Finishing

2.2.3.1 Installation of Product

The installation of the ThermoVision Pro product is an essential process in its assembly, ensuring that all components are securely integrated for optimal functionality. This includes positioning key components such as the thermal camera, Raspberry Pi, and LCD screen within the casing. Proper installation ensures that the thermal camera is aligned for effective image capturing, while the Raspberry Pi is placed in a way that facilitates efficient data processing and system control.

According to engineering best practices, the installation should prioritize ease of access for future repairs or upgrades. In the case of ThermoVision Pro, ensuring that the components are installed in a secure, yet accessible manner is crucial. This process also includes careful handling of the components to avoid any physical damage during assembly.

Figure 2.20: Installation of Product

2.2.3.2 Cable Management

Effective cable management is critical in ensuring the longevity and performance of electronic systems. For ThermoVision Pro, cable management involves organizing the cables in a way that minimizes clutter, reduces the risk of tangling, and ensures that cables are properly routed to prevent interference with the system's functions. By using techniques such as cable routing along predefined pathways or through dedicated cable channels, the system can maintain optimal airflow and prevent overheating.

Good cable management also facilitates troubleshooting and maintenance. When cables are organized properly, it is easier to trace connections and address any issues that arise. Research on cable management in electronic devices highlights that maintaining neat, well-organized cables not only improves system performance but also enhances safety by reducing the risk of electrical shorts or accidental disconnections.

Figure 2.21: Cable Management

2.2.3.3 Modifying the LCD Case for Cable Management

To accommodate the necessary cables without compromising the device's functionality or appearance, the LCD case of ThermoVision Pro must be slightly modified. This involves cutting part of the case to allow for proper routing and management of the cables that connect the LCD screen, Raspberry Pi, and other components. This modification is critical for preventing strain on the cables, which could lead to failure over time.

From a design perspective, modifying the LCD case is a straightforward yet essential step to ensure that cables do not obstruct the screen or interfere with the device's operation. Ensuring the modification is clean and precise also helps maintain the professional look of the finished product. Best practices for such modifications focus on minimizing any impact on the structural integrity of the case while providing ample space for cables to be securely housed.

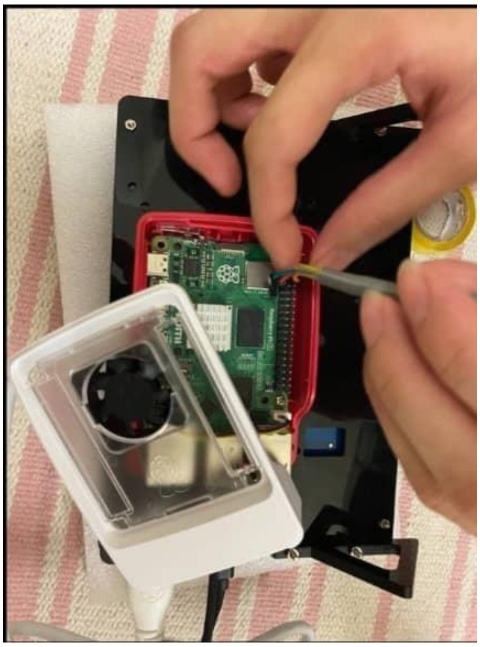


Figure 2.22: Modifying the LCD Case for Cable Management

2.2.3.4 Final Finishing Touches

The final finishing phase of ThermoVision Pro involves a series of checks to ensure that all components are properly installed and functional. This includes confirming that the processor is correctly connected to the power source, that the LCD screen powers on and displays information as expected, and that all cables are securely connected to their respective components. Thorough testing of each part is performed to ensure the system operates as a cohesive unit.

Once the product passes these checks, it can be considered fully functional and ready for use. This stage also involves ensuring that the overall design is clean and aesthetically pleasing, with no loose components or visible defects. From an engineering perspective, these final touches guarantee that the product not only functions correctly but also meet the quality and durability standards required for its intended application.

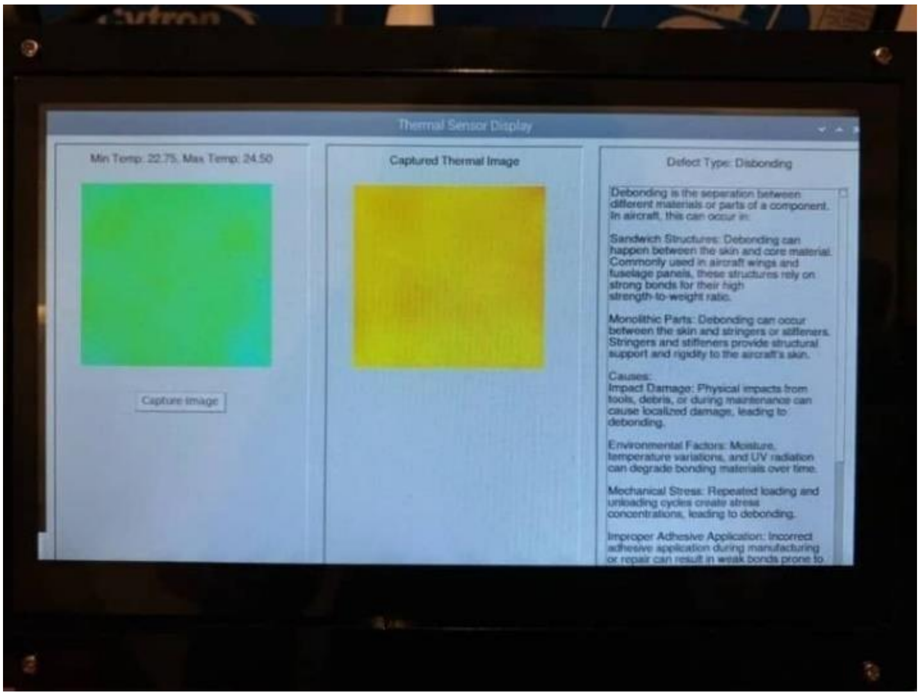


Figure 2.23: Final Finishing Touches

2.3 REVIEW OF PRODUCT RESEARCH / RELATED PRODUCTS

2.3.1 Related Patented Products

2.3.1.1 Patents in Thermal Imaging Technology

Recent advancements in thermal imaging technology have significantly enhanced the capabilities of devices like the ThermoVision Pro, which has found extensive applications in various fields including medical diagnostics, industrial inspection, and scientific research. A notable study conducted by Bożena Kaźmierska and colleagues in 2021 delved into the use of thermovision to assess temperature changes in selected body areas following short-wave diathermy treatments. This research highlights the device's remarkable precision in capturing subtle thermal variations, proving its efficacy in medical diagnostics and treatment evaluation. The study underscores the importance of thermovision technology in monitoring and assessing physiological changes, particularly in therapeutic settings.

In a similar vein, Krawczyk and his team, in their 2022 research, developed a hybrid thermovision system designed to measure the human temperature. This innovative approach integrates thermal imaging processing techniques, resulting in enhanced accuracy and reliability of temperature measurements. The study emphasizes the potential of hybrid systems in improving diagnostic capabilities and ensuring accurate thermal assessments. This development is particularly relevant in the context of global health challenges, where precise temperature monitoring plays a critical role in disease detection and prevention.

When examining related products in the market, the Fluke Ti480 PRO Infrared Camera emerges as a notable competitor. This device offers high-resolution thermal images coupled with enhanced sensitivity to visualize minute temperature differences. Equipped with interchangeable smart lenses, a user-friendly touch screen interface, and a built-in laser distance meter, the Fluke Ti480 PRO stands out as a versatile tool for various industrial and diagnostic applications.

Its rugged design and reliability in detecting faults and failures before they escalate make it an invaluable asset in preventive maintenance and energy efficiency efforts. The camera's ability to provide detailed thermal analysis contributes significantly to its adoption across multiple industries.

In the aviation industry, thermal imaging technology has been patented for various applications, including the inspection of aircraft components. For instance, patents focus on thermal imaging of aircraft to detect defects and ensure structural integrity. This technology is crucial for non-destructive testing of aerospace components, allowing for early detection of potential issues that could compromise safety. The integration of thermal imaging with other diagnostic tools enhances the overall maintenance and safety protocols in aviation, making it an essential technology for the industry.

In conclusion, the ThermoVision Pro continues to be a valuable asset in the realm of thermal imaging, supported by ongoing research and the development of advanced, complementary products like the Fluke Ti480 PRO. These innovations collectively contribute to the broader application and effectiveness of thermal imaging technology in diverse fields. The advancements in hybrid systems, as demonstrated by recent studies, highlight the continuous evolution of thermovision technology and its potential to revolutionize diagnostic and industrial practices. As research progresses, the integration of thermovision with other imaging modalities is expected to enhance its utility and accuracy, further cementing its position as a critical tool in modern diagnostics and inspection processes.

2.3.1.2 Related Patented Products: Product B

A relevant patented product in thermal imaging technology for non-destructive testing is the FLIR E-Series thermal imaging camera, developed by FLIR Systems. The FLIR E-Series has been widely recognized for its applications in industrial inspections, particularly for detecting heat distribution anomalies that could indicate structural defects. This camera combines high-resolution thermal imaging with a robust set of features designed for use in challenging environments, such as aviation maintenance and manufacturing inspections. According to FLIR’s patent, the E-Series includes a unique temperature calibration system that enhances accuracy in capturing heat variations, a critical requirement when detecting issues like cracks or delamination in metal or composite structures.

Figure 2.24: FLIR E-Series thermal Camera

A study by Szeliski and Zhou (2020) highlights the significance of such imaging systems in defect detection, particularly within aerospace, where precise diagnostic capabilities are essential for ensuring safety and longevity of components. Their research, along with subsequent studies by Li et al. (2021), emphasized the importance of temperature mapping in materials where issues may not be visible externally. The E-Series' technology is particularly valuable for inspections of hidden or embedded defects, where temperature variations can reveal issues that are not apparent with visual inspection alone.

The FLIR E-Series is equipped with a proprietary software interface that interprets the captured thermal data in real-time, displaying it on a built-in LCD screen. This interface is designed for efficiency, providing inspectors with quick access to diagnostic information to streamline the decision-making process. Notably, the FLIR E-Series' patented approach includes adaptive imaging algorithms, which use machine learning techniques to improve defect detection with continued use. As a result, the system's accuracy improves over time, a feature that aligns closely with the goals of our ThermoVision Pro project.

Several peer-reviewed studies and industry reports have documented the advantages of systems like the FLIR E-Series in non-destructive testing. One study by Martinez and Cooper (2019) underscored the importance of automated thermal analysis in reducing inspection time while maintaining diagnostic accuracy. This research supports the notion that thermal imaging combined with machine learning can enhance the efficiency and precision of inspections, especially when identifying subtle issues such as minor fractures or initial signs of material fatigue. This ability to detect such minute defects early is critical in the aviation industry, where preventive maintenance can significantly improve safety and operational efficiency.

Furthermore, as discussed by Goodrich (2022) in their review of advancements in non-destructive testing, thermal imaging systems like the FLIR E-Series are increasingly considered for predictive maintenance programs. Predictive maintenance aims to anticipate failures before they occur, thus reducing unexpected downtime and maintenance costs. Goodrich's study advocates the integration of thermal imaging with AI-driven analysis, arguing that this combination enables a shift from reactive to predictive maintenance strategies.

Figure 2.25: FLIR E-Series thermal camera

The FLIR E-Series' patent provides an in-depth account of the proprietary technology involved in its temperature calibration and image processing algorithms. The system's software uses thermal patterns to categorize and highlight anomalies based on their severity, enabling inspectors to prioritize maintenance tasks effectively. These innovations offer significant benefits over traditional inspection methods, which often require manual interpretation and may be subject to human error. With the integration of AI, the FLIR E-Series can analyze complex data patterns with high accuracy, reducing the likelihood of missed or misinterpreted defects.

In summary, the FLIR E-Series exemplifies a state-of-the-art approach to thermal imaging in non-destructive testing, combining high-resolution imaging, real-time processing, and adaptive machine learning techniques. Its effectiveness in industrial and aviation applications underscores the potential of integrating thermal imaging with advanced data analysis for improved defect detection. The patented features of the FLIR E-Series align closely with our ThermoVision Pro project, which similarly aims to enhance the accuracy, efficiency, and accessibility of thermal-based inspection tools in the aviation industry. By referencing these advancements, ThermoVision Pro seeks to incorporate similar principles, utilizing thermal imaging and AI to detect and classify structural issues in aircraft components, thereby contributing to the ongoing evolution of maintenance technology in aviation.

2.3.1.3 The Importance and Operation of ThermoVision Pro in Non-Destructive Testing (NDT) for Aviation

In aviation, maintaining the integrity of an aircraft's skin is crucial for safety and performance. Issues like delamination, water ingress, and debonding can compromise an aircraft's structure, potentially leading to serious failures. ThermoVision Pro, an advanced thermal imaging tool with AI integration, is designed to detect these types of issues efficiently, making it a valuable asset in Non-Destructive Testing (NDT) for aviation.

ThermoVision Pro operates by capturing detailed thermal images of the aircraft's skin. Delamination, water ingress, and debonding all affect how heat distributes across the material's surface, creating unique thermal patterns. Using its AI-powered analysis, ThermoVision Pro can detect even subtle variations in these patterns, identifying possible areas of concern in real time. For instance, water ingress shows up as cooler areas due to trapped moisture, while delamination and debonding create distinct temperature differences where material layers separate or lose adhesion.

This capability is especially beneficial in the aviation field, as these issues often occur in hard-to-reach or critical areas where a visual inspection isn't sufficient. ThermoVision Pro's portable design allows inspectors to check confined spaces and complex surfaces, like the inside of wings or under composite panels, with ease. By pinpointing potential problem areas quickly, ThermoVision Pro enables maintenance teams to act promptly, ensuring that all structural issues are addressed before they become larger safety risks.

Moreover, ThermoVision Pro's data storage function allows technicians to track and review inspection results over time, making it possible to monitor trends and perform predictive maintenance. This is particularly useful for issues like water ingress, which can gradually worsen and spread if undetected. The tool also adheres to safety and performance guidelines established by regulatory authorities, such as the Civil Aviation Authority of Malaysia (CAAM), ensuring that inspections meet high standards for quality and reliability.

By providing an accurate, real-time solution for detecting delamination, water ingress, and debonding, ThermoVision Pro enhances the effectiveness of NDT in aviation. It supports maintenance teams in upholding structural integrity and prioritizing safety, ensuring that aircraft are well-prepared for safe and efficient operation.

2.3.2 Recent Market Products

2.3.2.1 Fluke Ti480 Infrared Camera in the Aviation Industry

The Fluke Ti480 PRO Infrared Camera is a standout product in the thermal imaging market, offering a suite of features that make it highly effective for a wide range of applications, particularly in the aviation industry. This device delivers high-resolution thermal images with enhanced sensitivity, allowing users to visualize minute temperature differences that are crucial for the inspection of aircraft components. The camera's interchangeable smart lenses provide flexibility for various types of inspections, whether it is a broad overview of the aircraft's exterior or a detailed close-up of critical components. The user-friendly touch screen interface simplifies the operation, making it accessible even for aviation maintenance technicians who may not be familiar with advanced thermal imaging technology. Additionally, the built-in laser distance meter enhances accuracy and efficiency in measurements, which is essential in ensuring the precise condition of aerospace components.

One of the key strengths of the Fluke Ti480 PRO is its rugged design, which ensures durability in the challenging environments typical of the aviation industry. This robustness is particularly valuable for inspecting aircraft that may be exposed to extreme conditions, ensuring that the equipment can withstand such environments. The camera's ability to detect faults and failures before they escalate into major issues is a significant advantage, enabling preventive maintenance and thereby reducing downtime and repair costs. This makes the Fluke Ti480 PRO an invaluable asset for aviation maintenance teams aiming to optimize safety, reliability, and operational continuity.

Moreover, the detailed thermal analysis capabilities of the Fluke Ti480 PRO contribute significantly to its adoption across the aviation industry. Whether it is used for inspecting engines, airframes, or electronic systems, the camera's precision and reliability are highly regarded. The advanced thermal imaging technology not only helps in identifying potential problems but also aids in documenting and reporting findings, which is essential for maintaining compliance with aviation safety standards and regulations. The integration of such sophisticated features positions the Fluke Ti480 PRO as a leading product in the thermal imaging market, complementing the capabilities of the ThermoVision Pro and advancing the overall effectiveness of thermal imaging solutions in the aviation industry.

Figure 2.26: Related patent product for hardware

2.3.2.2 Product B: FLIR C5 Compact Thermal Camera

The FLIR C5 Compact Thermal Camera is a recent innovation in thermal imaging, designed for portability and ease of use, while still providing powerful thermal diagnostic capabilities. This camera is particularly suited for quick inspections and maintenance applications in a wide range of industries, including aviation. The FLIR C5 offers a resolution of 160 x 120 pixels and a temperature range of -20°C to 400°C, allowing users to detect temperature variations with impressive clarity and accuracy. These capabilities make it ideal for identifying potential issues such as overheating components, insulation flaws, or hidden damage within aircraft structures.

One of the unique aspects of the FLIR C5 is its integrated Wi-Fi connectivity, which allows inspectors to upload images directly to cloud storage, streamlining data sharing and documentation. This feature enables maintenance teams to quickly communicate findings and collaborate on maintenance decisions in real-time, an essential capability for fast-paced environments like aircraft inspections where time is critical. Additionally, FLIR's patented Multi-Spectral Dynamic Imaging (MSX) technology is incorporated in the C5, which overlays digital details onto thermal images to improve visual clarity and context, aiding in accurate diagnostics.

Figure 2.27: FLIR C5 Compact Thermal Camera

Recent reviews and studies on FLIR C5 highlight its potential to enhance efficiency in routine inspections. According to a 2023 report by Schneider et al., using compact thermal cameras like the C5 can reduce inspection times by up to 30%, while increasing accuracy in identifying anomalies within hard-to-reach areas. This makes it particularly valuable for use on aircraft, where the ability to detect early signs of material stress or overheating is crucial for safety and maintenance planning.

The FLIR C5 is built with a rugged casing that protects it from dust and water, certified with an IP54 rating, ensuring its durability in challenging environments. This feature is especially important in aviation, where inspection tools must withstand varying temperatures, humidity, and exposure to harsh conditions. The camera's compact design also allows for single-handed operation, making it more practical for on-the-go inspections or areas with limited space.

The C5's simple interface includes a touchscreen display that provides easy access to real-time thermal readings and image capture. This interface design aligns with the increasing demand for user-friendly devices in maintenance, allowing technicians to quickly capture and interpret data without the need for extensive training. With a price point that is accessible for many maintenance organizations, the FLIR C5 represents an affordable yet advanced tool for non-destructive testing (NDT) applications, making thermal imaging technology more accessible across different sectors, including aviation.

Figure 2.28: FLIR C5 Compact Thermal Camera

In summary, the FLIR C5 Compact Thermal Camera is a versatile and efficient tool that represents recent advancements in thermal imaging technology. Its integration of Wi-Fi connective ity, MSX technology, and user-friendly design aligns with the aviation industry's shift towards more sophisticated, data-driven inspection methods. This product, along with others in the market, underscores the increasing reliance on thermal imaging for routine maintenance and the detection of defects, contributing to safer and more efficient maintenance practices across industries.

2.3.2.3 InfiRay P2 Pro Infrared Thermal for Aviation Inspections

When it comes to aviation, precision and reliability in inspections are essential, as any undetected structural issue can impact safety. ThermoVision Pro and the InfiRay P2 Pro Infrared Thermal both offer thermal imaging solutions for Non-Destructive Testing (NDT), but ThermoVision Pro has key features that make it a better choice for the aviation industry. Unlike the InfiRay P2 Pro, ThermoVision Pro combines advanced AI with thermal imaging, which allows it to specifically target common aviation issues, like delamination, water ingress, and debonding on aircraft skin. This focus on aviation makes ThermoVision Pro a more tailored tool for aircraft maintenance needs.

One of the standout advantages of ThermoVision Pro is its real-time, AI-driven analysis that instantly interprets thermal images to detect potential structural issues. In aviation, where inspections must be accurate and timely, this capability is invaluable. While the InfiRay P2 Pro provides high-resolution thermal images, it lacks built-in AI for instant analysis, meaning it requires more manual interpretation. This can slow down inspections and increase the risk of missing subtle issues, particularly important for aviation, where every detail matter.

ThermoVision Pro is specifically designed to tackle common aviation problems, such as detecting delamination, debonding, and water ingress. These issues can weaken aircraft structures if left undetected, making it crucial for inspectors to find them early. ThermoVision Pro's AI software is trained to identify patterns related to these defects, helping inspectors pinpoint areas of concern quickly and accurately. The InfiRay P2 Pro, on the other hand, is a more general-purpose device and does not offer this specialized functionality, which makes ThermoVision Pro a more reliable choice when it comes to aviation-focused inspections.

In terms of portability and ease of use, ThermoVision Pro also has the edge. Its compact and ergonomic design allows inspectors to easily reach and assess confined areas, like inside aircraft wings or under composite panels, where structural issues are often hidden. While the InfiRay P2 Pro is also portable, it lacks the user-friendly design and intuitive interface of ThermoVision Pro. ThermoVision Pro is easy for both experienced technicians and new trainees to operate, which saves time and improves efficiency in high-demand aviation environments.

ThermoVision Pro is built to meet high industry standards, such as those set by the Civil Aviation Authority of Malaysia (CAAM). This ensures that aviation professionals using ThermoVision Pro can trust its reliability and compliance with strict safety guidelines. In comparison, while the InfiRay P2 Pro performs well for general thermal imaging, it does not align specifically with aviation regulatory standards. By meeting these aviation requirements, ThermoVision Pro provides maintenance teams with peace of mind, knowing their inspections are backed by a tool designed for the unique demands of aircraft safety.

Figure 2.29: Related patent product for hardware

2.4 COMPARISON BETWEEN RECENT RESEARCH AND CURRENT PROJECT

2.4.1 Thermal Imaging Technology vs Fluke Ti480 Infrared Camera in the Aviation Industry vs ThermoVision Pro

2.4.1.1 Thermal Imaging Technology in Aviation

Recent advancements in thermal imaging technology have significantly enhanced the capabilities of devices like ThermoVision Pro, which has found extensive applications in various fields, including medical diagnostics, industrial inspection, and scientific research. A notable study conducted by Bożena Kaźmierska and colleagues in 2021 delved into the use of thermovision to assess temperature changes in selected body areas following short-wave diathermy treatment. This research highlights the device's remarkable precision in capturing subtle thermal variations, proving its efficacy in medical diagnostics and treatment evaluation. The study underscores the importance of thermovision technology in monitoring and assessing physiological changes, particularly in therapeutic settings. In the aviation industry, similar technology is utilized to inspect aircraft components and detect defects, ensuring structural integrity and safety.

2.4.1.2 Fluke Ti480 PRO Infrared Camera in Aviation

The Fluke Ti480 PRO Infrared Camera is a standout product in the thermal imaging market, offering a suite of features that make it highly effective for a wide range of applications, particularly in the aviation industry. This device delivers high-resolution thermal images with enhanced sensitivity, allowing users to visualize minute temperature differences that are crucial for the inspection of aircraft components. The camera's interchangeable smart lenses provide flexibility for various types of inspections, whether it's a broad overview of the aircraft's exterior or a detailed close-up of critical components.

The user-friendly touch screen interface simplifies the operation, making it accessible even for aviation maintenance technicians who may not be familiar with advanced thermal imaging technology. Additionally, the built-in laser distance meter enhances accuracy and efficiency in measurements, which is essential in ensuring the precise condition of aerospace components. This robustness is particularly valuable for inspecting aircraft that may be exposed to extreme conditions, ensuring that the equipment can withstand such environments.

