POLITEKNIK BANTING SELANGOR

ELECTRONIC CENTRALIZED AIRCRAFT MONITORING (ECAM) TRAINING KIT SYSTEM

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DEPARTMENT OF AIRCRAFT MAINTENANCE

SESSION: I 2024/2025

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

SUPERVISOR:

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REPORT ENDORSEMENT

This report is being submitted, reviewed, and endorsed to fulfill the conditions and requirements of report writing as specified.

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Date : 3rd December 2024

CERTIFICATION OF PROJECT ORIGINALITY & OWNERSHIP

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

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ABSTRACT

The ECAM Training Kit System was developed as an educational tool to simulate the display of Electronic Centralized Aircraft Monitoring (ECAM) pages, providing aircraft maintenance students with a realistic and practical learning experience. Designed as a simplified and cost-effective alternative to full-scale ECAM simulators, the system replicates the visual and functional layout of ECAM displays without incorporating real-time data processing. Using Python programming on a Raspberry Pi 5 platform, the system features a user-friendly graphical interface that allows students to navigate various ECAM pages, such as engine, hydraulic, fuel, and electrical systems, for familiarization purposes. The training kit generates pre-programmed static data and visual representations of system parameters to mimic the typical operation of an aircraft's monitoring system. This project aims to provide students with hands-on experience in understanding ECAM displays, interpreting system statuses, and navigating between different pages. The product output includes clear and accurate visual simulations of ECAM pages, designed to meet educational standards and enhance comprehension of aircraft systems. By focusing solely on display functionalities, the kit ensures accessibility and affordability while maintaining relevance to the training needs of aviation students. This project contributes significantly to aviation education by offering an interactive and portable training platform, bridging the gap between theoretical classroom instruction and practical system understanding.

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h	-	Hour
in	-	Inch
kg	-	Kilogram
mm	-	Millimeter
nt	-	Nit
p	-	Pixel

LIST OF ABBREVIATIONS

AC	-	Alternating Current
BITE	-	Built-In Test Equipment
CFDS	-	Centralized Fault Display System
E/WD	-	Engine/Warning Display
ECAM	-	Electronic Centralized Aircraft Monitoring
EFIS	-	Electronic Flight Instrument System
EICAS	-	Engine Indicating and Crew Alerting System
FYP	-	Final-Year Project
GUI	-	Graphical User Interface
IDE	-	Integrated Development Environment
LCD	-	Liquid Crystal Display
MCDU	-	Multipurpose Control and Display Unit
MTO	-	Maintenance Training Organization
ND	-	Navigation Display
OLED	-	Organic Light-Emitting Diode
PC	-	Personal Computer
PFD	-	Primary Flight Display
PVC	-	Polyvinyl Chloride
RMP	-	Radio Management Panel
SD	-	System Display
VSC	-	Visual Studio Code

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The usage of avionics in aircraft has been increasingly prevalent since World War I began. “Avionics” means aviation electronics used in the cockpit of small or large aircraft as they replace the traditional “six-pack” aircraft instruments and other indication systems. Like other systems used by Boeing, Dornier, or Saab, Airbus implements their avionic system called the Electronic Centralized Aircraft Monitoring (ECAM) that reduces pilots' workload. Airbus fly-by-wire technology aircraft have state-of-the-art cockpits to complement the necessary technological advancements made on Airbus aircraft. Due to its commonality philosophy, the avionics in Airbus cockpits make aircraft operations, training, and maintenance easier.

Avionics covers a variety of electronic systems and equipment in aviation such as the Primary Flight Display (PFD), Navigation Display (ND), Multipurpose Control and Display Unit (MCDU), Radio Management Panel (RMP), and Audio Control Panel. Each serves a specific function and works together to form a fully functional aircraft. These systems require little interaction from the pilots as they are fully automated and help pilots fly the aircraft easily.

Figure 1.1: Airbus A320 flight deck (Airbus, 2020)

Figure 1.1 shows the flight deck of an Airbus A320 consisting of advanced flight instruments installed. As further improvements and modifications are made for the convenience of both pilots and maintenance personnel, additional training programs are required to produce qualified and skilled personnel to maintain such aircraft.

The demand for highly trained mechanics in the aviation sector by 2023 has been an issue since the pandemic in 2019. However, the requirements to meet these demands may not be possible due to the complexities in the syllabus in training schools.