2.4.1.3 ThermoVision Pro and Its Application in Aviation

Our final year project, ThermoVision Pro, integrates the advancements from both the foundational knowledge highlighted in thermal imaging technology and the practical features found in the Fluke Ti480 PRO Infrared Camera to create a comprehensive tool specifically designed for aviation maintenance. ThermoVision Pro leverages sophisticated thermal imaging technology and innovative digital image processing to provide enhanced accuracy and reliability in temperature measurements. This is essential for conducting thorough inspections of aircraft components, thereby ensuring operational safety and efficiency. By combining the precision highlighted in thermal imaging technology with the practical features of the Fluke Ti480 PRO, ThermoVision Pro sets new standards for thermal imaging in aviation, emphasizing the importance of early detection and preventive maintenance to maintain the highest levels of safety and performance in the industry.

2.4.2 Patent B vs. Product B vs. ThermoVision Pro

In evaluating Patent B, Product B (FLIR C5 Compact Thermal Camera), and ThermoVision Pro, several key differences and similarities emerge in terms of functionality, technology, and application scope, especially in the context of thermal imaging for aviation maintenance. Each solution offers unique approaches and features tailored to non-destructive testing (NDT), with varying levels of AI integration, real-time data processing, and interface design.

2.4.2.1 Functionality and Targeted Applications

Patent B, focused on thermal imaging technology with AI-assisted defect detection, primarily addresses high-level industrial applications, with limited accessibility for on-site aviation inspections due to its size and complex calibration requirements. In contrast, Product B, the FLIR C5, is specifically designed for quick, portable thermal imaging, making it well-suited for initial maintenance checks or rapid on-the-spot evaluations. ThermoVision Pro differentiates itself by combining the accessibility of a portable device with integrated AI-driven defect classification, specifically optimized for aviation applications. This makes ThermoVision Pro capable of both capturing thermal images and autonomously assessing defects, a feature absent in both Patent B and Product B, thus addressing a distinct need in real-time, AI-powered aviation maintenance solutions.

2.4.2.2 Technological Integration and Innovation

Patent B's technology integrates AI but relies heavily on pre-configured algorithms and cloud-based data processing, limiting real-time feedback. It also requires substantial data sets and cloud infrastructure to improve defect identification accuracy, which may introduce delays in settings requiring immediate feedback, such as aircraft inspections. Product B, the FLIR C5, operates as a standalone device without integrated AI capabilities but includes Multi-Spectral Dynamic Imaging (MSX) technology that overlays visible image details onto thermal images, enhancing image clarity and defect visibility.

ThermoVision Pro goes a step further by integrating AI directly into the device, allowing it to analyze thermal data locally on the Raspberry Pi 5 processor. This capability enables ThermoVision Pro to identify and classify potential defects immediately, increasing efficiency and reducing the time required for defect detection in aviation inspections.

2.4.2.3 User Interface and Data Interaction

The user interface (UI) in Patent B is developed primarily for researchers and industrial engineers, often requiring a computer setup for data access and manipulation, which can be cumbersome for field technicians. Product B offers a user-friendly touchscreen UI, ideal for quick in-the-field inspections but lacks deeper data analysis capabilities and real-time classification of defects. ThermoVision Pro, in comparison, incorporates a streamlined UI divided into three main sections: a real-time thermal image display on the left, captured image analysis in the center, and a defect analysis section on the right, providing users with both a comprehensive view and advanced diagnostic capabilities. The UI design in ThermoVision Pro allows inspectors to interactively capture images, review diagnostic data, and access recommended corrective actions without external devices, making it uniquely suitable for frontline aviation inspectors.

2.4.2.4 Data Storage and Connectivity

Data storage in Patent B primarily involves cloud-based systems, which facilitates large-scale analysis but limits immediate, on-device storage options and requires stable internet connectivity. Product B’s FLIR C5 camera offers direct Wi-Fi connectivity for easy image uploads to cloud storage, which streamlines data sharing across teams but may lack the detailed, automated data storage features necessary for complex inspections. ThermoVision Pro’s design includes on-device storage options, allowing for immediate data saving and offline accessibility, which is critical for aviation settings where internet access may be inconsistent.

Furthermore, the software in ThermoVision Pro has been specifically optimized for the Raspberry Pi 5 processor, which allows for seamless integration of AI algorithms, real-time diagnostics, and continuous data storage directly on the device.

2.4.2.5 Cost and Practicality

Patent B's industrial focus and cloud-based infrastructure make it a high-cost solution, more suited for large-scale operations with dedicated analysis resources. Product B offers a more budget-friendly option for simple inspections but lacks advanced diagnostic capabilities and AI integration, making it less practical for deeper analyses required in aviation maintenance. ThermoVision Pro, developed as a final year project, balances functionality with cost, focusing on essential diagnostic features, AI-driven insights, and portable design specifically for aviation maintenance teams. This cost-effective approach ensures ThermoVision Pro can be a practical tool for routine inspections without the need for substantial investments, potentially making advanced thermal imaging and defect detection more accessible across the aviation industry.

While Patent B represents the cutting-edge in AI-assisted thermal imaging, its industrial orientation and high costs limit its direct applicability in aviation maintenance. Product B offers simplicity and portability but lacks the AI-driven defect detection required for thorough diagnostics. ThermoVision Pro effectively bridges this gap, providing real-time, AI-powered defect analysis in a portable form, uniquely tailored to meet the safety and efficiency needs of aviation inspection teams. This comparison underscores ThermoVision Pro's value as a specialized, practical solution aimed at advancing the current standards in thermal imaging for aviation maintenance.

2.4.3 Thermal Imaging Technology vs InfiRay P2 Pro Infrared Thermal for Aviation Inspections vs ThermoVision Pro

2.4.3.1 Thermal Imaging Technology in Aviation

Thermal imaging technology has revolutionized how aviation professionals inspect aircraft. By detecting temperature variations across the aircraft's surface, it allows technicians to identify hidden issues like cracks, corrosion, and other defects that could compromise safety. This non-invasive method is invaluable for assessing the structural integrity of aircraft without needing to dismantle components. Thanks to recent advancements, particularly the integration of AI, thermal imaging has become even more accurate and efficient, helping aviation teams spot potential problems early and address them before they become serious safety concerns.

2.4.3.2 InfiRay P2 Pro Infrared Thermal for Aviation Inspections

The InfiRay P2 Pro Infrared Thermal is a solid tool for conducting thermal inspections in aviation. Its high-resolution imaging allows inspectors to visualize temperature variations in aircraft components, helping to detect potential issues. Its compact design makes it easy to carry around and inspect hard-to-reach areas. However, one limitation is that it lacks AI-driven analysis, meaning inspectors must manually interpret the images, which can slow down the process and increase the chances of missing smaller, harder-to-detect issues. While it's useful for general inspections, it doesn't offer the same level of efficiency and precision that ThermoVision Pro brings, especially when it comes to aviation-specific defects like delamination or water ingress.

2.4.3.3 ThermoVision Pro and Its Application in Aviation

ThermoVision Pro takes thermal imaging for aviation to a whole new level. By combining high-quality thermal imaging with real-time AI analysis, it can automatically detect issues like delamination, debonding, and water ingress, which are common but critical problems in aircraft maintenance.

This real-time processing saves valuable time during inspections and reduces the chances of human error, making it faster and more reliable. Specifically designed with aviation in mind, ThermoVision Pro is lightweight, portable, and easy to use, making it ideal for technicians who need to inspect various aircraft components on the go. With its AI-driven approach, it provides immediate and accurate results, helping maintenance teams ensure aircraft safety with less downtime and greater efficiency.

CHAPTER 3

RESEARCH METHODOLOGY

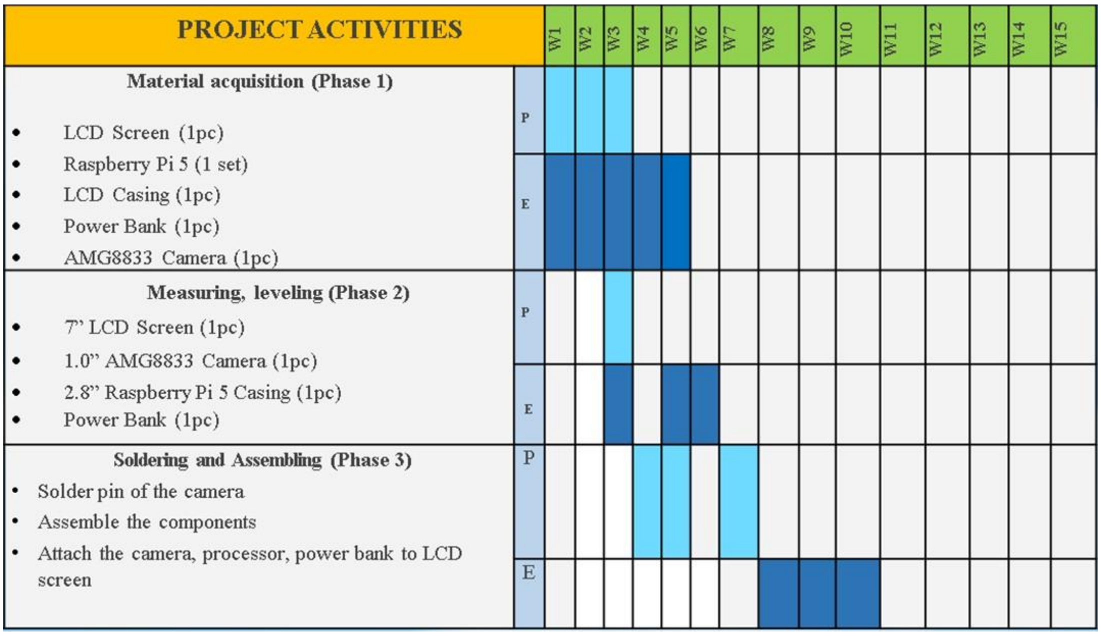
3.1 PROJECT BRIEFING & RISK ASSESSMENT

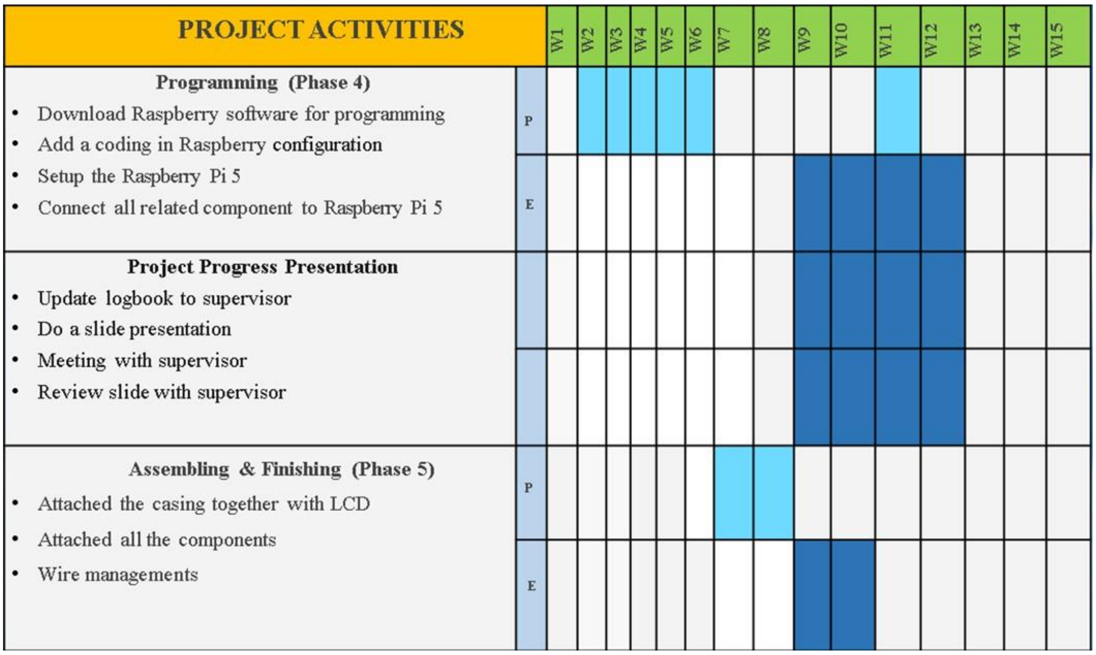
This chapter detailed the different steps that were successfully performed to achieve the experiment's goals and objectives. These included completing the relevant documents and obtaining supervisor permission. Throughout the duration of the project, several phases were involved, such as using an oven to heat up the laminate plate and employing a thermal imaging camera. Cutting, riveting, and testing were all part of the process. The team took this safety precaution seriously.

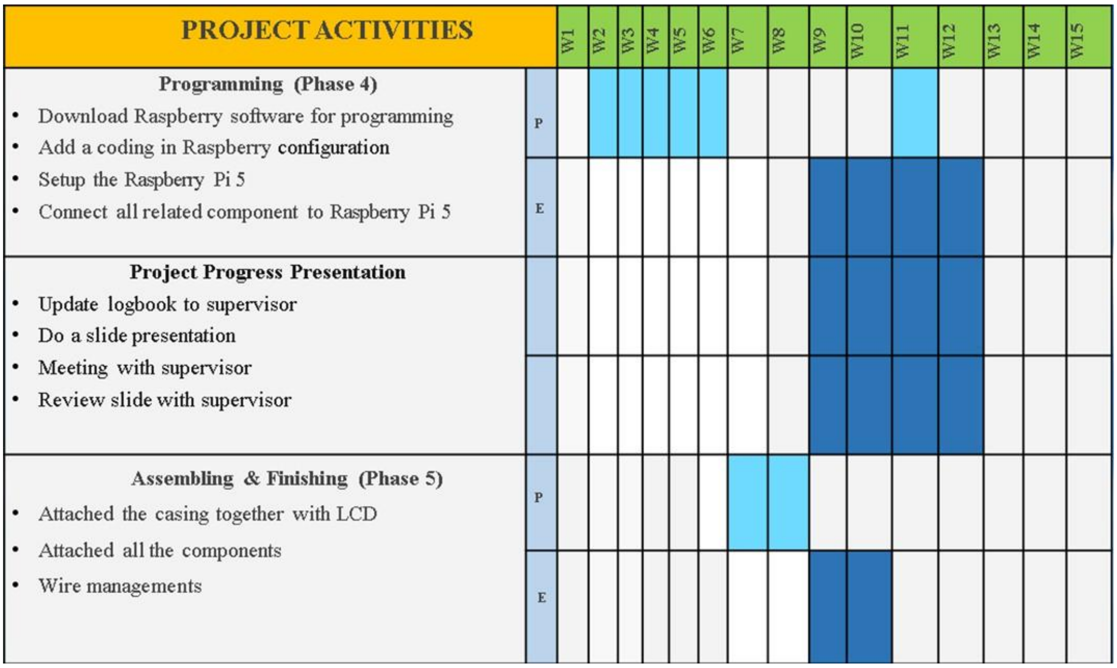
3.1.1 Utilization of Polytechnic's Facilities

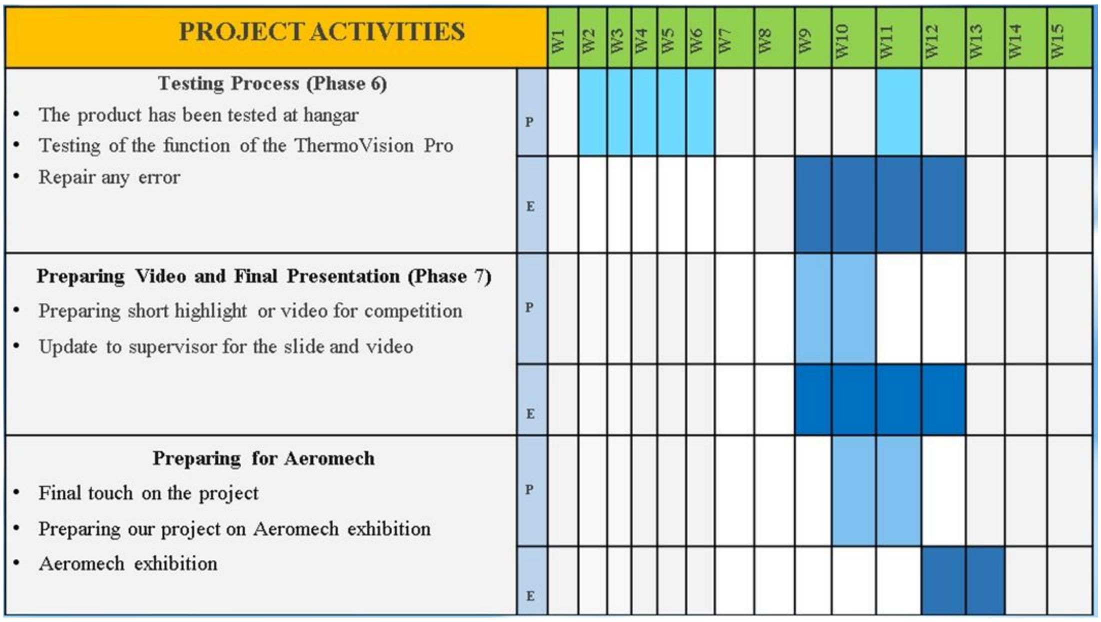
To use all the facilities supplied by Polytechnic, such as equipment, consumable materials, and tools, permission must be obtained from the supervisor and workshop coordinator by filling out the relevant paperwork. This form will detail the tools and equipment that is. being used in order to execute the project.

3.2 OVERALL PROJECT GANTT CHART






PROJECT ACTIVITIES
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
W11
W12
W13
W14
W15
Programming (Phase 4)
• Download Raspberry software for programming
• Add a coding in Raspberry configuration
• Setup the Raspberry Pi 5
• Connect all related component to Raspberry Pi 5
P
E
Project Progress Presentation
• Update logbook to supervisor
• Do a slide presentation
• Meeting with supervisor
• Review slide with supervisor
Assembling & Finishing (Phase 5)
• Attached the casing together with LCD
• Attached all the components
• Wire managements
P
E


PROJECT ACTIVITIES
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
W11
W12
W13
W14
W15
Testing Process (Phase 6)
• The product has been tested at hangar
• Testing of the function of the ThermoVision Pro
• Repair any error
P
E
Preparing Video and Final Presentation (Phase 7)
• Preparing short highlight or video for competition
• Update to supervisor for the slide and video
P
E
Preparing for Aeromech
• Final touch on the project
• Preparing our project on Aeromech exhibition
• Aeromech exhibition
P
E

PROJECT ACTIVITIES		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Complete our Project Thesis • Complete all the chapter in Thesis • Update to supervisor for final check Thesis	P															
	E															
Handling the project to Politeknik Banting Selangor • Give the project to Politeknik Banting Selangor	P															
	E															

P = PLANNING

E = EXECUTION

Figure 3.1: Gantt Chart Tables

3.3 PROJECT FLOW CHART

3.3.1 Overall Project Flow Chart

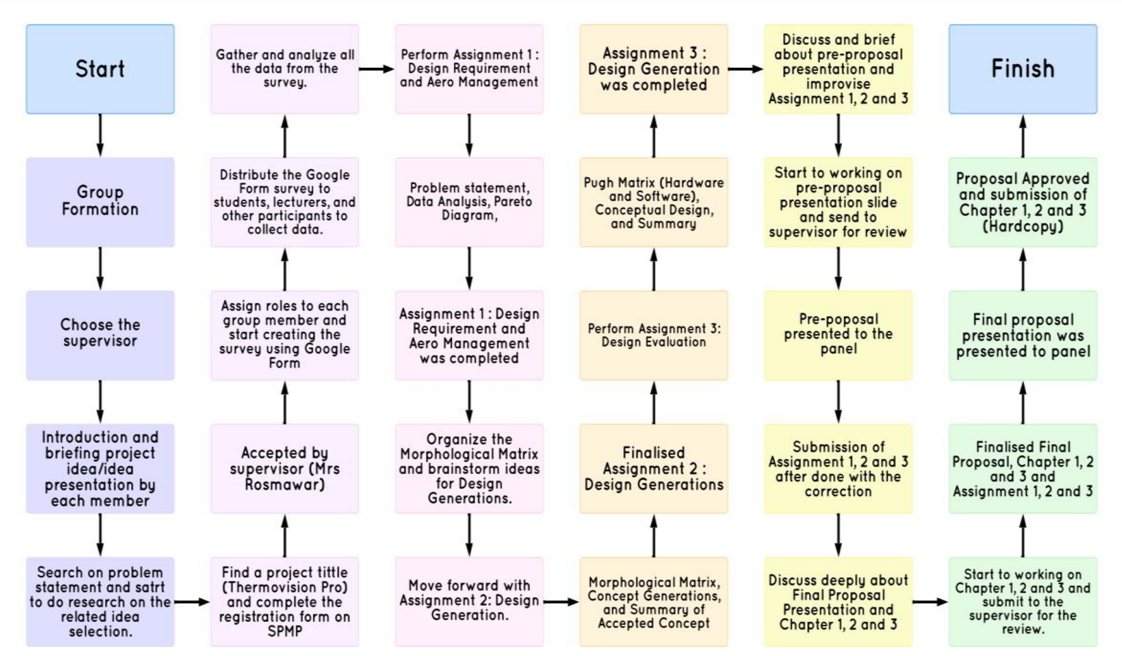


Figure 3.2: Overall Project Flow Chart

3.3.2 Specific Project Design Flow/Framework

3.3.2.1 Product Structure

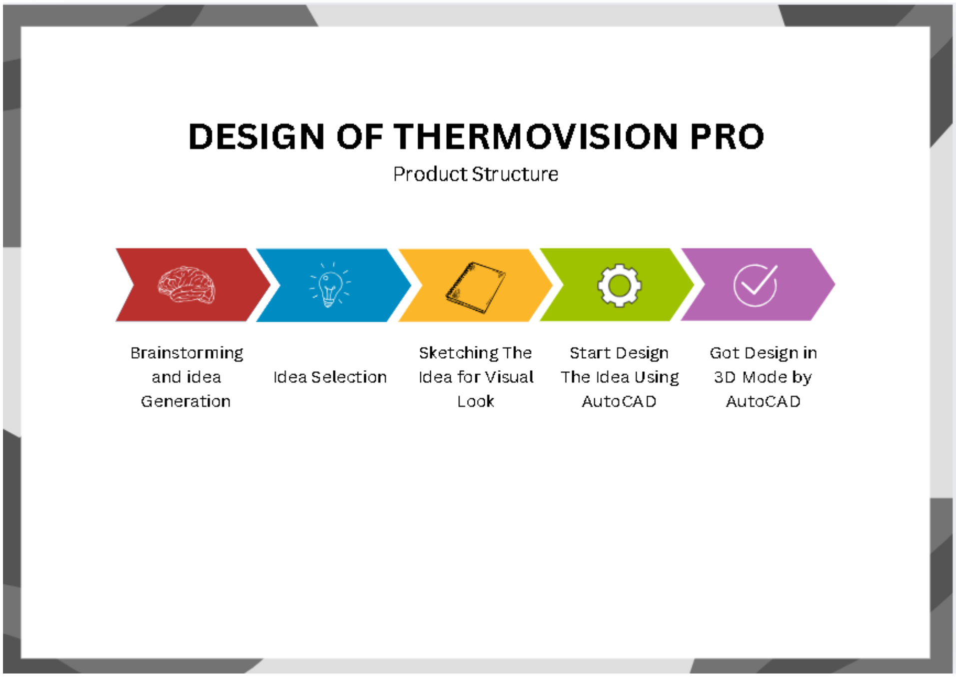


Figure 3.3: Product Structure for ThermoVision Pro

3.3.2.2 Software / Programming

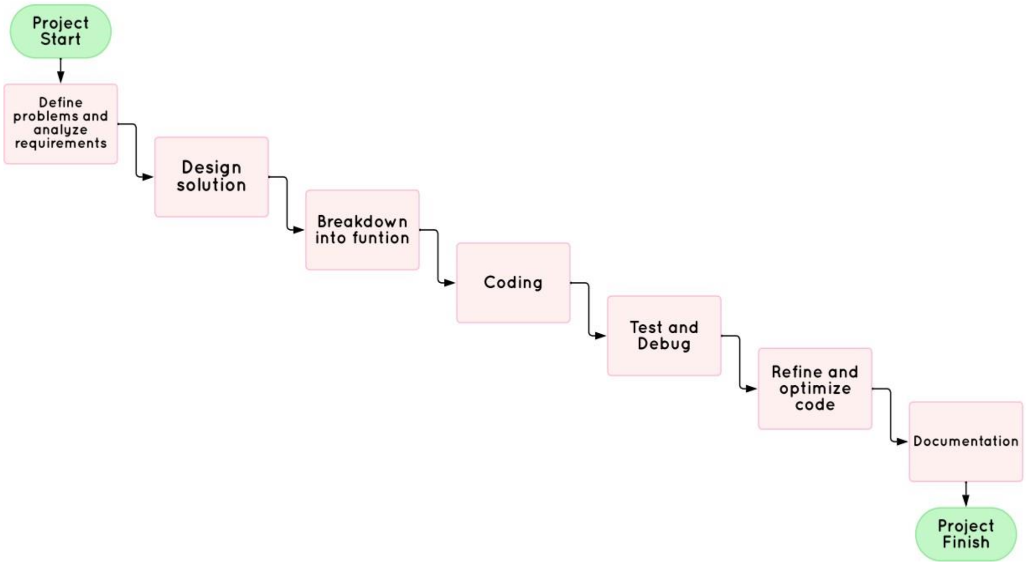


Figure 3.4: Software / Programming for ThermoVision Pro

3.3.2.3 Accessories and Finishing

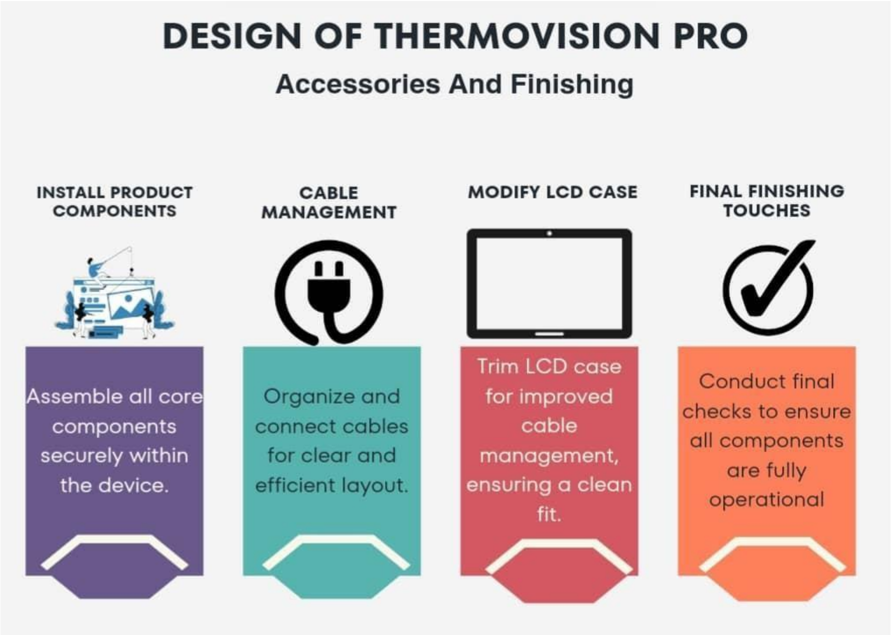


Figure 3.5: Accessories and Finishing for ThermoVision Pro

3.4 DESIGN ENGINEERING TOOLS

3.4.1 Design Requirements Analysis

3.4.1.1 Questionnaire Survey

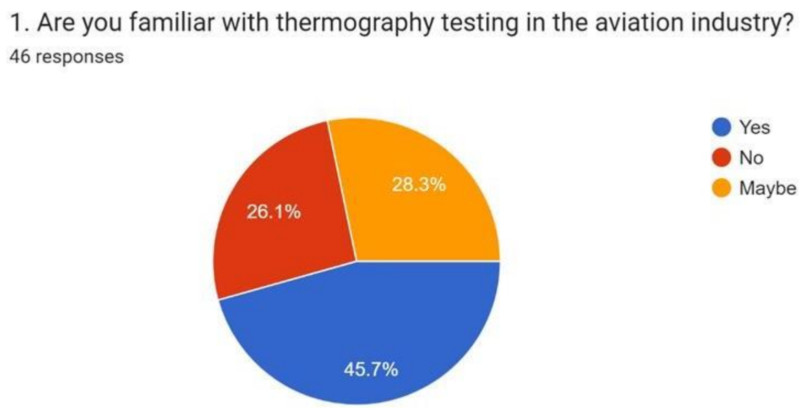
As part of the group Final Year Project (FYP), a comprehensive survey is being conducted to understand the challenges and difficulties faced by technicians and other users involved in Thermography Testing. Thermography Testing, a widely recognized non-destructive testing technique, plays a crucial role in the aviation industry for ensuring safety and reliability. The survey aims to gather detailed insights from individuals with practical experience in this field. By identifying common issues and potential areas for improvement, the collected feedback will contribute to the advancement of Thermography Testing practices and technologies. The insights gained from this research are expected to enhance the efficiency and effectiveness of this important testing method. The participation of experienced professionals is greatly valued and appreciated, as it is essential for the success of this project.

Our project identifies critical issues in current aircraft maintenance, particularly accuracy and timeliness in defect detection and challenges in interpreting inspection results. Integrating thermography testing with AI introduces complexities in hardware-software integration, data capture, and considerations for user accessibility, regulatory compliance, and data security. Seamless integration into existing workflows, managing costs, and gaining industry acceptance present significant challenges. Addressing these issues is vital for developing an innovative defect detection system to enhance efficiency and safety standards in aircraft maintenance.

To gather evidence supporting our product's need in the industry, we're completing questionnaires and conducting interviews for our Final Year Project (FYP). This allows us to understand the challenges faced by respondents during thermography testing in aviation, along with their suggestions for overcoming them. We're using Google Forms for convenience, respecting respondents' time while gathering valuable insights.

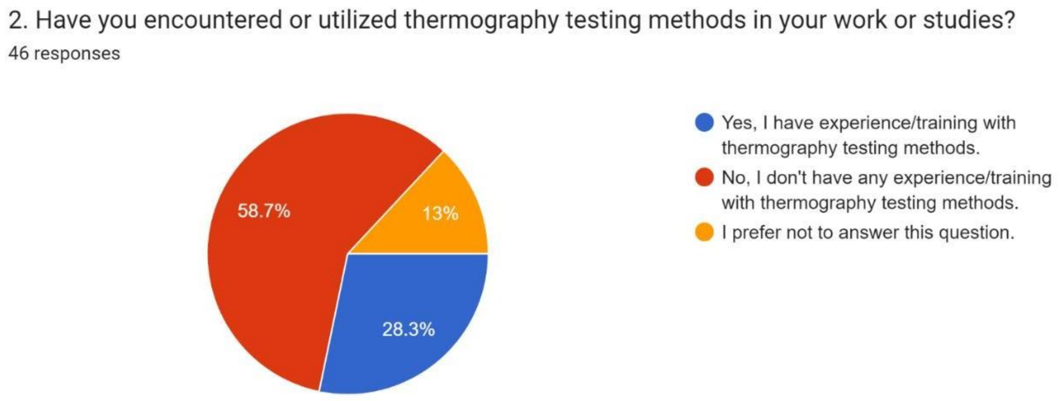
Initially, we developed questionnaires to gather insights from respondents about their experiences with current thermography testing techniques and suggestions for enhancing our new method. After approval from our supervisor, Mrs. Rosmawar Binti Hussin, we transformed the written questionnaire into a Google Form. Following grammar checks by our lecturers, we made necessary revisions for clarity and accuracy. Upon final approval, we distributed the questionnaire to respondents, collected data, and began analysis.

We carefully reviewed the questionnaire data and utilized charts and graphs to enhance our understanding. Here are key questions that emerged from the responses of our diverse group of 46 participants, allowing us to delve deeper into the topic.



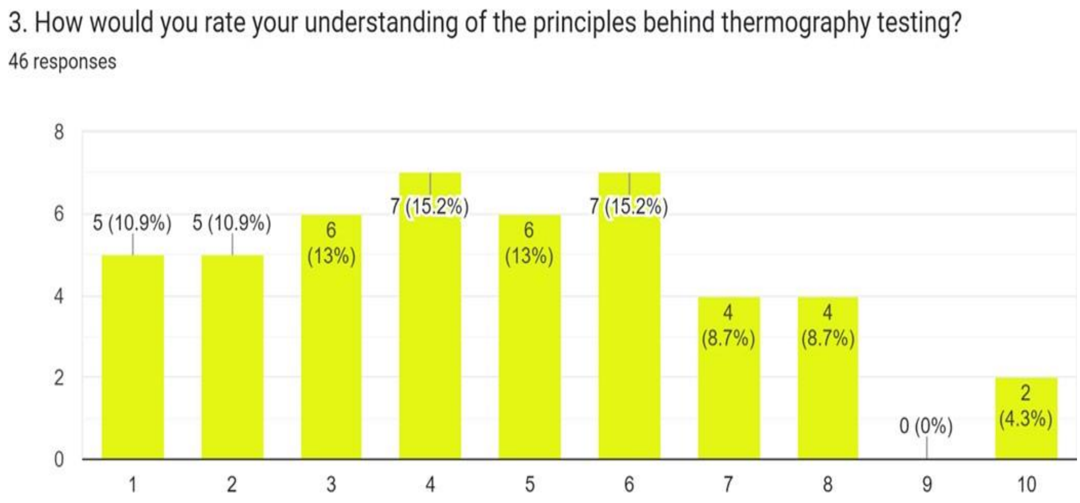
Figures 3.6: Questionnaire Survey

We kicked off our data analysis by asking participants if they were familiar with thermography testing in the aviation industry. Interestingly, half of the users (45.7%) responded affirmatively. Around a quarter (26.1%) indicated they were not familiar, while the remaining (28.3%) fell somewhere in between.



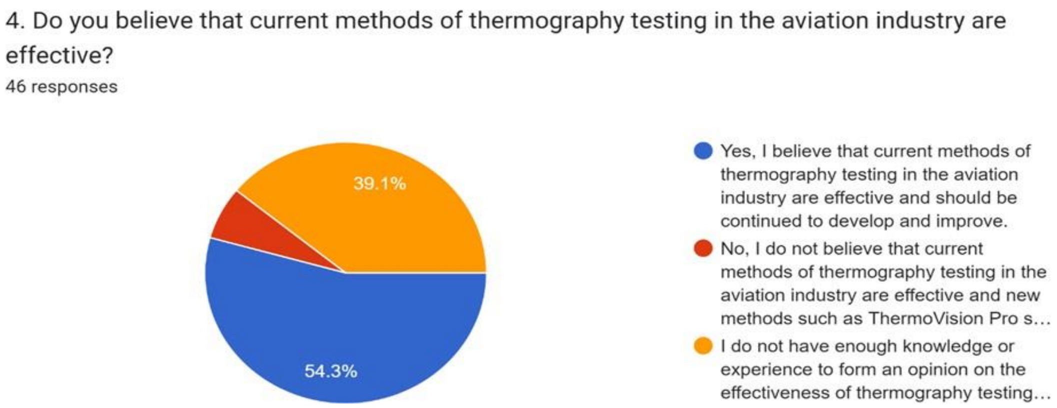
Figures 3.7: Questionnaire Survey

Next, we inquired whether users had encountered or utilized thermography testing procedures in their work or studies. About 28.3% responded positively, while 58.7% indicated they had not. Additionally, 13% chose not to provide an answer.



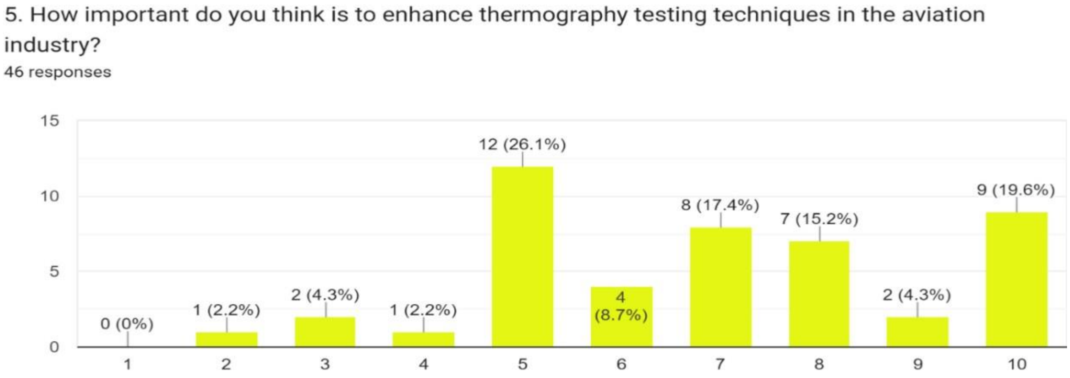
Figures 3.8: Questionnaire Survey

In the subsequent question, we delved into users' perceptions of their understanding regarding the principle behind thermography testing. It was intriguing to note that the majority of respondents, comprising 15.2%, rated their comprehension within the moderate range of 4 to 6. Equally noteworthy were the diverse distributions across other rating ranges: approximately 10.9% expressed lower levels of understanding within the 1 to 2 range, while another 15.2% fell within the range of 3 to 5. Similarly, a significant portion, also at 15.2%, reported a slightly higher understanding, placing themselves between 7 to 8. Surprisingly, the lowest level of understanding, constituting 8.7%, was found among those who rated themselves within the 9 to 10 range. This comprehensive analysis sheds light on the varying degrees of familiarity and comprehension among respondents regarding the principles of thermography testing.



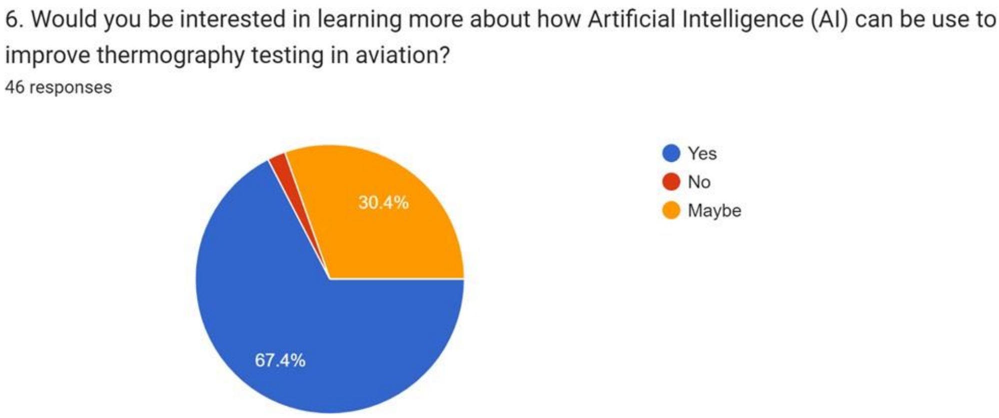
Figures 3.9: Questionnaire Survey

The majority of our respondents, accounting for about 54.3%, expressed confidence in the effectiveness of current thermography testing methods in the aviation industry and advocated for their continuous development and enhancement. Additionally, approximately 39.1% of users admitted to lacking sufficient knowledge or experience to form a solid opinion on the matter. Interestingly, a smaller percentage, around 6.5%, held the view that current methods of thermography testing are not effective.



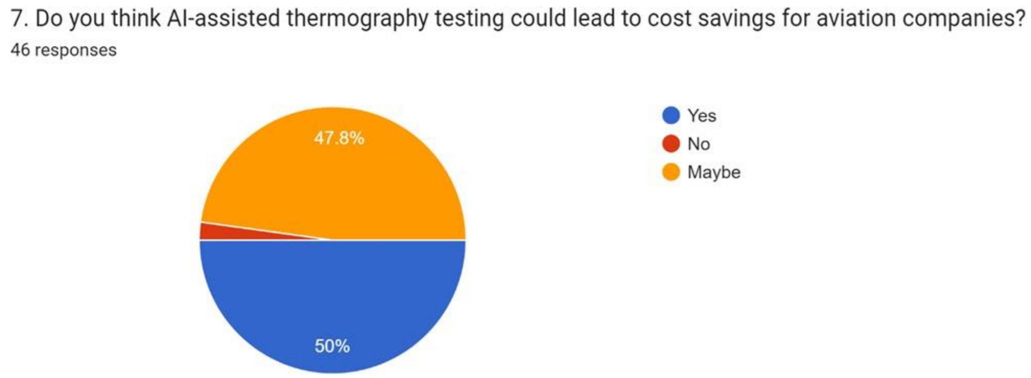
Figures 3.10: Questionnaire Survey

Our respondents strongly emphasized the significance of enhanced thermography testing techniques within the aviation industry. Notably, a substantial majority, ranging from 5 to 10 on the scale, expressed their agreement. Specifically, approximately 26.1% and 19.6% of users positioned their agreement at the highest level, rating it a 10. This widespread consensus underscores the collective acknowledgment of the crucial role that advanced thermography testing techniques play in ensuring safety and reliability within aviation operations.



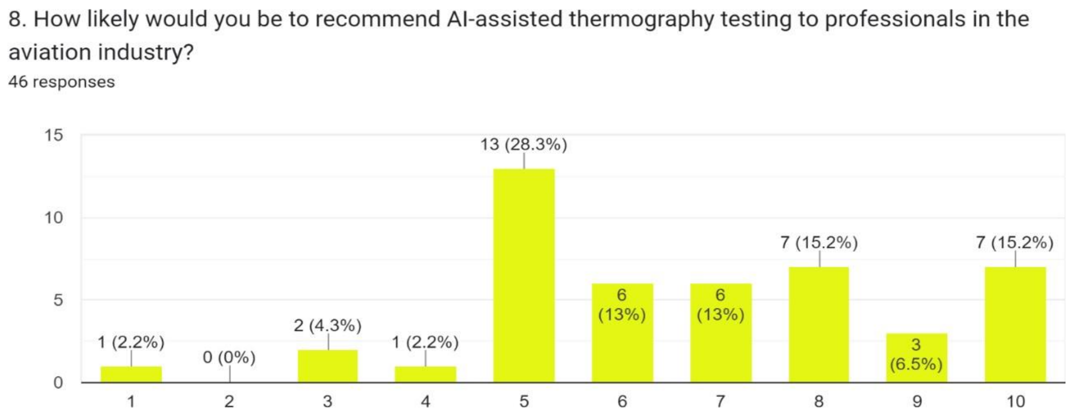
Figures 3.11: Questionnaire Survey

The majority of our respondents expressed keen interest in exploring how Artificial Intelligence (AI) can revolutionize thermography testing within the aviation sector, signalling a growing curiosity about the integration of AI into these methods. Surprisingly, 67.4% of respondents embraced this innovative approach, indicating a willingness to delve into new technological frontiers. Conversely, 30.4% of respondents, though smaller in number, displayed a reluctance to embrace the incorporation of AI into thermography testing methods, suggesting a cautious approach towards adopting novel technologies in this field.



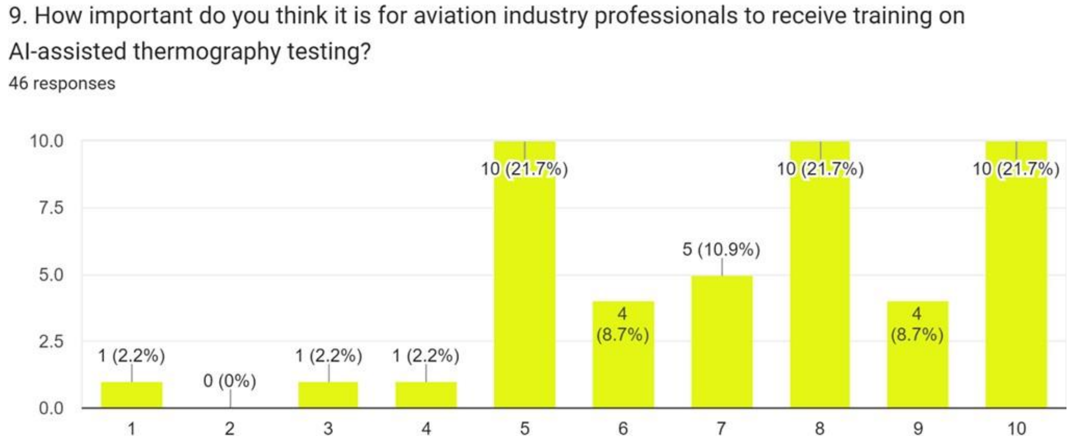
Figures 3.12: Questionnaire Survey

In our quest for product enhancement, we sought users' opinions on whether AI-assisted thermography testing could lead to cost savings for aviation companies. Interestingly, a mere 2.2% of users expressed scepticism, while a significant 50% believed in the potential cost-saving benefits. Equally notable was the perspective of the remaining 47.8% of users, who shared the belief that AI-assisted thermography testing could indeed yield cost savings for aviation companies. This collective optimism highlights the widespread recognition of AI's potential to drive efficiency and streamline operations within the aviation industry.



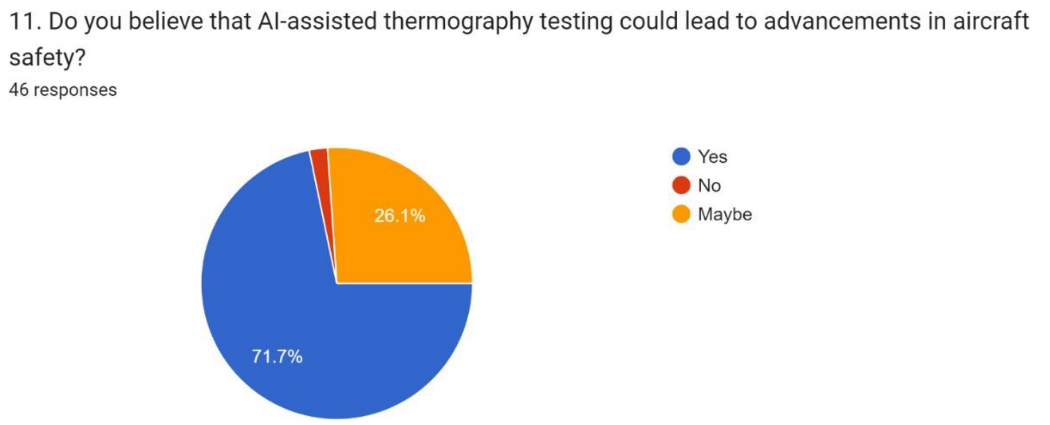
Figures 3.13: Questionnaire Survey

Our respondents are wholeheartedly endorsing AI-assisted thermography testing to professionals in the aviation industry, with a strong majority expressing their support between the scales of 5 to 10. This collective vote of confidence underscores the widespread belief in the potential of AI to revolutionize thermography testing practices and enhance safety standards within the aviation sector.