“There will be a massive demand for aircraft maintenance technicians and engineers over the next 15 to 20 years, but the risk of shortages is real.” (Christophe Ponnet, the Maintenance Training Operations Director for Airbus Customer Services, 2022)

1.2 PROBLEM STATEMENTS

A significant challenge for maintenance students and trainees is their inability to fully understand and grasp the complexities of ECAM systems. Given the technical nature of these systems, traditional classroom instructions, training notes, and lectures often fail to provide maintenance students and trainees with the hands-on experience and practical knowledge required to troubleshoot and maintain aircraft systems through an ECAM display effectively. As a result, this would be problematic due to the struggles of applying their theoretical knowledge in the field, leading to frustration and diminished confidence in their abilities.

Despite receiving classroom training in ECAM and aircraft avionics systems, students struggle to fully retain and understand complex information, leading to a lack of confidence and proficiency in these critical areas. This is causing unnecessary stress and frustration for students. To overcome this challenge, there is a need for an effective and comprehensive ECAM Training System that provides students with the opportunity to gain experience and practice their ECAM knowledge in a first-hand and interactive environment in the classroom. By addressing this critical issue, the project will improve the understanding and proficiency of students in the ECAM system, leading to increased reliability in future aviation maintenance.

1.3 PROJECT OBJECTIVES

1.3.1 General Project Objectives

1. To design a portable training kit system.
2. To demonstrate the compatibility of technology in education.
3. To reduce the cost of training equipment needed.
4. To improve the learning process in avionic subject classroom theory training.

1.3.2 Specific Individual Project Objectives

1.3.2.1 Product Structure

The specific objective of the product structure of the ECAM Training System Kit design is to develop a robust, portable, and functional framework that mimics the one-to-one configuration of the ECAM system in an Airbus A320 aircraft. That includes the main frame being made out of plywood to be durable and stable, and a Polyvinyl chloride (PVC) board for mounting things with key interactive components like the LCD and buttons. Material cutting and assembly precision are stressed to achieve ergonomic usability and realism, simulating the operational environment of an actual aircraft.

1.3.2.2 Product Mechanisms

The Airbus ECAM system is an advanced onboard diagnostic tool designed to monitor, process, and display crucial aircraft system data to pilots. The system integrates inputs from various sensors spread across critical components such as engines, hydraulics, electrical systems, and avionics. These inputs are processed by the ECAM's central computing unit, which compares the data against predefined safety parameters. If abnormalities are detected, the system prioritizes them based on severity, using a color-coded alert system (e.g., red for critical warnings, amber for cautions, and green for normal operations). The processed information is then displayed on two main cockpit screens: the Upper Display, which provides alerts and status messages, and the Lower Display, which shows detailed system diagrams and action steps. This structured design ensures that pilots receive clear, actionable information tailored to the flight's real-time needs.

A key feature of the ECAM is its ability to not only alert pilots to malfunctions but also guide them in resolving issues through procedural checklists displayed directly on-screen. For instance, in the event of an engine overheating, the system would detect the anomaly through its sensors, display a warning, and provide specific corrective actions, such as reducing engine thrust or shutting it down if necessary. By automating fault detection and providing immediate troubleshooting guidance, the ECAM significantly reduces pilot workload during high-stress situations. Additionally, its hierarchical alert prioritization helps maintain focus on the most critical tasks, enhancing overall safety and operational efficiency. Together, these mechanisms make the ECAM an indispensable tool in modern aviation.

1.3.2.3 Programming/Software

In the development of the ECAM Training Kit System, the specific objectives center around designing, implementing, and optimizing the software architecture to ensure seamless functionality and user interaction. Leveraging the capabilities of Raspberry Pi 5 as the primary hardware platform, the project aims to develop a robust and efficient control system using Python as the core programming language. This involves creating scripts to manage data processing and graphical user interface (GUI) functionalities that mimic real-world ECAM display pages. Utilizing Microsoft Visual Studio Code (VSC) as the integrated development environment (IDE) seeks to write, debug, and refine the code to achieve high levels of reliability. Additionally, the objective includes ensuring that the software is well-documented, modular, and scalable to allow for future enhancements, thereby contributing to the overall effectiveness of the training kit in providing practical and immersive learning experiences for end-users.

1.3.2.4 Accessories & Finishing

This project aims to furnish the ECAM Training Kit with appropriate and beneficial accessories to increase and improve its functionality. Besides that, it is also to finish the training kit with materials or coatings that can cover the outer to enhance the aesthetic of the design. Lastly, it is to design a training kit that can attract the users to use it and finish without affecting the functionality of the product.