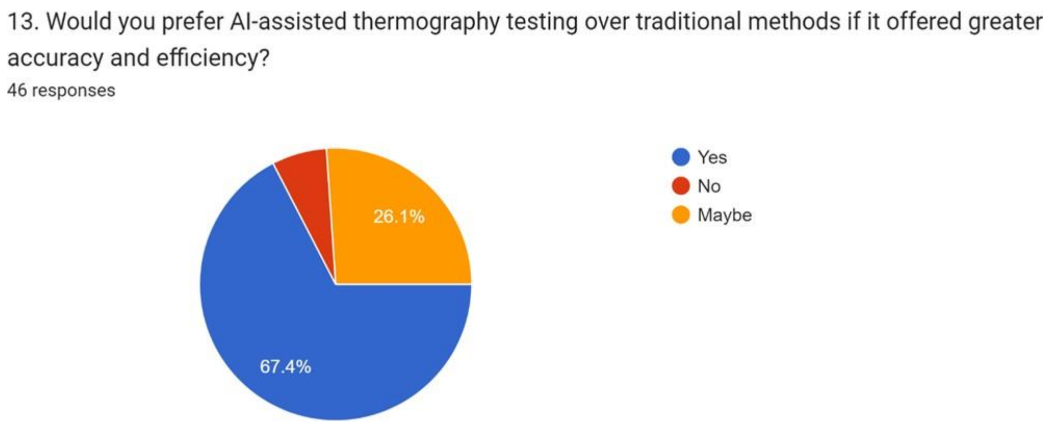
Figures 3.14: Questionnaire Survey

Most respondents believe that aviation industry experts should undergo training in AI-assisted thermography testing. This belief is reinforced by the fact that three times the same percentage, which is 21.7% of users, share this view.



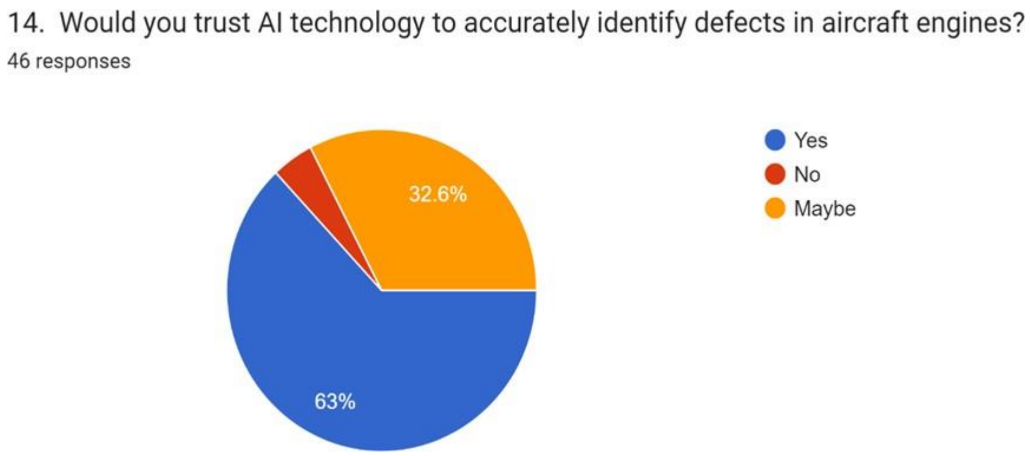
Figures 3.15: Questionnaire Survey

The majority of respondents hold the belief that AI-assisted thermography testing could significantly enhance flight safety, with approximately 71.7% expressing this view.



Figures 3.16: Questionnaire Survey

When asked whether they prefer AI-assisted thermography testing over traditional methods for delivering greater accuracy and efficiency, a vast majority of approximately 67.4% of users answered affirmatively. Interestingly, only around 6.5% expressed a preference for traditional methods.



Figures 3.17: Questionnaire Survey

When questioned about their trust in AI technology to accurately identify defects in aircraft engines, a significant majority of 63% of respondents expressed their confidence in AI's capability. This percentage significantly outweighs the 32.6% of respondents who displayed lower trust levels in AI technology for detecting defects in aviation engines.

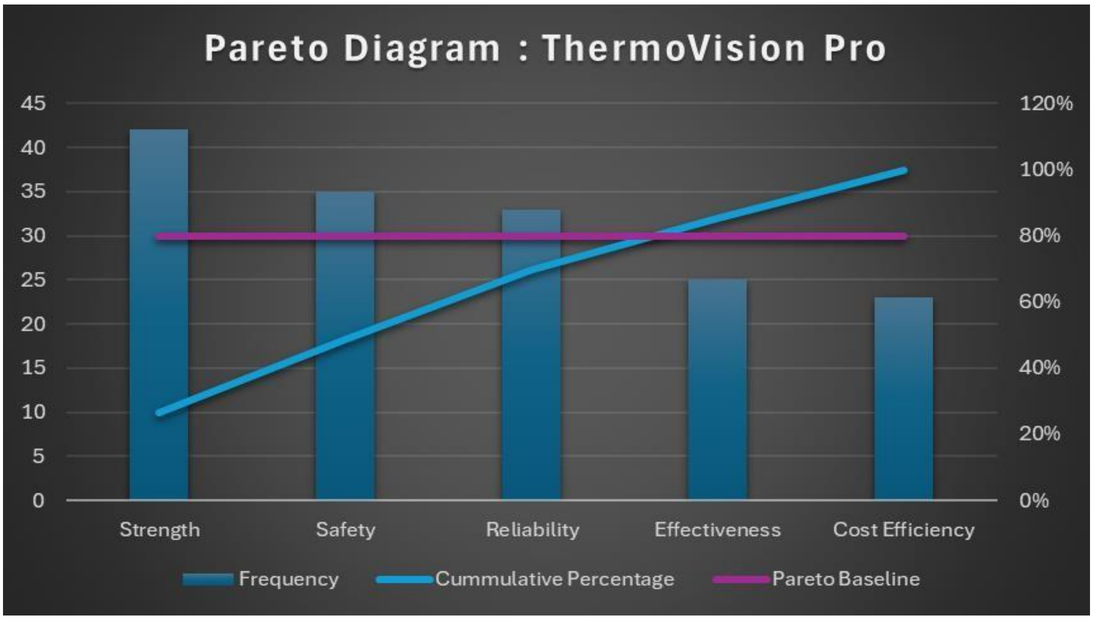
3.4.1.2 Pareto Diagram

A Pareto chart is a visual aid that sorts factors or issues based on their importance, displaying them as bars in descending order. The most significant factors appear on the left, with less critical ones on the right. This chart helps prioritize where to focus efforts for maximum impact. With ThermoVision Pro, a Pareto chart can highlight the most crucial challenges users face during thermography testing, guiding improvements to make the product more effective.

For ThermoVision Pro, a Pareto chart could help identify the most common issues or challenges faced by users during thermography testing. By analyzing feedback and data, the chart could highlight key areas for improvement or focus, guiding the development of the product to address the most critical needs of users effectively.

Features	Frequency	Cummulative	Total Percentage	Cummulative Percentage	Pareto Baseline
Strength	42	42	27%	27%	80%
Safety	35	77	22%	49%	80%
Reliability	33	110	21%	70%	80%
Effectiveness	25	135	16%	85%	80%
Cost Efficiency	23	158	15%	100%	80%
GRAND TOTAL	158				

Table 3.1: Pareto Data



Figures 3.18: Pareto Diagram

- The highest vote – Strength and Safety
- The lowest vote – Cost Efficiency
- Baseline Pareto – 80%

3.4.2 Design Concept Generation

3.4.2.1 Morphological Matrix

A Morphological Matrix is a tool used to explore all possible solutions to a problem by breaking it down into its key components and considering different options for each component. It helps systematically generate a wide range of ideas and combinations.

For ThermoVision Pro, our group created two tables using the Morphological Matrix: one for Hardware and one for Software. By identifying key components such as data capture, image analysis, user interface, and reporting for both hardware and software, we brainstormed various options for each. This approach allowed us to explore numerous potential enhancements and select the best combinations to improve the product's performance and user experience.

I. Hardware

FUNCTION	IDEA 1	IDEA 2	IDEA 3	IDEA 4
COST	RM 111	RM 729	RM 889	RM 281
SIZE	25.8 x 25.5 x 6.0(mm)	53 × 18.2 × 18.5 (mm)	34.4 × 56.6 × 12.1 (mm)	62 × 50 × 20 (mm)
PIXEL	8 x 8 (64 pixels)	$7.4\ \mu m$	$8 - 14\ \mu m$	$7.5\ \mu m$
TEMPERATURE RANGE	$0° - 80℃$	$-20° - 400\ ℃$	$-15° - 600°C$	$-40° - 300°C$
WEIGHT	2g	25g	20g	70g
COLOUR PELETTE	6	7	6	1
TEMPERATURE ACCURANCY	$\pm 2.5℃$	$\pm 2℃/\pm 2\%$	$\pm 2℃/\pm 2\%$	$\pm 2℃$
FRAME RATE	10Hz	25Hz	25Hz	8Hz
RESOLUTIONS	160 × 120	120 × 90	256 × 192	240 × 320
WORKING TEMPERATURE	$0° - 80℃$	$0° - 45\ ℃$	$-10° - 75\ ℃$	
FRAME OF VIEW (FOV)	$0° - 80°$	$50° - 38°$	$56° - 42°$	$55° - 35°$
ACCESSORIES	SOLDERING	TYPE-C/USB ADAPTOR	TYPE-C	TYPE-C

Table 3.2: Morphological Matrix (Hardware)

II. Software

FUNCTION	IDEA 1	IDEA 2	IDEA 3	IDEA 4
COST	Free / Paid	Open-source platform with no licensing costs	Open-source platform with no licensing costs	Affordable and budget-friendly
RELIABILITY	Used by various organizations for AI	User-friendly interface	Ease of use, with a user-friendly interface	High for small-scale projects
SECURITY	Compliance with regulations like GDPR and HIPAA	Data encryption, user authentication, and access controls	File encryption and user authentication	Moderate, customizable for security needs
SCALABILITY	Provides scalable solutions	Scalable solutions, allowing users to process and analyze large datasets	Suitable for small to medium-scale AI projects	Moderate, suitable for embedded projects
FLEXIBILITY	Data preparation, modelling, and deployment	Flexible in workflow design and customization	Flexible in workflow design and customization	Flexible, supports Python and AI libraries
PERFORMANCE	High-performance AI solutions	High-performance AI solutions	Exploratory data analysis and prototyping AI models	Moderate, suitable for edge computing
COMMUNITY SUPPORT	Forums, documentation, and online resources available	Forums, documentation, and online resources available	Forums, tutorials, and online resources available	Strong, active Raspberry Pi community
INTEGRATION	Various data sources, databases, and third-party tools	Various data sources, databases, and analytics tools	Various data formats and external libraries	Easy integration with hardware components

Table 3.3: Morphological Matrix (Software)

3.4.2.2 Proposed Design Concept 1

I. Hardware

FUNCTION	CONCEPT 1	JUSTIFICATION
COST	RM 111	The price is low and reasonable with the given application.
SIZE	25.8 x 25.5 x 6.0 (mm)	Small size and can be used for various types of products.
PIXEL	$8\ x\ 8\ (64\ pixels)$	The picture looks more real and accurate.
TEMPERATURE RANGE	$0° -\ 80℃$	The temperature range used is the lowest 0°C and can reach 80°C.
WEIGHT	2g	The lightest among other cameras.
COLOUR PELETTE	6	The color palette can be set as many as 6 designs.
TEMPERATURE ACCURACY	$\pm 2.5℃$	Temperature accuracy is minimal.
FRAME RATE	10Hz	Standard frame rate.
RESOLUTIONS	160 × 120	High resolution for thermal camera standards.
WORKING TEMPERATURE	$0° - 80\ ℃$	Can detect defects while working from 0° to 80°C.
FRAME OF VIEW (FOV)	$0° - 80°$	The higher in the view picture frame.
ACCESSORIES	soldering	Attach camera and wire using soldering

Table 3.4: Proposed Design Concept 1 (Hardware)

II. Software

FUNCTION	CONCEPT 1	JUSTIFICATION
COST	Free / Paid	Concept 1 offers both free and paid versions, with the paid versions providing additional features and support. Pricing varies based on the edition and development options.
RELIABILITY	Used by various organizations for AI	Concept 1 is known for its reliability, with a robust platform and a large user base. It has been used by various organizations for AI and data science projects.
SECURITY	Compliance with regulations like GDPR and HIPAA	Concept 1 prioritizes security, with features such as data encryption, access controls, and compliance with regulations like GDPR and HIPAA.
SCALABILITY	Provides scalable solutions	Concept 1 provides scalable solutions, allowing users to process large datasets and deploy AI models across different environments.
FLEXIBILITY	Data preparation, modelling, and deployment	Concept 1 offers flexibility in data preparation, modeling, and deployment, supporting various AI techniques and algorithms.
PERFORMANCE	High-performance AI solutions	Concept 1 delivers high-performance AI solutions, optimized for speed and efficiency in data processing and model training.
COMMUNITY SUPPORT	Forums, documentation, and online resources available	Concept 1 has an active community of users, with forums, documentation, and online resources available for support and collaboration.
INTEGRATION	Various data sources, databases, and third-party tools	Concept 1 integrates with various data sources, databases and third-party tools, enabling seamless integration into existing workflows and systems.

Table 3.5: Proposed Design Concept 1 (Software)

3.4.2.3 Proposed Design Concept 2

I. Hardware

FUNCTION	CONCEPT 2	JUSTIFICATION
COST	RM 729	The price is a little expensive and reasonable with the given application.
SIZE	53 × 18.2 × 18.5 (mm)	Medium size and does not require a large space.
PIXEL	$7.4\ \mu m$	Picture shown in standard condition.
TEMPERATURE RANGE	$-20° - 400\ ℃$	The temperature range used is the lowest -20°C and can reach 400°C.
WEIGHT	25g	Medium weights among other cameras.
COLOUR PALETTE	7	The color palette can be set as many as 7 designs.
TEMPERATURE ACCURACY	$\pm 2℃/\pm 2\%$	Temperature accuracy is minimal.
FRAME RATE	25Hz	Standard frame rate.
RESOLUTIONS	120 × 90	Lowest resolution for thermal camera standards.
WORKING TEMPERATURE	$0° - 45\ ℃$	Can detect defects while working from 0° to 45°C.
FRAME OF VIEW (FOV)	$50° - 38°$	Among the highest in display picture frames.
ACCESSORIES	TYPE-C/USB ADAPTOR	Can be used in all android applications that use type-c and laptops.

Table 3.6: Proposed Design Concept 2 (Hardware)

II. Software

FUNCTION	CONCEPT 2	JUSTIFICATION
COST	Open-source platform with no licensing costs	Concept 2 is an open-source platform with no licensing costs, making it an affordable option for AI and data science projects. Additional cost may be incurred for enterprise support and services.
RELIABILITY	User-friendly interface User-friendly interface	Concept 2 is known for its reliability and stability, with user-friendly interface and large community of users and contributors.
SECURITY	Data encryption, user authentication, and access controls	Concept 2 provides security features such as data encryption, user authentication, and access controls, ensuring data privacy and compliance.
SCALABILITY	Scalable solutions, allowing users to process and analyze large datasets	Concept 2 offers scalable solutions, allowing users to process and analyze large datasets efficiently using distribution computing and cloud resource.
FLEXIBILITY	Flexible in workflow design and customization	Concept 2 offers flexibility in workflow design and customization, supporting a wide range of AI algorithms and techniques.
PERFORMANCE	High-performance AI solutions	Concept 2 delivers high-performance AI solutions, optimized for speed and accuracy in data processing and analysis.
COMMUNITY SUPPORT	Forums, documentation, and online resources available	Concept 2 had a vibrant community of users and contributors, with forums, documentation, and online resource available for support and collaboration.
INTEGRATION	Various data sources, databases, and analytics tools	Concept 2 integrates with various data sources, databases, and analytics tools, enabling seamless integration into existing IT environments.

Table 3.7: Proposed Design Concept 2 (Software)

3.4.2.4 Proposed Design Concept 3

I. Hardware

FUNCTION	CONCEPT 3	JUSTIFICATION
COST	RM 889	The price is high and reasonable with the given application.
SIZE	34.4 × 56.6 × 12.1 (mm)	Small size and does not require a large space.
PIXEL	$8 - 14\ \mu m$	The picture looks more real and accurate.
TEMPERATURE RANGE	$-15° - 600°C$	The temperature range used is the lowest -15°C and can reach 600°C.
WEIGHT	20g	Medium weights among other cameras.
COLOUR PALETTE	6	The color palette can be set as many as 6 designs.
TEMPERATURE ACCURACY	$\pm 2℃/\pm 2\%$	Temperature accuracy is minimal.
FRAME RATE	25Hz	Standard frame rate.
RESOLUTIONS	256 × 192	The higher resolution for thermal camera standards.
WORKING TEMPERATURE	$-10° - 75\ ℃$	Can detect defects while working from -10° to 75°C.
FRAME OF VIEW (FOV)	$56° - 42°$	Highest in picture frame display.
ACCCESSORIES	TYPE-C	Can be used in all android applications that use type-c.

Table 3.8: Proposed Design Concept 3 (Hardware)

II. Software

FUNCTION	CONCEPT 3	JUSTIFICATION
COST	Open-source platform with no licensing costs	Concept 3 is an open-source platform with no licensing costs, making it accessible to users with budget constraints. Additional costs may be incurred for premium add-ons and support.
RELIABILITY	Ease of use, with a user-friendly interface	Concept 3 is known for its reliability and ease of use, with a user-friendly interface and extensive documentation.
SECURITY	File encryption and user authentication	Concept 3 provides basic security features, such as file encryption and user authentication, to protect sensitivity data and ensure privacy.
SCALABILITY	Suitable for small to medium-scale AI projects	Concept 3 is suitable for small to medium-scale AI projects but may not be as scalable as some enterprise-grade solutions for larger deployments.
FLEXIBILITY	Flexible in workflow design and customization	Concept 3 offers flexibility in workflow design and customization, supporting various AI techniques and algorithms through its modular approach.
PERFORMANCE	Exploratory data analysis and prototyping AI models	Concept 3 delivers decent performance for exploratory data analysis ad prototyping AI models but may not be as optimized for large-scale data processing.
COMMUNITY SUPPORT	Forums, tutorials, and online resources available	Concept 3 has an active community of users and contributor, with forums, tutorials, and online resources available for support and collaboration.
INTEGRATION	Various data formats and external libraries	Concept 3 integrates with various data formats and external libraries, enabling interoperability with other tools and platforms in the AI ecosystem.

Table 3.9: Proposed Design Concept 3 (Software)

3.4.2.5 Proposed Design Concept 4

I. Hardware

FUCNTION	CONCEPT 4	JUSTIFICATION
COST	RM 281	The price is the cheapest and most affordable with the given application.
SIZE	62 × 50 × 20 (mm)	Large size and needs its own space.
PIXEL	7.5 μm	Picture shown in standard condition.
TEMPERATURE RANGE	$-40° - 300°C$	The temperature range used is the lowest at -40°C and can reach 300°C.
WEIGHT	70g	Heaviest among other cameras.
COLOUR PALETTE	1	Only one color can be set.
TEMPERATURE ACCURACY	± 2℃	Temperature accuracy is minimal.
FRAME RATE	8Hz	Lowest frame rate.
RESOLUTION	240 × 320	High resolution for thermal camera standards.
WORKING TEMPERATURE		
FRAME OF VIEW (FOV)	$55° - 35°$	Highest in picture frame display.
ACCESSORIES	TYPE-C	Can be used in all android applications that use type-c.

Table 3.10: Proposed Design Concept 4 (Hardware)

II. Software

FUNCTION	CONCEPT 4	JUSTIFICATION
COST	affordable platform with a budget-friendly	Concept 4 software and hardware are cost-effective, with low initial investment required for both the hardware and the software environment. No additional licensing fees are necessary, which helps keep the project within budget.
RELIABILITY	reliability in small-scale and embedded applications	Concept 4 is designed for reliability in small-scale and embedded applications, its performance can depend on the complexity of the tasks. For simple AI models and embedded systems, it offers steady and consistent performance.
SECURITY	moderate security features	Concept 4 provides moderate security features, including customizable encryption and firewall configurations. While it may not offer enterprise-level security out of the box, it allows users to implement adequate data protection for most projects, with flexibility to enhance security as needed.
SCALABILITY	suitable for smaller scale, edged computing applications	Concept 4 is suitable for smaller-scale, edge computing applications. While it is not built for large-scale AI systems, it can support scalability in embedded environments with multiple devices working together for distributed tasks, making it flexible within its scope.
FLEXIBILITY	high flexibility in software development	Concept 4 offers high flexibility in software development, supporting various programming languages (especially Python) and AI frameworks (like TensorFlow, OpenCV, etc.). This allows for rapid prototyping and customization to fit project-specific needs.
PERFORMANCE	suitable for less resource-intensive AI models and local processing tasks	Concept 4 is suitable for less resource-intensive AI models and local processing tasks. While it may not match the performance of high-end servers, it provides adequate performance for real-time edge computing applications, making it suitable for inspecting aircraft engine components.

COMMUNITY SUPPORT	strong and active community of developers, engineers, and hobbyists	Concept 4 has a strong and active community of developers, engineers, and hobbyists. This provides extensive online resources, tutorials, forums, and troubleshooting support, ensuring that help is readily available for any issues that arise during development.
INTEGRATION	integrates well with various hardware components	Concept 4 seamlessly integrates well with various hardware components, including sensors, cameras, and other peripherals. It also supports various APIs and libraries, making it easy to integrate with existing systems or software, providing a seamless connection for real-time data processing and machine learning tasks.

Table 3.11: Proposed Design Concept 4 (Software)

3.1.2.6 Accepted Vs. Discarded Solution

In summary, for our Final Year Project (FYP), our team selected Concept 1, featuring the AMG8833 thermal imaging camera. This choice was made due to its cost-effectiveness and compact size, making it ideal for integrating into portable devices for component inspections. The AMG8833 provides precise and efficient temperature detection, suitable for detailed thermal assessments. Its lightweight design enhances the overall portability of our project. The camera offers more than adequate resolution for our needs, ensuring accurate thermal imaging. It is powered via jumper wires connected to the processor, facilitating easy activation and integration. Additionally, it transfers captured images to the display screen in real-time, making the analysis process seamless and efficient. These features collectively made Concept 1 an optimal choice for our thermal imaging solution.

For software development, Concept 4 was selected due to its affordability, providing a cost-effective solution that allows the project to stay within budget while meeting the software requirements. It offers reliable performance for small-scale applications and edge computing, making it suitable for the project’s needs. The software’s moderate security features are customizable, enabling the implementation of necessary encryption and data protection measures.

Additionally, its flexibility in supporting multiple programming languages and AI frameworks makes it adaptable for future development and customization. Concept 4 also provides adequate performance for real-time AI tasks, which is essential for the project's goal of inspecting aircraft engine components. The strong community support available through tutorials, forums, and troubleshooting resources adds value, ensuring smooth development. Furthermore, the software integrates seamlessly with hardware components, making it ideal for real-time data collection and processing tasks required in the project.

3.4.3 Evaluation & Selection of Conceptual Design

3.4.3.1 Pugh Matrix

The Pugh Matrix is a decision-making tool used to compare and evaluate multiple concepts against a set of criteria. It helps in identifying the best option by systematically scoring each concept based on how well it meets the defined criteria. This method provides a clear and objective way to assess various alternatives, facilitating informed decision-making.

For our project, ThermoVision Pro, our team utilized the Pugh Matrix to evaluate both hardware and software options. We created two separate matrices: one for hardware and one for software. By scoring each concept against essential criteria such as cost, efficiency, reliability, and compatibility, we were able to identify the most suitable hardware and software solutions for our thermography testing tool. This approach ensured that we selected the best components to enhance the performance and user experience of ThermoVision Pro.

PUGH MATRIX: CONCEPT 4 AS DATUM

I. HARDWARE

CRITERION	FACTOR	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4
STRENGTH	0.2	2	3	2	DATUM
SAFETY	0.2	3	1	3	
RELIABILITY	0.2	2	2	2	
EFFECTIVENESS	0.2	3	2	3	
COST EFFICIENCY	0.2	3	1	1	
TOTAL SCORE	1·0	2.6	1.8	2.2	
RANKING		1	3	2	

Table 3.12: PUGH Matrix (Hardware)

[Score Legend: 3(+) 2(=) 1(-)]

II. SOFTWARE

CRITERIA	FACTOR	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4
EFFECTIVENESS	0.2	3	2	1	DATUM
SECURITY	0.2	3	2	1	
RESPONSE TIME	0.2	2	2	3	
WORKING HOUR	0.2	3	2	2	
TIME TO IMPLEMENT	0.2	1	3	2	
TOTAL SCORE	1·0	2.4	2.2	1.8	
RANKING		1	2	3	

Table 3.13: PUGH Matrix (Software)

[Score Legend: 3(+) 2(=) 1(-)]

PUGH MATRIX: CURRENT PRODUCT AS DATUM

I. HARDWARE (TR120E)

CRITERION	CONCEPT 1	CONCEPT 2	TR120E	CONCEPT 3	CONCEPT 4
STRENGTH	3	2	DATUM	3	1
SAFETY	3	2		3	1
RELIABILITY	2	2		2	2
EFFECTIVENESS	3	2		3	1
COST EFFICIENCY	3	1		1	3
TOTAL SCORE	14	9		12	8
RANKING	1	3		2	4

Table 3.14: PUGH Matrix Current Product (Hardware)

[Score Legend: 3(+) 2(=) 1(-)]

II. SOFTWARE (GOOGLE CLOUD AI PLATFORM)

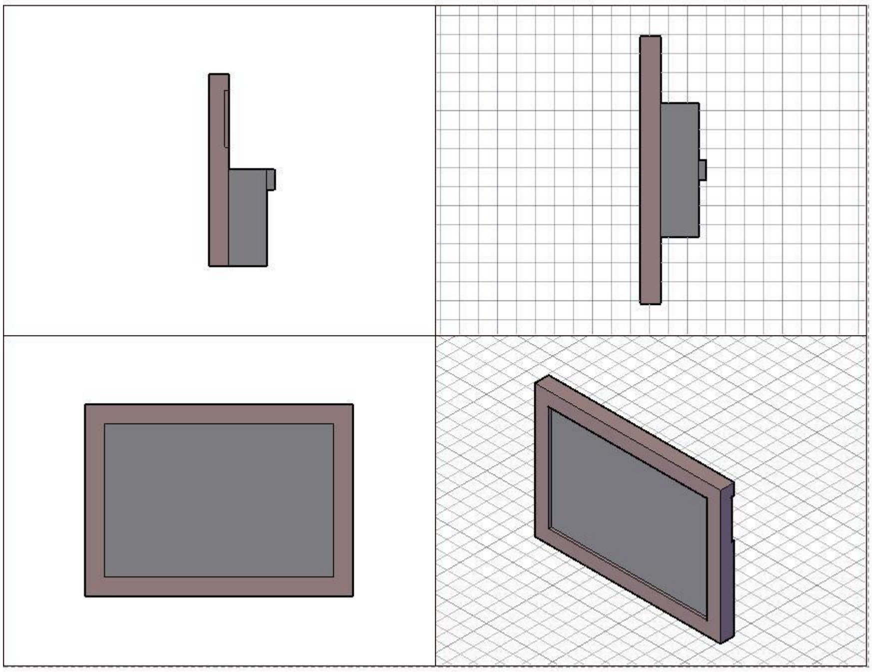
CRITERIA	FACTOR	CONCEPT 1	CONCEPT 2	GOOGLE CLOUD	CONCEPT 3	CONCEPT 4
EFFECTIVENESS	0.2	3	2	DATUM	1	3
SECURITY	0.2	3	2		1	3
RESPONSE TIME	0.2	2	2		3	3
WORKING HOUR	0.2	3	2		2	2
TIME TO IMPLEMENT	0.2	1	3		2	2
TOTAL SCORE	1·0	2.4	2.2		1.8	2.6
RANKING		2	3		4	1

Table 3.15: PUGH Matrix Current Product (Software)

[Score Legend: 3(+) 2(=) 1(-)]

3.5 PRODUCT DRAWING / SCHEMATIC DIAGRAM

3.5.1 General Product Drawing



Figures 3.19: Sketch for ThermoVision Pro

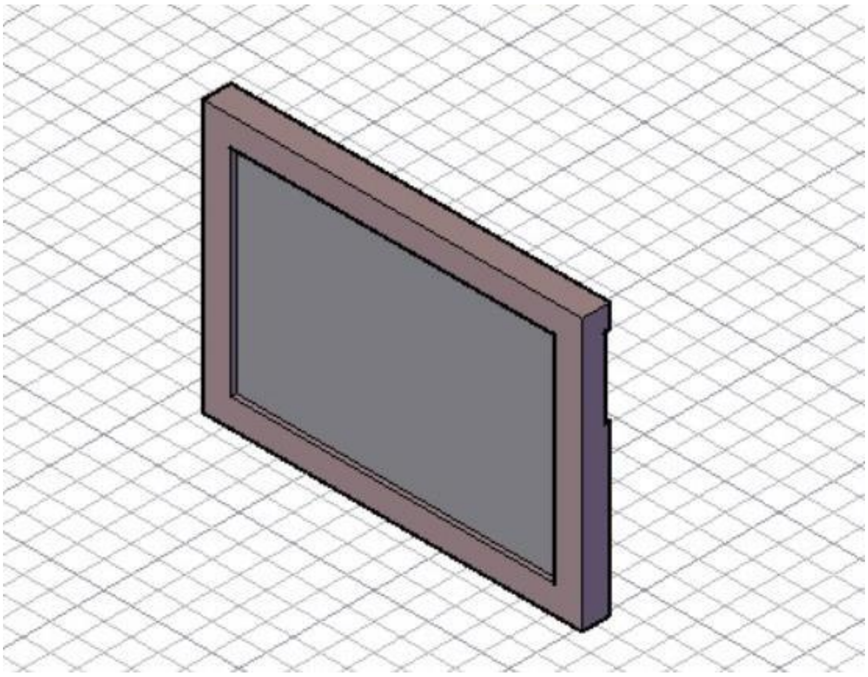
By projecting three-dimensional objects onto planes parallel to their coordinate axes, orthographic projection is a technical drawing technique used to portray objects in three dimensions. Because it gives precise, true-to-size measurements, it is essential for technical and engineering representations.

Isometric projection, on the other hand, uses two 54 dimensional planes to visually depict objects in three dimensions. With equal foreshortening along all three axes, usually at 120-degree angles, it creates a more realistic image.

In architectural and creative contexts, isometric projection is frequently used, sacrificing exact measurements for aesthetic appeal. Both techniques have different uses; orthographic projection is more accurate, while isometric projection provides a more logical visual depiction.

3.5.2 Specific Part Drawing / Diagram

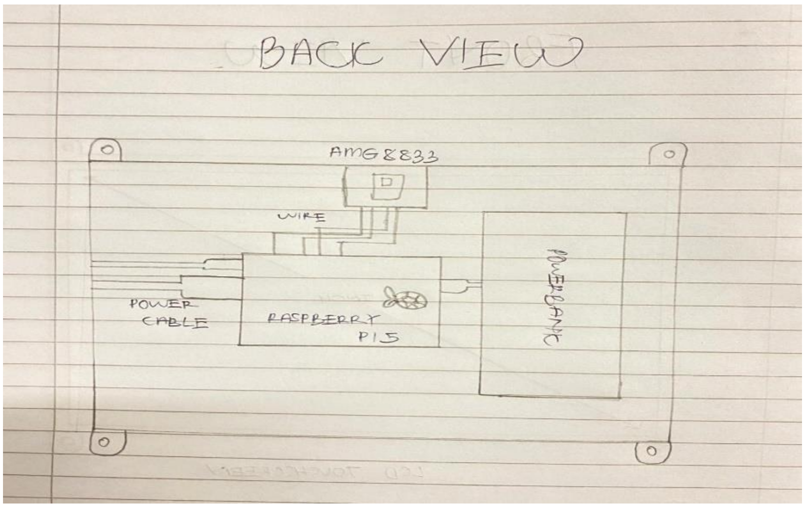
3.5.2.1 Product Structure



Figures 3.20: Product Structure of ThermoVision Pro

The product structure will operate as a panel for the Thermovision Pro system, with a Raspberry Pi 5 at the back of the product part for easy access during troubleshooting and maintenance. LCD display screen will be used on the front of the product to provide an enclosed case and visualization for the entire process of thermal imaging and analysis using the Thermovision Pro.

3.5.2.2 Accessories and Finishing

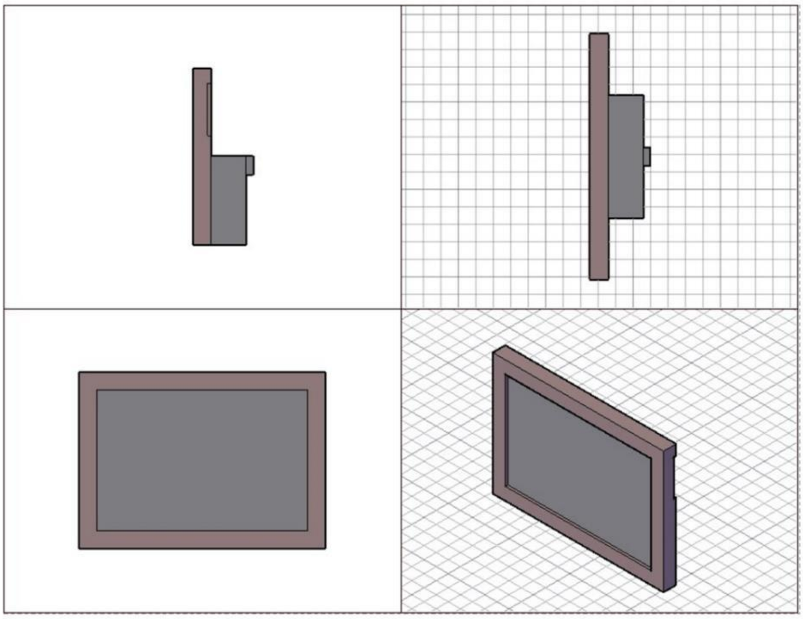


Figures 3.21: Accessories and finishing of ThermoVision Pro

ThermoVision Pro is built with high-quality cables that connect the power, processor, and camera. These durable cables handle the energy needed for the device to work effectively without risking wear or damage, ensuring smooth and reliable performance over time. By choosing these materials, ThermoVision Pro is designed to be long-lasting and dependable, ready to meet the demanding needs of aviation inspections**.**

3.6 PROTOTYPE / PRODUCT MODELLING

3.6.1 Prototype / Product Modelling



Figures 3.22: Prototype / Product Modelling

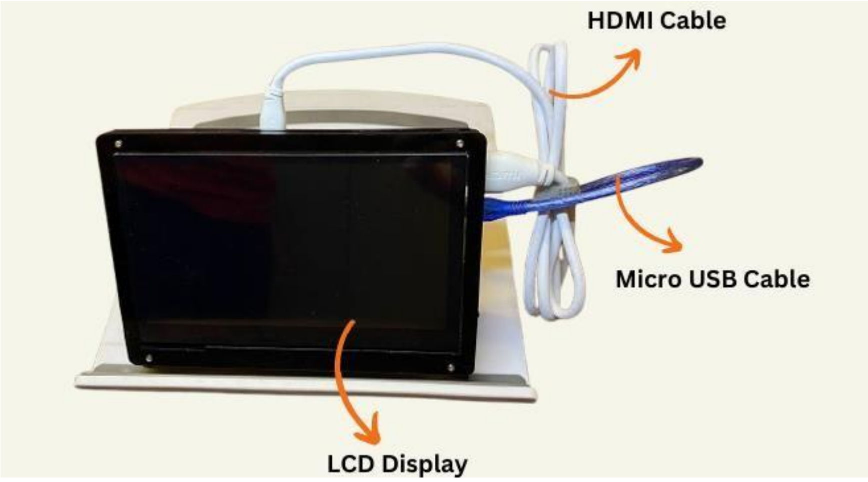
The ThermoVision Pro is a sophisticated thermal imaging device designed with a focus on functionality, portability, and durability. At its core, the device features the powerful Raspberry Pi 5 processor, ensuring efficient data processing and handling. The high-resolution AMG8833 thermal camera is integrated to deliver precise and detailed thermal imagery. Complementing these components is a high-quality LCD from a reputable China brand, providing clear, real-time display of thermal images.

To connect and power these components, the device utilizes HDMI, micro-USB, and Type-C cables, ensuring seamless communication between the thermal camera, processor, and display. The entire assembly is housed in a durable plastic casing, protecting the internal components from environmental damage. Additionally, a processor fan is included to maintain optimal operating temperatures, while a dedicated processor case offers extra protection for the Raspberry Pi. A portable power bank ensures the device's mobility and reliable power supply, making it ideal for field applications.

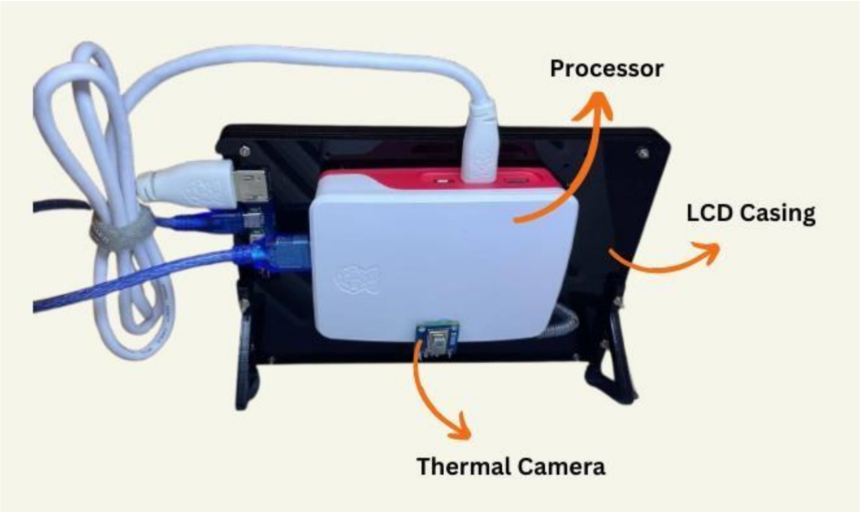
The design also emphasizes the importance of visual documentation, employing various types of drawings to aid in the assembly and understanding of the device. Isometric drawings provide a three-dimensional view of the assembly, highlighting how components fit together. Orthographic projections offer detailed views from different angles, such as the front, top, and side, facilitating precise measurements and manufacturing processes. Block diagrams illustrate the functional relationships between the main components, offering a clear overview of the system's operation. This comprehensive approach to design and documentation ensures that the ThermoVision Pro is both user-friendly and efficient, making it a valuable tool for thermal imaging tasks.

3.6.2 Prototype Development

The development of the ThermoVision Pro prototype was a meticulous process that involved integrating advanced components to ensure optimal performance. The project began with selecting the core components, including the Raspberry Pi 5 processor and the AMG8833 thermal camera. The development team focused on creating a compact and efficient design, starting by designing the internal layout to accommodate these key components along with the high-quality LCD screen and necessary connectors, such as HDMI, micro-USB, and Type-C cables.



Figures 3.23: Front View of ThermoVision Pro



Figures 3.24: Back View of ThermoVision Pro

Once the component layout was finalized, attention turned to the casing. A durable plastic casing was designed to protect the internal components while allowing easy access for assembly and maintenance. The team also included a processor fan and a dedicated processor case to ensure proper cooling and protection for the Raspberry Pi. The final steps involved integrating a power bank to provide reliable and portable power, followed by extensive testing and refinement to ensure all components worked seamlessly together. The end result was a robust and user-friendly thermal imaging device, ready for real-world applications.

3.7 DEVELOPMENT OF PRODUCT

3.7.1 Material Acquisition

NO	MATERIAL	DESCRIPTION
1		The main processing unit, chosen for its robust computing capabilities and compatibility with thermal imaging software.
2		Provides protection and cooling for the Raspberry Pi, ensuring stable operation within the device
3		Captures thermal images, essential for detecting issues like delamination, debonding, and water ingress
4		Connect components within the system, enabling data and power transfer between the Raspberry Pi and other parts

5		Powers the Raspberry Pi, ensuring consistent and safe energy flow to the processing unit.
6		Displays thermal images in real-time, allowing users to monitor inspection results directly on the device
7		Protects the LCD screen, with a slight modification for optimal cable management within the device
8		Provides portable power to the device, allowing field use without reliance on external power sources.

9		Secures components and cables, ensuring stability and reducing movement within the casing
10		Connects the Raspberry Pi to the LCD screen, enabling image and data transmission for display.

Table 3.16: List of Material Acquisition

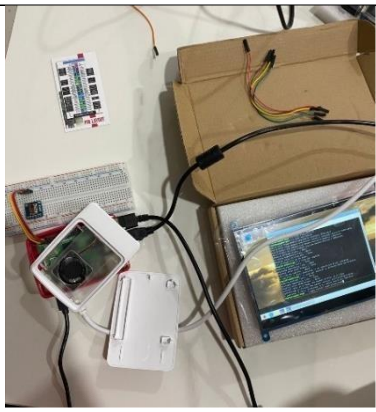
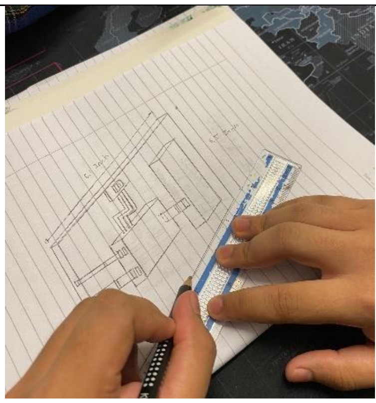
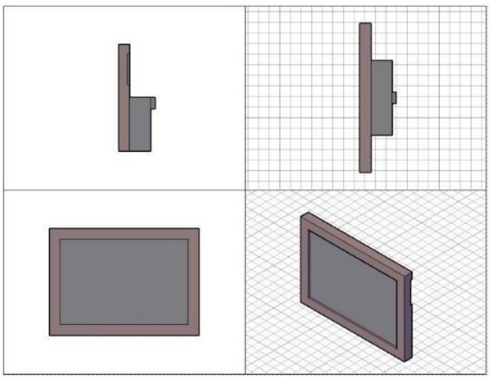
3.7.2 Machines and Tools

NO	TOOLS	DESCRIPTION
1.	 **Soldering Set**	The soldering machine set is used to attach the thermal camera's pins to jumper wires securely. It includes a temperature-controlled soldering iron for safe connections and fine tips for precise work on small pins.
2.	 **Screwdriver Set**	The screwdriver set is used to assemble all components in the product, including securing the processor, attaching the processor case and fan, and mounting the LCD casing.

Table 3.17: List of Machines and Tools

3.7.3 Specific Project Fabrication

3.7.3.1 Phase 1 (Base Structure)

No	Fabrication Process	Description
1	 **Material was checked**	The quality of the raw material was checked for any physical damage such as scratch and crack.
2	 **Sketch Product for Visual**	All the length of the dimension was measured and marked on the material or components before assembling.
3	 **AutoCAD for 3D Visual**	All the materials and components were assembled into one product using AutoCAD to create a 3D visual of the product.

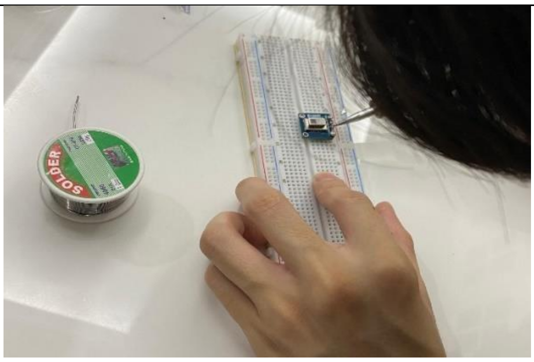
4	 **Soldering pin of the Thermal Camera**	Soldering the pin of the thermal camera made it easier to connect the jumper wire to the camera before connecting it to the processor.

Table 3.18: Phase 1 (Base Structure)

3.7.3.2 Phase 2 (Accessories & Finishing)

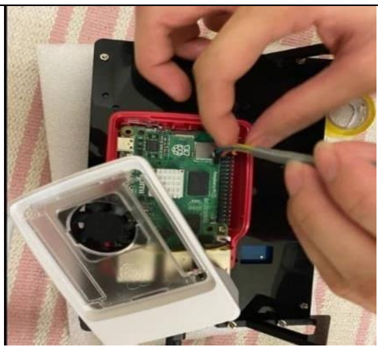
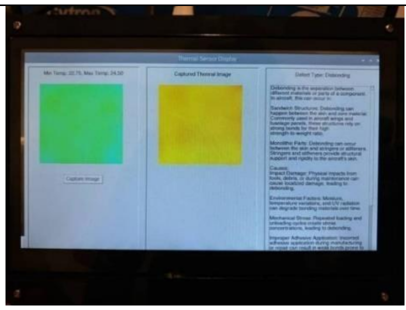
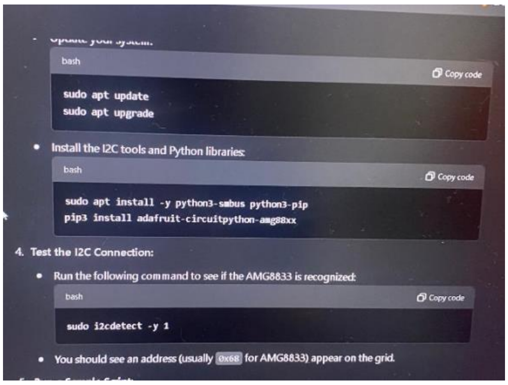
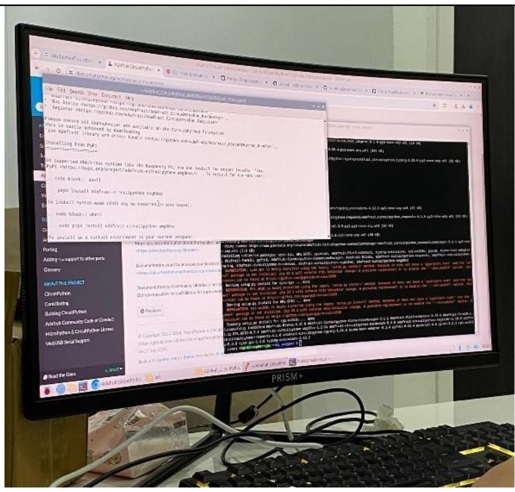
No	Fabrication Process	Description
1	 **Installation of Product**	Components like the thermal camera, Raspberry Pi, and LCD screen are securely installed for optimal alignment and performance. This setup also allows for easy access for future repairs.
2	 **Cable Management**	Organized cable routing reduces clutter and ensures safe, efficient operation, making it easier to maintain and troubleshoot.
3	 **Modifying the LCD case for cable management**	A small cut in the LCD case allows for clean cable routing, reducing strain and keeping a professional appearance.
4	 **Final Finishing Touches**	Final checks confirm all components function correctly, cables connect properly, and the device looks polished and ready for use.

Table 3.19: Phase 2 (Accessories & Finishing)

3.7.3.3 Phase 3 (Programming & Electrical Circuit)

No	Fabrication Process	Description
1.	 **Connecting Cable**	Connecting jumper wires between the thermal camera and processor allows data transfer and communication between components. Proper pin alignment is essential to ensure accurate signal flow, enabling the camera to capture thermal data for processing and display.
2.	 **Gathering Information**	Gathering information involves researching and collecting the necessary coding to install the thermal camera software into the processor. This ensures proper integration, enabling the processor to communicate with the camera, interpret the thermal data, and display the results accurately.
3.	 **Software Installation**	Installing the thermal camera software onto the processor enables it to interpret and display thermal imaging data. This setup allows the processor to communicate with the camera, process real-time images, and provide accurate thermal readings.

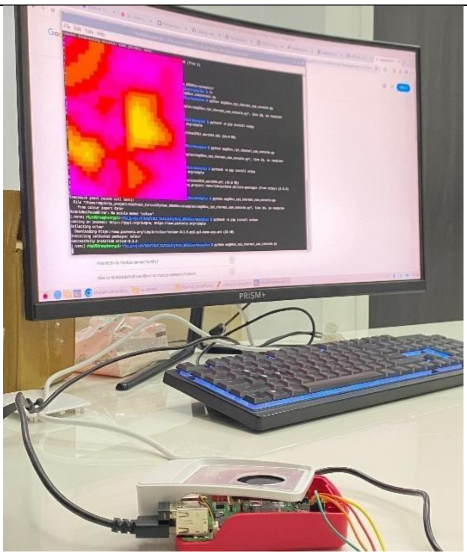
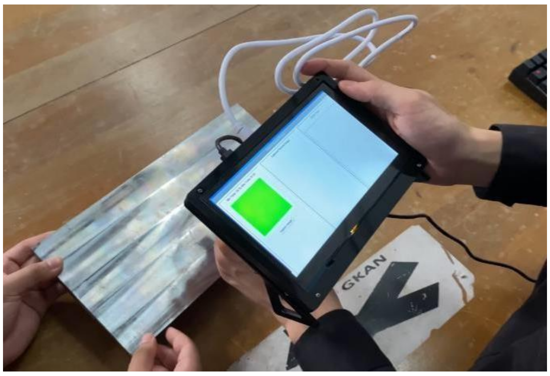
4.	 **Sensor Evaluation**	After the camera is operational, the sensor is evaluated to ensure accurate thermal detection. This involves testing the sensor's response to various temperature ranges, checking for consistency and reliability in capturing thermal data, and confirming that the system produces accurate readings for analysis.
5.	 **Product Testing**	Product testing is conducted using a laminating plate to assess the thermal camera's performance. The plate is used to simulate real-world conditions, allowing the system to detect temperature variations and verify that the camera accurately captures and processes thermal data, ensuring the system is functioning as intended.

Table 3.20: Phase 3 (Programming & Electrical Circuit)

3.8 PRODUCT TESTING / FUNCTIONALITY TESTS

Product testing for the ThermoVision Pro system was conducted using a laminating plate, which was borrowed from the Non-Destructive Testing (NDT) laboratory at the Polytechnic of Banting, Selangor. To simulate realistic testing conditions, the laminating plate was heated first to create a controlled temperature gradient. The goal was to observe how the thermal camera detects temperature variations across the surface, as temperature anomalies are often indicative of defects like delamination or disbonding in materials. By applying heat to the plate, we could effectively test the camera's sensitivity to subtle temperature differences and assess its ability to identify potential defects.

The thermal camera captured the temperature data, which was processed by the Raspberry Pi 5, while the integrated AI within the software analyzed the images in real-time. The AI system had been specifically trained to identify and classify common defects, such as delamination, based on temperature patterns. As the camera scanned the heated plate, the AI successfully detected the thermal inconsistencies, highlighting areas where temperature deviations occurred, which corresponded to delaminated sections of the laminate. These thermal anomalies were clearly displayed on the software interface, confirming the AI's capability to identify potential structural issues.

The successful detection and classification of the delamination defect validated the functionality of the ThermoVision Pro system. The product performed as expected, with the software providing accurate and reliable results in identifying temperature variations and corresponding defects. This testing phase was crucial in confirming that the ThermoVision Pro system met the design specifications and could be used effectively in real-world Non-Destructive Testing (NDT) scenarios. The successful outcome of the test marked an important milestone, demonstrating the product's readiness for use in aviation maintenance and other industries requiring precise thermal inspection.

Figures 3.25: Testing Process of ThermoVision Pro

3.9 LIST OF MATERIALS & EXPENDITURES

3.3.1 Product Structure				
No	**Items**	**Unit**	**Price/Unit (RM)**	**Total (RM)**
1	Screwdriver SET	**1**	**5.90**	**5.90**
2	LCD Screen Casing	**1**	**24.70**	**24.70**
3	PowerBank	**1**	**19.79**	**19.79**
3.3.2 Software/Programming				
No	**Items**	**Unit**	**Price/Unit (RM)**	**Total (RM)**
1	Official Red/White Case Kit with Raspberry Pi 5 - 4GB RAM (UK Plug)	**1**	**509.00**	**509.00**
2	AMG8833 IR 8*8 Thermal Imager	**1**	**110.22**	**110.22**
3	7 Inch IPS Touch Screen for Raspberry Pi 5	**1**	**111.83**	**111.83**
3.3.3 Assembling & Finishing				
No	**Items**	**Unit**	**Price/Unit (RM)**	**Total (RM)**
1	Cable USB to Micro	**1**	**15.00**	**15.00**
2	Jumper Wire (15cm)	**1**	**2.25**	**2.25**
3	Micro USB Cable	**2**	**5.19**	**10.38**
4	Candle	**1**	**2.40**	**2.40**
GRAND TOTAL				**806.28**

Table 3.21: List of Materials & Expenditures

CHAPTER 4

RESULT & DISCUSSION

4.1 PRODUCT DESCRIPTION

4.1.1 General Product Features & Functionalities

The Thermovision Pro is designed to meet the demands of modern thermal imaging applications, offering a range of advanced features and functionalities. Central to its design is the high-resolution AMG8833 thermal camera, which provides precise temperature detection and detailed thermal imagery. This sensor can identify subtle thermal variations, making it ideal for applications in the aviation industry where accuracy and reliability are paramount. The thermal camera's data is processed by the robust Raspberry Pi 5, ensuring quick and efficient handling of thermal information.

One of the standout features of the Thermovision Pro is its user-friendly interface, facilitated by a high-quality LCD display screen. This display allows users to view real-time thermal images and data, making it easier to conduct inspections and analyze results on the spot. The clear and bright visuals provided by the LCD screen enhance the overall user experience, allowing for detailed examination of thermal data and facilitating prompt decision-making in critical situations.

The Thermovision Pro's portability is another significant advantage, especially in field applications. Encased in a durable and lightweight casing, the device is designed to withstand various environmental conditions, making it suitable for use in harsh aviation environments. Its compact design ensures ease of handling and transportation, allowing technicians and engineers to carry it effortlessly during inspections and maintenance tasks. The device's robust construction ensures longevity and reliability, even in demanding operational scenarios.

In addition to its hardware capabilities, Thermovision Pro is equipped with advanced software functionalities. These include customizable settings for temperature ranges, alarm thresholds, and image processing options. Users can tailor the device's operations to suit specific requirements, enhancing its versatility across different applications. The software also supports data storage and transfer, enabling users to record thermal images and analysis for further examination and reporting. This combination of high-performance hardware and sophisticated software makes Thermovision Pro an indispensable tool for professionals in the aviation industry.

4.1.2 Specific Part Features

4.1.2.1 Product Structure

The Thermovision Pro boasts a meticulously designed product structure that enhances its functionality and usability. At the heart of the device is the high-resolution AMG8833 thermal camera, securely housed within a robust and lightweight casing. This casing not only protects the sensitive components from environmental damage but also provides an ergonomic grip for ease of use. The device features an LCD display screen that offers clear and real-time thermal imagery, ensuring that users can quickly and accurately interpret thermal data during inspections and maintenance tasks.

To facilitate seamless connectivity and data processing, the Thermovision Pro incorporates the Raspberry Pi 5 as its motherboard. This powerful processor is integrated within the panel, allowing for efficient data management and processing capabilities.

Additionally, the product structure includes strategically placed ports and connectors, enabling easy attachment of external accessories and peripheral devices. The overall design ensures that all components work harmoniously together, delivering a reliable and efficient thermal imaging solution tailored for the demanding environments of the aviation industry.

4.1.2.2 Software / Programming

The software and programming component of ThermoVision Pro is a critical aspect that powers the real-time thermal analysis and defect identification capabilities of the system. At the core, the software was specifically designed to interpret thermal data from the AMG8833 thermal camera, which captures heat signatures from aircraft components under inspection. The thermal data is processed by a Raspberry Pi 5, a powerful and efficient microprocessor chosen to handle large data streams and run AI algorithms seamlessly. Through custom programming, the software interface was built to be intuitive and functional, presenting users with a straightforward, accessible experience.

Programming integrates an artificial intelligence algorithm that autonomously analyzes captured thermal images, detecting potential defects such as delamination, disbonding, or material inconsistencies by interpreting temperature variations. This algorithm relies on a set of predefined parameters that the AI continuously references to identify patterns associated with common structural flaws. Advanced coding languages, such as Python, were employed to connect the thermal camera to the processor and to facilitate smooth communication between the software modules. This connection enables the camera to transmit high-resolution thermal images to the software, where each image undergoes immediate analysis and classification.

To ensure functionality, an interface layout was developed that segments the display into three main sections: real-time thermal imaging, captured image display, and defect classification. The real-time imaging section provides a live feed from the thermal camera, while the captured image area allows for image review and defect inspection. The right section includes information on defect type, definitions, and recommended actions.

The software requires a few terminal commands to initialize, allowing users to quickly activate the program and view results. By automating defect detection, this software program significantly reduces the inspection time, increases accuracy, and offers a cost-effective solution for Non-Destructive Testing in aviation maintenance.

4.1.2.3 Accessories and Finishing

The accessories and finishing touches for ThermoVision Pro are carefully chosen to ensure every part works together seamlessly, making the device easy to use and highly durable. Quality components, like strong cables, a custom-modified LCD casing, and a portable power bank, all contribute to a solid design that supports ThermoVision Pro's demanding non-destructive testing (NDT) applications in aviation. The Raspberry Pi casing protects the processor from bumps and overheating, while organized jumper wires ensure secure connections between parts. The LCD screen and its casing are modified for clean cable management, keeping the setup tidy and reducing clutter, making it easier to handle during inspections.

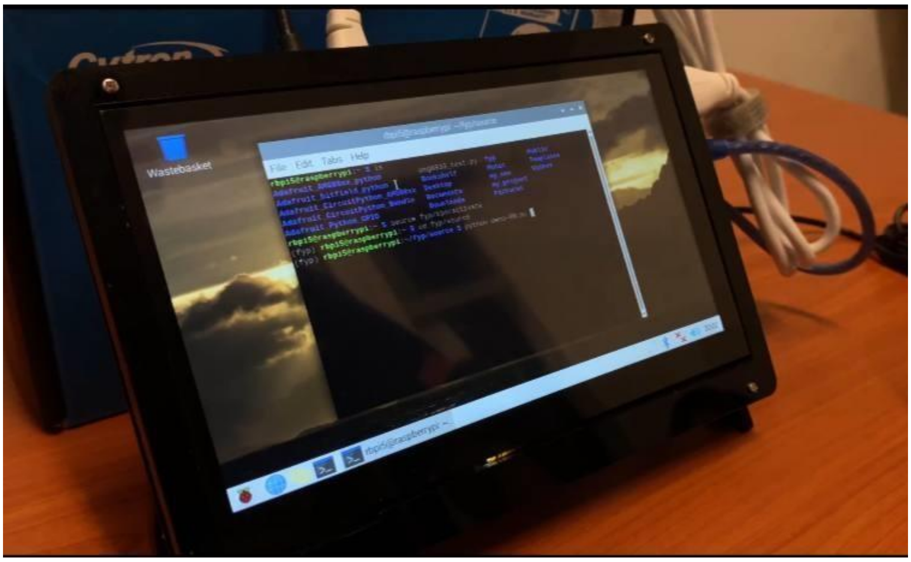
Each accessory also adds to ThermoVision Pro's resilience and ease of maintenance. The power bank keeps the device portable, allowing it to be used in the field without needing a plug, while HDMI and USB cables ensure smooth connections for power and display. The screwdriver set and hot glue gun are essential tools for assembly, helping secure parts firmly and preventing wear over time. This focus on detail—from organized cable layout to protective casings—means ThermoVision Pro not only delivers precise imaging but is also built to handle regular, heavy-duty use in aviation.

4.1.3 General Operation of the Product

ThermoVision Pro operates as an integrated thermal inspection tool designed for Non-Destructive Testing (NDT) in aviation maintenance. The general operation begins with powering on the device, which activates both the Raspberry Pi 5 processor and the AMG8833 thermal camera. The thermal camera immediately starts capturing real-time thermal images of the aircraft component under inspection, detecting any temperature variations that might indicate structural issues such as delamination or disbonding. This live feed is displayed on the left section of the interface, allowing users to monitor temperature changes directly from the device screen.

When the user identifies a specific area of interest, they can capture an image by selecting the 'Capture' button on the screen. This action freezes the current thermal image and transfers it to the center display section, where it is saved for further analysis. Simultaneously, the AI-driven software in the device begins analyzing the captured image for any potential defects, using pre-trained algorithms to detect abnormalities. The results, including detected defect types and descriptions, are displayed on the right section of the interface, along with suggested actions to address each defect.

The system's interface was designed to be user-friendly, with a straightforward sequence of operations that minimizes training time and enhances usability. Additionally, all captured data and analysis results are stored in the device's memory, allowing inspectors to reference or export the data for future inspections. This comprehensive setup enables ThermoVision Pro to deliver fast, reliable, and consistent thermal inspections, contributing to enhanced maintenance efficiency and safety in aviation applications.



Figures 4.1: Activate the App of ThermoVision Pro

4.1.4 Operation of the Specific Part of the Product

4.1.4.1 Product Structure

The Thermovision Pro is meticulously designed to optimize its operational effectiveness and user experience. Central to its structure is the high-resolution AMG8833 thermal camera, which is securely housed within a durable and lightweight casing. This case not only protects the sensitive components from environmental damage but also includes strategically placed transparent panels, allowing users to observe internal components without needing to disassemble the device. The structure also features a hinged lid at the top, providing quick and easy access to the internal parts for maintenance and troubleshooting. Additionally, the device is equipped with a high-quality LCD display, offering clear real-time thermal imagery, which is crucial for accurate inspections and analysis. This thoughtful design ensures that all critical components are both accessible and well-protected, enhancing the overall reliability and efficiency of the Thermovision Pro in various operational environments.

4.1.4.2 Software / Programming

The software and programming of ThermoVision Pro are fundamental to its functionality, enabling efficient defect detection and thermal analysis. Upon powering up the device, the Raspberry Pi 5 processor runs a custom-developed application designed to manage the thermal camera’s input, process thermal data, and display results in an accessible format. The software is launched by entering specific commands in the terminal, which initiates the application and activates the thermal camera for live imaging.

The application interface is structured into three main sections: real-time thermal imaging, captured image analysis, and defect reporting. In real time, the software continuously processes thermal data from the AMG8833 camera, displaying it on the left side of the screen for live monitoring. Once the 'Capture' button is pressed, the current image is frozen and displayed in the central section of the interface, allowing the user to analyze the image for potential defects.

After capturing an image, the software’s AI algorithm runs a detailed analysis, searching for signs of defects based on temperature variations detected in the image. This defect analysis is displayed on the right side of the interface, where the system categorizes the defect type, explains the potential issue, and suggests corrective actions based on the inspection data. The software’s seamless operation is critical to the device’s functionality, enabling fast, user-friendly, and reliable thermal inspections suitable for aviation maintenance applications.

4.1.4.3 Accessories and Finishing

The operation of specific accessories and finishing elements in ThermoVision Pro is designed to support the device's overall functionality, ease of use, and longevity, particularly in high-demand aviation inspection settings. Each part plays a vital role: the power bank provides a steady, portable power source, allowing uninterrupted use in the field without needing a nearby outlet. Durable, high-quality cables connect the power source, processor, and camera, ensuring reliable energy flow and data transmission without compromising performance. The HDMI cable bridges the Raspberry Pi with the LCD screen, enabling clear, real-time thermal imaging display crucial for non-destructive testing (NDT) tasks. To maintain a clean and secure internal layout, the jumper wires are organized with efficient cable management, reducing the risk of interference, tangling, or overheating, while modified LCD casings allow for smooth cable routing and a professional finish. Assembly tools like the screwdriver set and hot glue gun are essential for securing each part within the casing, preventing movement or wear, which ultimately enhances device stability and durability over time. Each of these components works in tandem to create a robust, user-friendly, and field-ready ThermoVision Pro device tailored for the rigorous standards of aviation inspections.

4.2 PRODUCT OUTPUT ANALYSIS

ThermoVision Pro's output is crafted to meet the demanding standards of non-destructive testing (NDT) in aviation, offering high-resolution thermal imaging that identifies critical issues like delamination, debonding, and water ingress in aircraft surfaces. By capturing subtle temperature variations that reveal structural flaws not visible to the naked eye, the device gives maintenance teams a powerful way to assess aircraft health. This level of detail in thermal images supports safety by helping technicians quickly spot and address potential issues, which not only prevents further wear and tear but also cuts down on the need for extensive and costly repairs.

A key advantage of ThermoVision Pro's output is its immediate data processing capability, which speeds up inspections significantly. The Raspberry Pi processor embedded in the system rapidly analyzes thermal data, providing clear, high-quality images in real time. This quick feedback allows maintenance crews to identify and respond to issues on the spot, without long waits for data processing. With accurate, instantaneous imaging, ThermoVision Pro enhances both the speed and reliability of inspections, helping teams make informed decisions that keep aircraft in peak operating condition.

ThermoVision Pro's thermal data also creates an ongoing record of an aircraft's structural health, as each scan can be stored and reviewed over time to track any changes. In aviation, where components need continuous monitoring, this record-keeping feature is especially valuable. By comparing images from past inspections, technicians can spot trends and take preventative action before issues worsen. This approach not only improves daily maintenance but also builds a larger data set for long-term safety and durability, making ThermoVision Pro an essential part of modern aviation inspections.

4.3 ANALYSIS OF PROBLEM ENCOUNTERED & SOLUTION

4.3.1 Product Structure

During the development of Thermovision Pro, a significant issue was encountered with the product structure. The purchased case, initially intended to house all components, proved inadequate as the LCD screen and connecting cables were obstructed by the case's dimensions. This misalignment resulted in an improper fit, which could potentially compromise the device's functionality and accessibility. The constraints of the case made it clear that an adjustment was necessary to ensure that all components could be securely and effectively integrated.

To address this issue, a small section of the casing was meticulously cut to create the required space for the LCD screen and cables. This modification allowed the components to fit seamlessly within the case without obstruction. The careful cutting ensured that the structural integrity of the casing was maintained while providing the necessary clearance for the components. Once the adjustments were made, the assembly process continued smoothly, and the components were securely fitted into the modified case. The result was quite satisfactory, with the LCD and cables fitting perfectly into the casing, thereby ensuring the device's optimal performance and ease of maintenance.

4.3.2 Software / Programming

During the development of the ThermoVision Pro software, several challenges arose that required innovative solutions to ensure optimal functionality. One of the primary issues encountered was the compatibility of the thermal camera's software with the latest Raspberry Pi 5 processor. As the processor is a relatively new release, existing resources and tutorials primarily focused on previous Raspberry Pi models. This led to difficulties in finding appropriate guidance for establishing communication between the thermal camera and the processor. To address this, ChatGPT was utilized to adapt existing code from Raspberry Pi 4 configurations, allowing the team to modify and integrate compatible coding solutions for the thermal camera setup on the Raspberry Pi 5.

Another challenge involved optimizing the AI algorithm responsible for defect detection. Initial tests revealed that the AI model occasionally misclassified certain types of defects due to subtle variations in temperature readings. This was especially noticeable in high-temperature settings, where the system struggled to differentiate between minor surface anomalies and genuine delamination defects. To resolve this, the programming team refined the model by training it with additional thermal data specific to the types of defects expected in aviation maintenance applications. This data augmentation enhanced the AI's ability to accurately identify defect types, improving both reliability and detection precision.

Finally, a significant issue was the software's processing speed when managing live thermal images while performing real-time analysis. The initial configuration resulted in slight delays, which could hinder the user's ability to capture accurate images in dynamic inspection environments. By optimizing the software's code and reallocating resources within the Raspberry Pi 5's processing architecture, the team achieved a smoother operation. These solutions collectively strengthened ThermoVision Pro's software, ensuring its effective use in thermal inspections for the aviation industry.

4.3.3 Accessories and Finishing

While developing ThermoVision Pro, we ran into a few challenges with accessories and finishing that needed careful solutions to create a polished, functional device suited for aviation inspections. One of the main issues was managing the cables within the compact space inside the device. Without proper organization, cables could easily become tangled or interfere with airflow, causing potential overheating and disrupting performance. The limited space around the internal components made this especially tricky. To solve this, we focused on creating a clean, organized layout by routing cables along specific paths and using adhesive points to keep everything in place. We also modified the LCD casing to create openings for cable routes, allowing us to keep a neat and professional setup without compromising on safety or design.

Another challenge was finding a way to secure the parts firmly while also allowing easy access for any future repairs or upgrades. Since ThermoVision Pro includes delicate components like the thermal camera, Raspberry Pi, and LCD screen, it was crucial to balance sturdiness with accessibility. We tackled this by using high-quality fastening tools and choosing a durable but lightweight casing material to hold everything securely. Tools like a precision screwdriver and hot glue gun helped us fix components without the risk of loosening or damage over time. This approach resulted in a solid, well-organized interior that supports the device's durability and performance while making maintenance easier. With these solutions, ThermoVision Pro is now ready for heavy-duty use in non-destructive testing (NDT) tasks within aviation, combining functionality with a professional finish.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 ACHIVEMENT OF AIM & OBJECTIVES OF THE RESEARCH

5.1.1 General Achievements of the Project

Upon completion of the final-year project testing, ThermoVision Pro successfully operated and produced the intended output. ThermoVision Pro captures the image of the laminate plate by manually pressing the button located on the left side of the screen display. Additionally, the product displays the captured image in real-time. The objectives have been achieved, as the defects are described on the right side of the app.

Furthermore, a post-survey was conducted to evaluate user satisfaction. Based on the collected data, the majority of respondents agreed that ThermoVision Pro is effective as a visual aid and teaching material for lecturers when discussing Non-Destructive Testing (NDT) topics, particularly thermography testing. This tool helps students better understand the combination of thermography testing and artificial intelligence operation.

Moreover, ThermoVision Pro's portability, efficiency, and accuracy make it highly valuable in the aviation industry. Its compact design allows for easy transportation and use in various locations, while its real-time imaging and accurate detection contribute to more efficient maintenance and inspection processes. This enhanced capability ensures higher safety standards and reduces downtime for aircraft.

5.1.2 SPECIFIC ACHIEVEMENT OF PRODUCT OBJECTIVES

5.1.2.1 Product Structure

The goal of creating the ThermoVision Pro structure has been met. To achieve this goal the suitable shape and dimensions of the structure are identified, and ThermoVision Pro is developed in accordance with this aspect. The ThermoVision Pro structure was methodically created ad built by using AUTODESK-AUTOCAD, since we already have already experienced using it beforehand and also because of its user-friendly design and modelling applications. Once the ideal shape and dimensions were determined.

5.1.2.2 Software / Programming

The software and programming components of ThermoVision Pro achieved several critical objectives that were central to the success of the project. One of the primary achievements was the development of a user-friendly interface that effectively organizes thermal imaging and defect analysis. The interface layout provides users with real-time thermal images, captured images, and a detailed defect analysis section, each accessible through a straightforward navigation panel. This design ensures that inspectors can easily operate the system and interpret the results without extensive training, meeting the objective of creating an intuitive user experience.

Another significant accomplishment was the seamless integration of AI into the thermal imaging analysis. By combining thermography with AI-driven algorithms, the software could successfully identify and classify defects like delamination and disbonding in aircraft components.

The AI component was meticulously trained on aviation-specific defect data to enhance detection accuracy, resulting in a powerful diagnostic tool that aligns with the project's objectives of improving detection capabilities in aviation maintenance.

Lastly, the objective of providing a portable and efficient thermal imaging solution was achieved through the software's optimization for the Raspberry Pi 5 platform. Despite being compact and power-efficient, the Raspberry Pi 5 processor was fully leveraged to handle real-time thermal data analysis and display without significant lag. The software's successful performance on this compact hardware setup underscores its value as a cost-effective, highly portable solution for aviation maintenance. Each of these achievements contributes to ThermoVision Pro's promise as a practical and advanced tool for improving safety and inspection efficiency in the aviation industry.

5.1.2.3 Accessories and Finishing

ThermoVision Pro's accessories and finishing have been carefully designed to create a durable and organized device that can handle the demands of field use in aviation inspections. We focused on ensuring that each component, from the thermal camera to the processor, was securely placed and that cables were routed neatly to avoid any tangling or interference. This thoughtful cable management not only keeps everything in order but also ensures proper airflow, helping to prevent overheating during use. The modifications made to the LCD casing were done with precision, allowing cables to pass through without disrupting the device's sleek and professional look, making sure the system stays reliable and ready for long-term use.

The finishing touches were equally important in making sure that ThermoVision Pro is both functional and easy to maintain. We used high-quality materials and careful fastening techniques to secure all the parts, while also making sure they can be easily accessed for future repairs or upgrades. The integration of the thermal camera, processor, and display was done seamlessly, allowing the device to operate smoothly and effectively. These final steps ensure that the ThermoVision Pro is not only a dependable tool for aviation inspections but also looks and feels professional, meeting the high standards of performance and durability that are essential for non-destructive testing in the industry.

5.2 CONTRIBUTION OR IMPACT OF THE PROJECT

ThermoVision Pro has the potential to make significant contributions to the field of aviation maintenance by enhancing inspection accuracy, efficiency, and overall safety standards. One of the project's most impactful features is its combination of thermal imaging and AI-driven analysis, a step forward in the standard of non-destructive testing (NDT) for aircraft maintenance. This integration allows for swift detection of concealed defects, such as delaminations and disbonds, which may not be easily identified through conventional visual inspections. By increasing the precision of defect detection, ThermoVision Pro has the potential to improve preventative maintenance processes and reduce the likelihood of in-service failures, ultimately contributing to a higher level of safety within aviation.

The project also contributes to greater cost-efficiency and operational ease in aircraft maintenance. Unlike more complex and costly diagnostic equipment, ThermoVision Pro is compact, portable, and accessible, utilizing the efficiency of the Raspberry Pi platform. Its design is optimized for both field applications and training environments, with a user-friendly interface that makes it suitable for maintenance personnel with varying levels of experience. By reducing the need for extensive training or costly equipment, ThermoVision Pro provides a practical solution for aviation institutions and maintenance departments looking to adopt advanced inspection technology on a limited budget.

Furthermore, ThermoVision Pro's AI capabilities offer promising advancements toward data-driven aviation maintenance. As the integrated machine learning algorithms improve with continued use, the project supports a shift toward predictive maintenance strategies. This approach enables maintenance teams to anticipate potential issues based on real-time data analysis, aligning with the aviation industry's goals of maximizing aircraft uptime and minimizing reactive maintenance procedures. By fostering a proactive maintenance model, ThermoVision Pro promotes efficiency and reliability in aviation operations.

Lastly, this project stands to make educational contributions to aviation and engineering training programs. By providing an accessible and functional model of a sophisticated diagnostic tool, ThermoVision Pro can be used as a learning kit in educational institutions. Students gain hands-on experience with thermal imaging and AI software, equipping them with modern skills relevant to today's aviation technology. Overall, ThermoVision Pro's contributions not only enhance operational efficiency and safety in the industry but also support the advancement of education and training in aviation maintenance.

5.3 IMPROVEMENTS OR IMPACT OF THE PROJECT

5.3.1 Product Structure

1. Enhanced Fit of LCD Display Screen Casing

One significant improvement is ensuring that the casing of the LCD display screen is more precisely fitted. This enhancement will streamline the assembly process, making it more efficient and reducing the time required for production. A better-fitted casing will also ensure that the screen is securely housed, preventing any movement or misalignment during operation. As a result, the overall durability and reliability of the product will be improved, leading to higher user satisfaction.

2. Improved Component Arrangement

Another crucial improvement is the attachment and arrangement of the internal components. The current setup may have components that are not neatly arranged, which can lead to difficulties during assembly and maintenance. By working on the neat arrangement of components, the product will be more organized and easier to assemble. This improvement will not only enhance the aesthetic appeal of the internal structure but also contribute to better heat dissipation and overall performance.

3. Impact on User Experience

The improvements mentioned above will have a positive impact on the user experience, particularly for engineers and technicians who handle the product. A more precisely fitted casing and neatly arranged components will make the product more comfortable to use and handle in various environments.

Engineers will appreciate the ease of assembly and maintenance, leading to increased efficiency in their workflow. Additionally, the enhanced durability and reliability of the product will build confidence in its performance, making ThermoVision Pro a preferred choice for non-destructive testing in various industries, including aviation.

5.3.2 Software / Programming

ThermoVision Pro has substantial room for enhancements in both its hardware and software aspects, with promising improvements in the quality of thermal imaging and the overall user experience. One of the primary software-related upgrades is tied to the quality of the thermal camera. The current thermal camera model is cost-effective but limited by its pixelated resolution, which can obscure finer details of inspected components. Upgrading to a more advanced thermal camera with a higher resolution would allow for more precise imaging, capturing the full shape and finer structural details of the object. This improvement would enable inspectors to detect smaller or more complex defects with ease, enhancing the accuracy and reliability of the product for practical applications in the field.

Another valuable improvement lies in redesigning the product's casing and structure to make it more compact and user-friendly. The current model has exposed wiring at the back, which can interfere with handling and limits portability. By designing a full-coverage, ergonomic casing, ThermoVision Pro would not only be easier to carry and use but also more durable and less prone to accidental disconnections or wear and tear. Such an upgrade would cater to a seamless user experience and ensure better protection for the internal components, making it ideal for field applications and long-term usage in demanding environments.

Future software enhancements could also include more advanced AI algorithms for defect detection and classification. By training the software to recognize an expanded range of defect patterns and interpret them with greater accuracy, the system could increase its diagnostic capabilities.

This could make ThermoVision Pro a more robust tool for various types of inspections beyond aviation, potentially extending its application to sectors like automotive and manufacturing. Enhanced AI would enable the system to become more autonomous, requiring minimal input from users and making it accessible to a broader range of professionals.

Furthermore, the addition of wireless connectivity features could enable remote access and data sharing directly from the device, making ThermoVision Pro more versatile in a connected work environment. This would allow inspectors to upload thermal images and analyses to cloud storage, facilitating collaborative review and integration into centralized maintenance databases. These upgrades, both structural and functional, would significantly improve ThermoVision Pro's performance and adaptability, reinforcing its potential as an innovative diagnostic tool across industries.

5.3.3 Accessories and Finishing

1. Enhanced Durability and Longevity

By focusing on the quality of materials and careful assembly, ThermoVision Pro’s accessories and finishing have greatly improved their durability. The secure management of cables and use of high-quality casings have helped ensure the device can withstand the rigors of field use in aviation. Given the demanding environments and frequent handling of inspection tools, the attention to detail in the construction of ThermoVision Pro means it will last longer, minimizing the need for repairs or replacements and ultimately making it a reliable companion for aviation professionals.

2. Improved User Experience and Accessibility

The thoughtful design of ThermoVision Pro's internal layout has made the device easier to operate and maintain. Organizing the components and cables efficiently not only keeps the device functional but also ensures that it's user-friendly for technicians in the field. When you're performing an aviation inspection, the last thing you want is equipment that slows you down. With easy access to parts for repairs and a hassle-free setup, ThermoVision Pro improves workflow and boosts productivity, allowing aviation professionals to get their work done quickly and accurately.

3. Professional Aesthetic and Presentation

The finishing touches on ThermoVision Pro have made it not only a functional tool but also a sleek, professional-looking device. The careful modification of the LCD case and attention to detail in the external finish create a product that's visually appealing as well as practical. In aviation, having equipment that looks the part is just as important as how well it works. The polished design reinforces the credibility of ThermoVision Pro as a high-quality tool, helping it stand out as a trusted asset in non-destructive testing.

4. Optimization for Aviation Inspections

Every part of ThermoVision Pro has been carefully optimized to meet the specific needs of aviation inspections. The organization of components and the proper routing of cables ensures that the device performs at its best, whether in the workshop or on the runway. With all parts securely in place and easy to access, ThermoVision Pro helps technicians detect issues like delamination, debonding, and water ingress with greater accuracy. The result is a tool that not only makes inspections easier but also contributes to safer, more reliable aircraft operations.

List of References

1. "Aviation Ndt: Improving Flight Safety," *One Stop Ndt*, Available: Https://Www.Onestopndt.Com/Ndt-Articles/Aviation-Ndt-Improving-Flight-Safety. [Accessed: Feb 14,2024]

2. "Dot_57623_Ds1.Pdf," *National Transportation Library (Rosap)*, [Online]. Available: Https://Rosap.Ntl.Bts.Gov/View/Dot/57623/Dot_57623_Ds1.Pdf. [Accessed: Feb 3,2024]

3. "Mstar Vision," *Mstar Vision*, [Online]. Available: Https://Www.Mstarvision.Com/?Gad_Source=1&Gclid=Cj0kcqjwu8uybhc6arisakwbgpq7wt72_Yby_Jrefhfkh2vbtxr1-Awbz6ksdoj6nhfpbutmndqv-Gaaas16ealw_Wcb. [Accessed: Feb 4,2024]

4. "Ndt In Aviation." *Sky Aviation Holdings*, N.D., Https://Skyaviationholdings.Com/Ndt-In-Aviation/.

5. "Non-Destructive Testing & Materials Testing," *Flir Systems*, [Online]. Available: Https://Www.Flir.Com/Instruments/Science/Ndt-Materials-Testing/. [Accessed: Feb 3,2024]

6. "Non-Destructive Testing Of Composite Materials In Aviation," *SKYbrary*, Available: Https://Skybrary.Aero/Articles/Non-Destructive-Testing-Composite-Materials-Aviation. [Accessed: Feb 20,2024]

7. “Infrared Camera," *Aeroexpo*, [Online]. Available: Https://Www.Aeroexpo.Online/Aeronautic-Manufacturer/Infrared-Camera-6374.Html. [Accessed: Feb 2,2024]

8. A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications," in IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2347-2376, Fourthquarter 2015, doi: 10.1109/COMST.2015.2444095. [Accessed: July 9,2024]

9. A. Author, “Top Open-Source Artificial Intelligence Software,” Spiceworks, Apr. 25, 2023. [Online]. Available: https://www.spiceworks.com/tech/innovation/articles/top-open-source-artificial-intelligence-software/ . [Accessed: April 18,2024]

10. AI in Thermal Imaging**:** L. Choi, S. Lee, and J. Kim, "Integration of AI with Thermal Imaging for Industrial Inspections," *IEEE Transactions on Industrial Electronics*, vol. 68, no. 4, pp. 1234-1242, Apr. 2021 . [Accessed: Oct 25,2024]

11. Brown, R. K. (2023). Advanced AI-Based Defect Detection in Aircraft Engines using Thermography. In Proceedings of the International Conference on Aviation Technology, 45-56. [Accessed: Jun 8,2024]

12. Eddy Current Testing**:** M. Blitz, *Electrical and Magnetic Methods of Nondestructive Testing*. London, U.K.: Chapman & Hall, 1997. [Accessed: Oct 25,2024]

13. F. Hou, Y. Zhang, Y. Zhou, M. Zhang, B. Lv, and J. Wu, "Review on Infrared Imaging Technology," Sustainability, vol. 14, no. 18, p. 11161, 2022, doi: 10.3390/su141811161. [Accessed: Aug 17,2024]

14. F. Hou, Y. Zhang, Y. Zhou, M. Zhang, B. Lv, and J. Wu, "Review on Infrared Imaging Technology," Sustainability, vol. 14, no. 18, p. 11161, 2022, doi: 10.3390/su141811161. [Accessed: Sept 29,2024]

15. G. Ananthanarayanan, P. Bodik, S. Chaudhuri, M. Philipose, P. Bahl, and R. Ramjee, "Real-time Video Analytics: The Killer App for Edge Computing," in Computer, vol. 50, no. 10, pp. 58-67, Oct. 2017, doi: 10.1109/MC.2017.3641638. [Accessed: July 17,2024]

16. García-González, D., & Díaz-Reza, J. R. (2017). “Pugh matrix: A systematic review of applications and opportunities.” Quality Engineering, 29(3), 407-421. [Accessed: April 18,2024]

17. H. Kramer And A. Hetzel, "Thermal Imaging In Aviation," *Researchgate*, Jun. 2016. [Online]. Available:

Https://Www.Researchgate.Net/Publication/304584391_Thermal_Imaging_In_Aviation. [Accessed: Feb 2,2024]

18. I. Calvo, J. M. Gil-García, I. Recio, A. Lópe, and J. Quesada, "Building IoT Applications with Raspberry Pi and Low Power IQRF Communication Modules," Electronics, vol. 5, no. 3, p. 54, 2016, doi: 10.3390/electronics5030054. [Accessed: Aug 19,2024]

19. Intel, "AI Development Software: Empowering Developers with AI Tools and Frameworks," [Online]. Available: https://www.intel.com/content/www/us/en/developer/topic-technology/artificial-intelligence/development-software.html. [Accessed: May 3,2024]

20. International Civil Aviation Organization (Icao)."Challenges And Opportunities For Artificial Intelligence (A) In Aviation," [Online] Available: Https://WwwIcao.IntMeetings/InnovationSeries/PagesChallenges-And-Opportunities-For-Artificial-Intelligence-(Ai-In-Aviation.Aspx [Accessed: Feb 24,2024]

21. Ishak, Aulia, et al. "Orange software usage in data mining classification method on the dataset lenses." IOP Conference Series: Materials Science and Engineering. Vol. 1003. No. 1. IOP Publishing, 2020. [Accessed: May 15,2024]

22. J. Barela, K. Firmanty, and M. Kastek, "Measurement and Analysis of the Parameters of Modern Long-Range Thermal Imaging Cameras," Sensors, vol. 21, no. 17, p. 5700, 2021, doi: 10.3390/s21175700. [Accessed: July 21, 2024].

23. J. Barela, K. Firmanty, and M. Kastek, "Measurement and Analysis of the Parameters of Modern Long-Range Thermal Imaging Cameras," Sensors, vol. 21, no. 17, p. 5700, 2021, doi: 10.3390/s21175700. [Accessed: Aug 24,2024]

24. J. Barela, K. Firmanty, and M. Kastek, "Measurement and Analysis of the Parameters of Modern Long-Range Thermal Imaging Cameras," Sensors, vol. 21, no. 17, p. 5700, 2021, doi: 10.3390/s21175700. [Accessed: Oct 2 ,2024]

25. J. Chawla, “AI in Aircraft Maintenance: A Shift in Approach,” LinkedIn, Available: https://www.linkedin.com/pulse/ai-aircraft-maintenance-shift-approach-jagdeep-chawla-o7jkc?trk=public_post_main-feed-card_feed-article-content . [Accessed: Jun 18,2024]

26. J. R. Doe et al., “Advanced Technologies in Aircraft Maintenance,” IEEE Aerospace Conference, vol. 3, pp. 1201-1210, Mar. 1997. Available: https://apps.dtic.mil/sti/pdfs/ADA288382.pdf . [Accessed: Jun 27,2024]

27. J. W. Jolles, "Broad-Scale Applications of the Raspberry Pi: A Review and Guide for Biologists," BES Journals, 2021, doi: 10.1111/2041-210X.13652. [Accessed: Aug 17,2024]

28. Kahraman, R., & Cetin, B. (2013). “Infrared Thermography Applications in Nondestructive Testing.” Journal of Nondestructive Evaluation, 32(1), 98-113. This paper provides an overview of infrared thermography techniques and their applications in non-destructive testing, including defect detection, material characterization, and structural health monitoring. [Accessed: April 3,2024]

29. KNIME, “What’s New in KNIME Analytics Platform 5.2,” KNIME Blog, Available: https://www.knime.com/blog/whats-new-knime-analytics-platform-52. [Accessed: May 5,2024]

30. Maierhofer, C., Larcher, M., & Veit, R. (2016). “Infrared Thermography in Non-Destructive Testing.” Infrared Physics & Technology, 75, 41-50. This paper discusses the principles of infrared thermography and its application in non-destructive testing, with a focus on defect detection and material characterization. [Accessed: April 3,2024]

31. Malaysian Investment Development Authority (Mida).” Malaysian Aviation, Aerospace Industry Set To Soar Higher,” Mida Website, March 2,2023.). (Access Data: Mac 12,2024).

32. Malaysian Investment Development Authority (Mida.” How Al Is Revolutionising The Industry.” Malaysian Investment Development Authority

(Mida).” How Al Is Revolutionising The Industry.” Mida Website, (Access Data: Mac 13, 2024).

33. Maldague, X.P.V. (ed.) (2002). “Introduction to NDT by Infrared Thermography.” Materials Evaluation, Vol. 60, No. 9. This special issue provides an introduction to the principles and applications of infrared thermography in non-destructive testing. [Accessed: Mac 23,2024]

34. Marzukhi, Syahaneim, et al. “RapidMiner and machine learning techniques for classifying aircraft data.” Journal of Physics: Conference Series. Vol. 1997. No. 1. IOP Publishing, 2021. [Accessed: May 3,2024]

35. Mendioroz, A., Cobo, A., Usamentiaga, R., & Sánchez, D. (2019). “Infrared Thermography in Non-Destructive Testing: A Review.” Sensors, 19(2), 334. This review paper summarizes recent advancements in the use of infrared thermography for non-destructive testing applications. [Accessed: Mac 25,2024]

36. Microsoft Azure, “Azure Machine Learning: Enterprise-grade Machine Learning Service,” [Online]. Available: https://azure.microsoft.com/en-us/products/machine-learning . [Accessed: April 30,2024]

37. Mordor Intelligence. Malaysia Aviation Market – Growth, Trends, Covid-19 Impact, And Forecasts (2024- 2029) (Report). Mordor Intelligence,2024 (Date Accessed: Mac 21, 2024).

38. Non-Destructive Testing Overview**:** American Society for Nondestructive Testing (ASNT), "Introduction to Non-Destructive Testing," ASNT. [Online]. Available: https://www.asnt.org. [Accessed: Oct. 20, 2024].

39. Orange, “Orange Data Mining,” Orange, Available: https://orangedatamining.com. [Accessed: May 5,2024]

40. Panasonic, "AMG8833 Infrared Array Sensor," Panasonic, 2024. [Online].Available: https://na.industrial.panasonic.com/products/sensors/infrared-sensors/grid-eye. [Accessed: July 5, 2024].

41. Precedence Research. Artificial Intelligence In Aviation Market Report 2022-2030 (Report). Precedence Research, 2022.). (Access Data: Mac 3,2024).

42. Pugh, S. (1990). “Concept Selection: A Method That Works.” Journal of Mechanical Engineering Science, 204(1), 10-12. [Accessed: April 13,2024]

43. Python Programming for Raspberry Pi: B. Lüthje and S. Hepp, *Learn Python on the Raspberry Pi: Creating Projects for Computing and Electronics*. Hoboken, NJ, USA: Wiley, 2018. [Accessed: Nov 15,2024]

44. Rajic, N., & Milovic, L. (2017). “Infrared Thermography and Its Applications in Non-Destructive Testing.” Thermal Science, 21(5), 1979-1995. This paper explores the principles of infrared thermography and its various applications in non-destructive testing, including industrial, aerospace, and civil engineering sectors. [Accessed: April 13,2024]

45. Raspberry Pi and AMG8833 Integration: M. Gupta, "AMG8833 Thermal Camera Integration with Raspberry Pi for NDT Applications," presented at the *6th Int. Conf. on Embedded Systems and IoT*, Apr. 2023. [Accessed: Nov 18,2024]

46. Raspberry Pi Foundation, "Raspberry Pi 5," Raspberry Pi Foundation, 2024. [Online]. Available: https://www.raspberrypi.org/products/raspberry-pi-5/. [Accessed: July 2, 2024].

47. S. De Bree, “The Impact of AI on Aircraft Airworthiness Management,” LinkedIn, Available: https://www.linkedin.com/pulse/impact-ai-aircraft-airworthiness-management-sander-de-bree-gdljc . [Accessed: Jun 28,2024]

48. S. J. Johnston and S. J. Cox, "The Raspberry Pi: A Technology Disrupter, and the Enabler of Dreams," Electronics, vol. 6, no. 3, p. 51, 2017, doi: 10.3390/electronics6030051. [Accessed: Aug 19,2024]

49. Smith, J. A., & Johnson, L. M. (2022). Integrating Thermography and Artificial Intelligence for Aircraft Engine Defect Detection. Journal of Aerospace Technology, 10(4), 123-136. [Accessed: Mac 25,2024]

50. Study.com, "What is Programming? – Definition & Introduction for Beginning Programmers," [Online]. Available: https://study.com/academy/lesson/what-is-programming-definition-introduction-for-beginning-programmers.html. [Accessed: May 3,2024]

51. Symphony Solutions. "Ai Revolution In Aviation: Shaping The Future Of Air Travel," Online. Available: Https://wwwVeryon.Com/Blogltransforming-Aviation-The-Ai-Revolution-Takes-Fligh-With-Veryon (Access Data: Mac 2. 2024)

52. Thermal Cameras in NDT: P. Maldague, *Theory and Practice of Infrared Technology for Nondestructive Testing*. New York, NY, USA: Wiley, 2001. [Accessed: Nov 15,2024]

53. Thermal Defect Detection in Aviation Panels: S. Smith and J. Harris, "Advances in Thermal Imaging for Aircraft Maintenance," *Journal of Aerospace Technology and Management*, vol. 15, no. 2, pp. 123-130, Jun. 2022. [Accessed: Nov 18,2024]

54. Ultrasonic Testing Principles: Krautkrämer, J., and Krautkrämer, H., *Ultrasonic Testing of Materials*, 4th ed. Berlin, Germany: Springer, 1990. [Accessed: Oct 25,2024]

55. Verma, Ankita, et al. "A detailed study of azure platform & its cognitive services." 2019 International conference on machine learning, big data, cloud, and parallel computing (COMITCon). IEEE, 2019. [Accessed: May 25,2024]

56. W. A. N. Wilson, K. Gupta, B. H. Koduru, A. Kumar, A. Jha, and L. R. Cenkeramaddi, "Recent Advances in Thermal Imaging and its Applications using Machine Learning: A Review," IEEE Sensors Journal, under review, 2024. [Accessed: Aug 8,2024]

57. W. A. N. Wilson, K. Gupta, B. H. Koduru, A. Kumar, A. Jha, and L. R. Cenkeramaddi, "Recent Advances in Thermal Imaging and its Applications using Machine Learning: A Review," IEEE Sensors Journal, under review, 2024. [Accessed: Sept 29,2024]

58. Yang, D. C., & Ko, H. S. (2008). “A systematic approach to the concept evaluation using the Pugh matrix.” Journal of Mechanical Science and Technology, 22(7), 1245-1252. [Accessed: April 15,2024]

APPENDIX A: DECLARATION OF TASK SEGREGATION

SUB-CHAPTERS	DESCRIPTION
	MUHAMMAD AMIRUL DANIAL BIN MAZRUL
1.1	Background of Study
1.3.2.1	Specific Individual Project Objectives (Product Structure)
1.4.1	Automate the Data Collection and Analysis Process
1.4.4	Standardize the Inspection Process
1.5.2.1	Specific Individual Scope (Product Structure)
2.1.1	Demand in Aviation
2.1.2	Types of Typical Non-Destructive Testing (NDT) on aircraft
2.2.1	Specific Literature Review (Product Structure)
2.3.1.1	Patents in Thermal Imaging Technology
2.3.2.1	Fluke Ti480 Infrared Camera in the Aviation Industry
2.4.1	Thermal Imaging Technology vs Fluke Ti480 Infrared Camera in the Aviation Industry vs ThermoVision Pro
3.1.1	Utilisation of Polytechnic's Facilities
3.2	Overall Project Gantt Chart
3.3.2.1	Design of ThermoVision Pro in Product Structure
3.4.2.1	Morphological Matrix
3.4.2.2	Proposed Design Concept 1
3.4.3.1	Pugh Matrix
3.5.2	Specific Part Drawing / Diagram (Product Structure)
3.6.1	Prototype / Product Modelling

3.7.3.1	Phase 1 (Base Structure)
3.9	List of Materials & Expenditures
4.1.1	General Product Features & Functionalities
4.1.2.1	Specific Part Features (Product Structure)
4.1.4.1	Operation of the Specific part of the Product (Product Structure)
4.3.1	Analysis of Problem Encountered & Solutions (Product Structure)
5.1.1	General Achievements of the Project
5.1.2.1	Specific Achievements of the Project Objective (Product Structure)
5.3.1	Improvement & Suggestions for Future Research (Product Structure)
	AMAR ZULHADI BIN ZULKIFLI
1.2	Problem Statement
1.3.2.2	Software / Programming of ThermoVision Pro
1.4.2	Enhance Portability and User-Friendliness
1.4.5	Improve Cost Efficiency and Integration with Exist Systems
1.5.1	General Project Scope
1.5.2.2	Software / Programming of ThermoVision Pro
2.1.3	Ultrasonic Testing
2.1.4	Eddy Current Testing
2.2.2	Software / Programming
2.3.1.2	Related Patented Products: Product B
2.3.2.2	Product B: FLIR C5 Compact Thermal Camera

2.4.2	Patent B vs. Product B vs. ThermoVision Pro
3.3.1	Overall Project Flow Chart
3.3.2.2	Software / programing
3.4.2.3	Proposed Design Concept 2
3.4.2.4	Proposed Design Concept 3
3.7.2	Machines and Tools
3.7.3.3	Phase 3 (Programming & Electrical Circuit)
3.8	Product Testing / Functionality Tests
4.1.2.2	Software / Programming
4.1.3	General Operation of the Product
4.1.4.2	Software / Programming
4.3.2	Software / Programming
5.1.2.2	Software / Programming
5.2	Contribution or Impact of the Project
5.3.2	Software / Programming
	MUHAMMAD AIMAN DANIAL BIN MOHAMAD FAIZELI
1.3.1	General Project Objectives
1.3.2.3	Specific Individual Project Objective (Accessories and Finishing)
1.4.3	Provide Real-Time Insights and Explanations
1.5.2.3	Specific Individual Scope (Accessories & Finishing)

2.1.5	Magnetic Particle Testing
2.1.6	Concept And Theory of Non -Destructive Testing (NDT)
2.1.7	Thermovision In Non -Destructive Testing
2.2.3	Specific Literature Review (Accessories & Finishing)
2.3.1.3	The Importance and Operation of Thermovision Pro in Non-Destructive Testing (NDT) For Aviation
2.3.2.3	Infiray P2 Pro Infrared Thermal for Aviation Inspections
2.4.3	Thermal Imaging Technology Vs Infiray P2 Pro Infrared Thermal for Aviation Inspections Vs Thermovision Pro
3.3.2.3	Specific Project Design Flow/ Framework (Accessories & Finishing)
3.4.1.1	Questionnaire Survey
3.4.1.2	Pareto Diagram
3.4.2.5	Proposed Design Concept 4
3.5.2.2	Specific Part Drawing/Diagram (Accessories & Finishing)
3.7.1	Material Acquisition
3.7.3.2	Phase 2 (Accessories & Finishing)
4.1.2.3	Specific Part Features (Accessories & Finishing)
4.1.4.3	Operation of the Specific Part of The Product (Accessories & Finishing)
4.2	Product Output Analysis
4.3.3	Analysis of Problem Encountered and Solution (Accessories & Finishing)

5.1.2.3	Specific Achievement of Project Objectives (Accessories & Finishing)
5.3.3	Improvement and Suggestions for Future Research (Accessories & Finishing)

APPENDIX B: TURNITIN SIMILARITY REPORT

THESIS PROPOSAL THERMOVISION PRO .pdf

ORIGINALITY REPORT

10%	6%	4%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Jabatan Pendidikan Politeknik Dan Kolej Komuniti Student Paper	2%
2	my.cytron.io Internet Source	<1%
3	M. Rizk, I. Bayad. "Human Detection in Thermal Images Using YOLOv8 for Search and Rescue Missions", 2023 Seventh International Conference on Advances in Biomedical Engineering (ICABME), 2023 Publication	<1%
4	vbn.aau.dk Internet Source	<1%
5	fastercapital.com Internet Source	<1%
6	Karwan Mustafa Kareem. "The Intelligence Technology and Big Eye Secrets: Navigating the Complex World of Cybersecurity and Espionage", PsyArXiv, 2024 Publication	<1%

7	Submitted to Universiteit Hasselt Student Paper	<1 %
8	www.researchandmarkets.com Internet Source	<1 %
9	Submitted to University of Western Macedonia Student Paper	<1 %
10	Submitted to Kingston University Student Paper	<1 %
11	Submitted to West Herts College Student Paper	<1 %
12	www.coursehero.com Internet Source	<1 %
13	Submitted to University Der Es Salaam Student Paper	<1 %
14	Submitted to University of Glamorgan Student Paper	<1 %
15	www.hoer-wissen-im-wandel.de Internet Source	<1 %
16	Submitted to Kaplan Professional Student Paper	<1 %
17	Sara Nawghare, Rachna K. Somkunwar, Zarina Shaikh. "Indian Railways Smart Ticketing Validation System with Improved	<1 %

	Alert Approach", 2023 International Conference on Sustainable Computing and Smart Systems (ICSCSS), 2023 Publication	
18	Submitted to Universiti Teknikal Malaysia Melaka Student Paper	<1 %
19	"Proceedings of the International Conference on Advancing and Redesigning Education 2023", Springer Science and Business Media LLC, 2024 Publication	<1 %
20	Submitted to CSU, San Jose State University Student Paper	<1 %
21	Submitted to Institute of Technology Blanchardstown Student Paper	<1 %
22	Submitted to La Trobe University Student Paper	<1 %
23	repository.embuni.ac.ke Internet Source	<1 %
24	www.verifiedmarketresearch.com Internet Source	<1 %
25	www.test-meter.co.uk Internet Source	<1 %

Applications, and Implementation", CRC Press, 2024
Publication

36	Submitted to Embry Riddle Aeronautical University Student Paper	<1 %
37	Fatih Yildiz. "Advances in Food Biochemistry", CRC Press, 2019 Publication	<1 %
38	Submitted to HCUC Student Paper	<1 %
39	bura.brunel.ac.uk Internet Source	<1 %
40	www.findtheneedle.co.uk Internet Source	<1 %
41	www.springerprofessional.de Internet Source	<1 %
42	Submitted to Bilkent University Student Paper	<1 %
43	Submitted to International Business School Student Paper	<1 %
44	Submitted to Monash University Student Paper	<1 %
45	magenest.com Internet Source	<1 %

46	ndtlibrary.asnt.org Internet Source	<1 %
47	sensotec.ir Internet Source	<1 %
48	"Emerging Trends in Expert Applications and Security", Springer Science and Business Media LLC, 2024 Publication	<1 %
49	"NDT Info", Insight - Non-Destructive Testing and Condition Monitoring, 02/2003 Publication	<1 %
50	Gang Wu, ZhiQiang Chen, Ji Dang. "Intelligent Bridge Maintenance and Management", Springer Science and Business Media LLC, 2024 Publication	<1 %
51	Submitted to Pembrokeshire College Student Paper	<1 %
52	Submitted to Staffordshire University Student Paper	<1 %
53	ebin.pub Internet Source	<1 %
54	purehost.bath.ac.uk Internet Source	<1 %
55	www.anhnghison.com Internet Source	

<1%

56	www.aussietreasurechest.com.au Internet Source	<1%
57	Ashok Kumar Singh, Zeeshan Ali Siddiqui, Siddharth Singh, Amit Kumar Singh, Tanveer J. Siddiqui. "Recent Advances in Computational Intelligence and Cyber Security - Proceedings of the International Conference on Computational Intelligence and Cyber Security (ICCICS-2023), November 07–09, 2023, Lucknow, India", CRC Press, 2024 Publication	<1%
58	Submitted to Nelson Mandela Metropolitan University Student Paper	<1%
59	Submitted to Southern New Hampshire University - Continuing Education Student Paper	<1%
60	Submitted to University of Surrey Student Paper	<1%
61	A M Viswa Bharathy, Dac-Nhuong Le, P. Karthikeyan. "Applications of Blockchain and Artificial Intelligence in Finance and Governance", CRC Press, 2024 Publication	<1%

coek.info

62	Internet Source	<1 %
63	core.vmware.com Internet Source	<1 %
64	ir.uitm.edu.my Internet Source	<1 %
65	marutitech.com Internet Source	<1 %
66	www.goodcall.com Internet Source	<1 %
67	www.tester.co.uk Internet Source	<1 %
68	Deepa Jose, Preethi Nanjundan, Sanchita Paul, Sachi Nandan Mohanty. "AI-Driven IoT Systems for Industry 4.0", CRC Press, 2024 Publication	<1 %
69	Submitted to Michigan Institute of Aviation And Technology Student Paper	<1 %
70	Theodoros Varzakas, Constantina Tzia. "Handbook of Food Processing, Two Volume Set", CRC Press, 2019 Publication	<1 %
71	Submitted to Virginia Polytechnic Institute and State University Student Paper	<1 %

72 Y. Danon, C. Lee, C. Mulligan, G. Vigilante. "Characterizing Tantalum Sputtered Coatings on Steel by Using Eddy Currents", IEEE Transactions on Magnetics, 2004 — <1 %
Publication

73 orca.cardiff.ac.uk — <1 %
Internet Source

74 research.ou.nl — <1 %
Internet Source

75 tud.qucosa.de — <1 %
Internet Source

76 www.israc.gov.il — <1 %
Internet Source

77 "Non-Destructive Evaluation of Corrosion and Corrosion-assisted Cracking", Wiley, 2019 — <1 %
Publication

78 Amal Adnan Ashour, Alaa Shafie. "Recent progress in cellulose derivatives and cellulose-based composites for bioimaging and anticancer applications (2020–2024)", Cellulose, 2024 — <1 %
Publication

79 Ataul Karim Patwary, Md Sazzad Hossain, Trishna G. Mistry, M. Omar Parvez. "Enhancing service adaptability: a moderated mediation model of workplace ostracism, — <1 %

robot anthropomorphism, employees' readiness to change, and performance efficacy", Journal of Hospitality and Tourism Technology, 2024
Publication

80	Submitted to Northwest Independent School District Student Paper	<1 %
81	Submitted to Singapore Polytechnic Student Paper	<1 %
82	Stefanuto, Bruno Matheu Moreira. "Development of an Open Access System for Remote Operation of Robotic Manipulators", Instituto Politecnico de Braganca (Portugal), 2024 Publication	<1 %
83	e-journal.unair.ac.id Internet Source	<1 %
84	www.gabormelli.com Internet Source	<1 %
85	Lu Zhang, Shangda Jia, Chong Qiao, Yongze Tang, Hongyu Li, Tonghao Zhang. "The volumetric ultrasound imaging strategy for quantification of the defects in concrete based on the optimized cumulative kurtosis method", NDT & E International, 2024 Publication	<1 %

86	wheon.com Internet Source	<1 %
87	www.archerssleepcentre.co.uk Internet Source	<1 %
88	www.e3s-conferences.org Internet Source	<1 %
89	50skyshades.com Internet Source	<1 %
90	Fei Hu. "UAV Swarm Networks - Models, Protocols, and Systems", CRC Press, 2020 Publication	<1 %
91	fdokumen.id Internet Source	<1 %
92	flatlogic.com Internet Source	<1 %
93	umpir.ump.edu.my Internet Source	<1 %
94	www.peoplegoal.com Internet Source	<1 %
95	www.techbriefs.com Internet Source	<1 %
96	"Analysis of a prestressed-concrete containment vessel exposed to high pressure	<1 %

and temperature", Czech Technical University in Prague - Central Library, 2024
Publication

97	A. N. Wilson, Khushi Anil Gupta, Balu Harshavardan Koduru, Abhinav Kumar, Ajit Jha, Linga Reddy Cenkeramaddi. "Recent Advances in Thermal Imaging and its Applications Using Machine Learning: A Review", IEEE Sensors Journal, 2023 Publication	<1 %
98	Ashwin Pajankar. "Chapter 1 Introduction to Single Board Computers and Raspberry Pi", Springer Science and Business Media LLC, 2017 Publication	<1 %
99	Dragorad A. Milovanovic, Zoran S. Bojkovic, Tulsi Pawan Fowdur. "Driving 5G Mobile Communications with Artificial Intelligence towards 6G", CRC Press, 2023 Publication	<1 %
100	Submitted to Institute of Research & Postgraduate Studies, Universiti Kuala Lumpur Student Paper	<1 %
101	Islam, Md. Zobaer. "Wireless Non-Contact Incoherent Light-Wave Sensing Systems: Applications, Prospects, and Challenges", Oklahoma State University, 2024	<1 %

Publication

102	Neeraj Anand Sharma, Rishal Ravikesh Chand, Zain Buksh, A. B. M. Shawkat Ali, Ambreen Hanif, Amin Beheshti. "Explainable AI Frameworks: Navigating the Present Challenges and Unveiling Innovative Applications", Algorithms, 2024 Publication	<1 %
103	Peter J. Shull. "Nondestructive Evaluation - Theory, Techniques, and Applications", CRC Press, 2019 Publication	<1 %
104	ceur-ws.org Internet Source	<1 %
105	dspace.lib.cranfield.ac.uk Internet Source	<1 %
106	gesci.org Internet Source	<1 %
107	mm.digikey.com Internet Source	<1 %
108	researchportal.northumbria.ac.uk Internet Source	<1 %
109	softradar.com Internet Source	<1 %
110	www.mida.gov.my Internet Source	<1 %

111	"NDT Info", Insight - Non-Destructive Testing and Condition Monitoring, 04/2008 Publication	<1 %
112	Deepika Ghai, Kirti Rawal, Kanav Dhir, Suman Lata Tripathi. "Artificial Intelligence Techniques for Sustainable Development", CRC Press, 2024 Publication	<1 %
113	Lavanya Sharma. "Towards Smart World - Homes to Cities Using Internet of Things", CRC Press, 2020 Publication	<1 %
114	Om Prakash Mahela, Baseem Khan, Puneet Kumar Jain. "Emerging Electrical and Computer Technologies for Smart Cities - Modelling, Solution Techniques and Applications", CRC Press, 2024 Publication	<1 %
115	Teles, Duarte Paulo Goncalves Cabral. "Data Protection with Ethereum Blockchain", Instituto Politecnico do Porto (Portugal) Publication	<1 %
116	Submitted to University of Warwick Student Paper	<1 %
117	aicontentfy.com Internet Source	<1 %
	digitalcommons.lsu.edu	

118	Internet Source	<1 %
119	eprints.usm.my Internet Source	<1 %
120	etheses.whiterose.ac.uk Internet Source	<1 %
121	www.hst-j.org Internet Source	<1 %
122	www.scielo.br Internet Source	<1 %
123	Danny Van Hemelrijck, Athanassios Anastassopoulos, Theodore Philippidis. "Emerging Technologies in NDT - Proceedings of the 2nd International Conference, Thessaloniki, Greece, 1999", CRC Press, 2022 Publication	<1 %
124	Kadhir Palani, Jothsna Kethar, Sarada Prasad, Virgel Torremocha. "Impact of AI and Generative AI in transforming Cybersecurity", Journal of Student Research, 2024 Publication	<1 %
125	Karim A.A. Mahmoud, Mohamed M. Badr, Noha A. Elmalhy, Ragi A. Hamdy, Shehab Ahmed, Ahmed A. Mordi. "Transfer learning by fine-tuning pre-trained convolutional neural network architectures for switchgear	<1 %

fault detection using thermal imaging",
Alexandria Engineering Journal, 2024

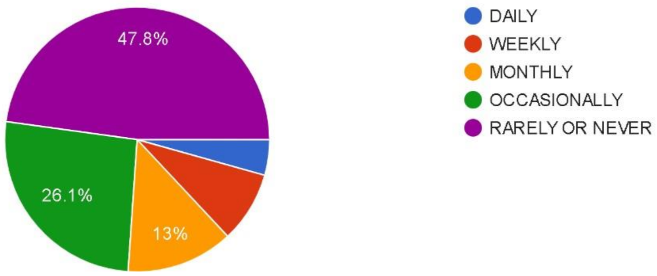
Publication

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		

APPENDIX C: POST SURVEY

HOW OFTEN DO YOU PERFORM NON-DESTRUCTIVE TESTING (NDT) AS PART OF YOUR WORK?

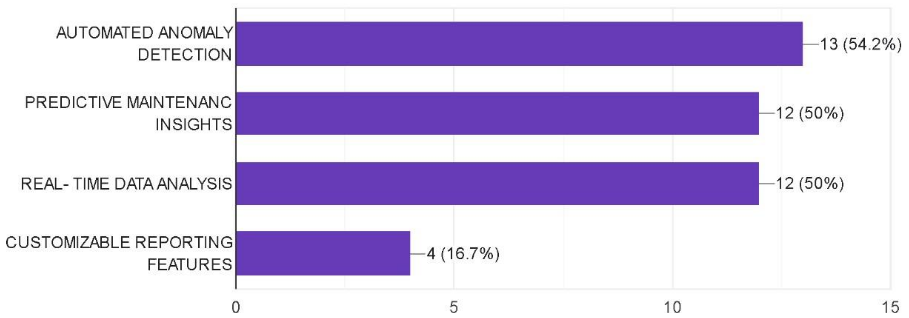
23 responses



\

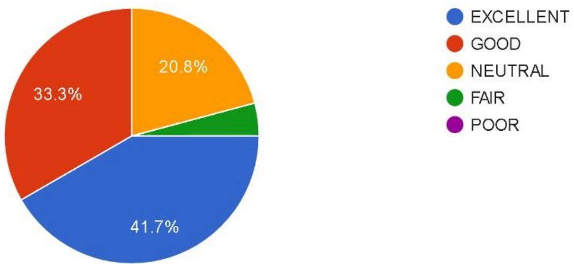
IN YOUR OPINION, WHICH OF THESE ARTIFICIAL INTELLIGENCE (AI) BASED FEATURES WOULD BE MOST USEFUL IN THERMOVISION PRO?

24 responses



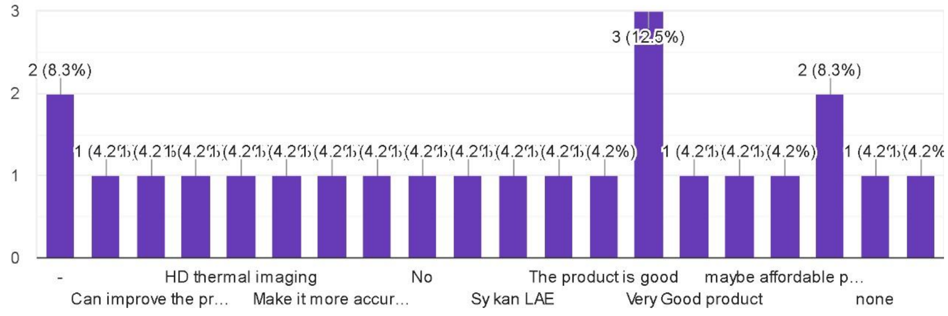
OVERALL, HOW YOU WOULD YOU RATE THE POTENTIAL OF THERMOVISION PRO TO MEET YOUR PROCESSWORK NEED IN NON-DESTRUCTIVE TESTING (NDT).

24 responses

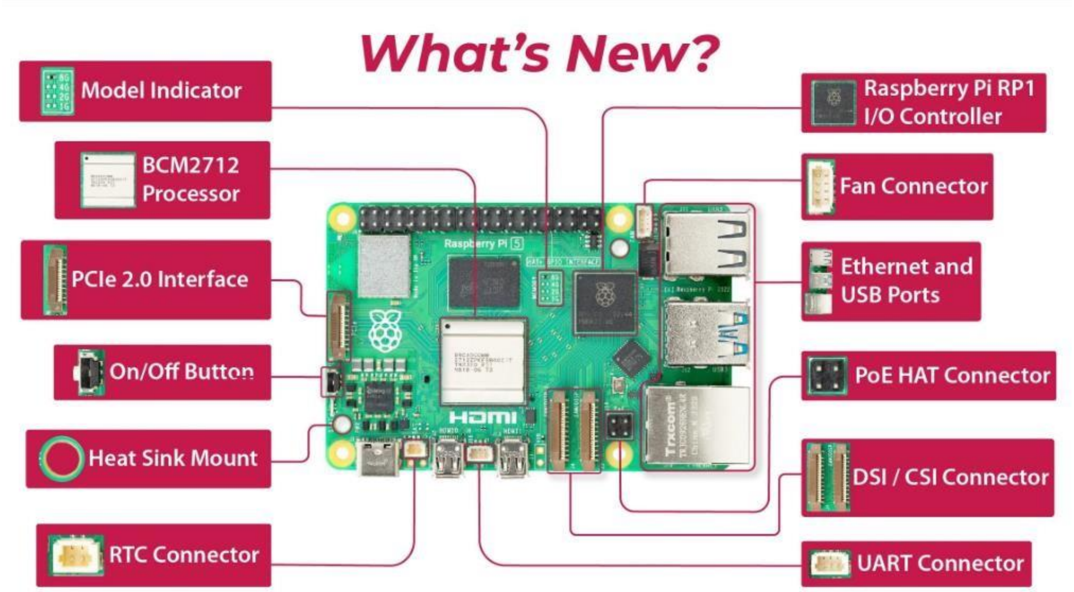


DO YOU HAVE ANY OPINIONS/ SUGGESTIONS/ RECOMMENDATION TO IMPROVES THERMOVISION PRO?

24 responses



APPENDIX D: RASPBERRY PI 5



Raspberry Pi is a single-board computer developed by the Raspberry Pi Foundation in the UK to promote the teaching of basic computer science in schools and developing countries. It has become a reliable microcomputer even beyond the education field, finding use in science, engineering, IT, and various industries, especially in conjunction with IR4.0.

Raspberry Pi boards function similarly to standard PCs but in a more compact form factor. They include essential components such as a CPU, GPU, RAM, HDMI, and USB ports, as well as wireless and wired connectivity options, camera interfaces, and a microSD slot. Additionally, they feature General Purpose Input /output (GPIO) pins, which allow for connection with other components, turning this single-board computer into the central processing unit for prototypes, systems, or even robots.