1.4 PURPOSE OF PRODUCT

The ECAM Training System Kit was designed to fill a need for an affordable and practical aviation maintenance training tool, one that closely mirrors the Airbus A320 ECAM interface. This kit fills the gap between theory and practice and teaches students the skills of system navigation and understanding. It is designed to be economical and portable, to accommodate aviation schools and training facilities for the delivery of high-quality education without recourse to expensive simulators. The ECAM is designed to improve students' confidence and proficiencies to achieve a more realistic, interactive experience to help prepare them for real-world maintenance tasks. Moreover, the product facilitates innovation in aviation training to continue to meet an increasing need for skilled technicians while still maintaining a commitment to safety, efficiency, and operational readiness.

1.5 SCOPE OF PROJECT

1.5.1 General Project Scopes

Its practical and specific features are given priority in the scope of the ECAM Training System Kit as a general project. It is designed for use against non-heavy duty use and the product is not constructed to withstand any external force that might damage the product. Cadet pilots and Aircraft Maintenance Engineering students are the target users as it is a purpose of education. It replicates the Airbus A320 ECAM display panel on a one-to-one scale for authenticity. In addition, it combines complex applications of hardware and software to achieve maximum learning outcomes for aviation education, helping provide an effective training tool.

1.5.2 Specific Individual Scopes

1.5.2.1 Product Structure

The product structure for the ECAM Training System Kit has been scoped to create a realistic, one-to-one copy of the Airbus A320 ECAM system with a focus on functionality, durability, and portability. Structural stability is provided by plywood with PVC board for the LCD and buttons. The design process consists of the selection of appropriate materials, cutting to size, and assembly, followed by reinforcement to an ergonomic shape for training. It is also designed for easy transport and set up in a range of educational settings.

1.5.2.2 Product Mechanisms

In the context of a Training Kit System, the Airbus ECAM mechanism is a simulated version designed to replicate the core functionalities of the real aircraft system for educational purposes. The Training Kit System emulates the data flow by using virtual inputs that mimic the outputs of real aircraft sensors. These inputs represent operational parameters such as engine performance, hydraulic pressures, or electrical system states. Instead of physical sensors, the kit relies on programmed scenarios or user-defined inputs to simulate various operational and failure conditions. These inputs are processed by the system's central logic unit, which is designed to mimic the decision-making algorithms of the real ECAM system. The system categorizes scenarios into alerts, statuses, and normal operations using the same prioritization hierarchy—critical, cautionary, and informational.

The display mechanism in the Training Kit System mirrors the dual-screen layout of the actual ECAM, with an emphasis on user interaction and educational clarity. The Upper Display presents simulated warnings and corrective procedures, while the Lower Display visualizes simplified system diagrams and operational trends. Instructors or trainees can initiate specific fault scenarios to study how the system reacts, ensuring a hands-on understanding of how alerts are generated, prioritized, and addressed. The Training Kit System also includes a feature for step-by-step guidance through standard operating procedures, reinforcing the practical application of troubleshooting during simulated events. By replicating the core logic and interface of the real ECAM, the Training Kit System provides an accessible and safe environment for learning and mastering the principles of modern aircraft monitoring systems.

1.5.2.3 Software/Programming

The scope of the project involves the development and implementation of a software system that integrates seamlessly with the hardware components of the ECAM Training Kit System. The scope includes the utilization of the Raspberry Pi 5 as the central processing unit to manage inputs, outputs, and data flow within the system. The project encompasses the use of Python programming language to create and execute scripts that facilitate the simulation of ECAM functionalities. Microsoft VSC serves as the development environment for writing, debugging, and refining the software to ensure precision and reliability. Furthermore, the scope extends to designing a GUI that enables intuitive user interaction and accurately replicates ECAM system displays. Emphasis is placed on achieving a modular and scalable software structure, ensuring compatibility with future system upgrades while maintaining system stability and performance.

1.5.2.4 Accessories & Finishing

The ECAM Training System Kit's accessories and finishing phase are composed of phases involving quality, alignment, and functionality. It consists of making sure all the materials and equipment are required for the project and checking in an in depth way that components are fitted and aligned properly. A comprehensive test of the ECAM system is also performed, and clear and detailed user instructions are prepared to improve usability and understanding. This further steps in order to make sure the final product will be perfect, functional, and ready to use.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL LITERATURE REVIEW

2.1.1 Education Industry in Malaysia

As opposed to numerous non-formal and informal kinds of socialization, education refers to the discipline that is concerned with techniques of teaching and learning in schools or school-like situations. Lectures and students are typically associated with education. Nowadays, there are many kinds of learning methods. Since there had been no internet invention during the 1990s, students faced a lot of difficulty accessing information about their studies and were forced to rely solely on their books for information. Considering the development of education, those challenges now only affect people aged in the 1990s.

However, the internet and various educational resources readily accessible to us in today's world are useful in our line of endeavor.

Malaysia's aviation industry has experienced remarkable growth in recent years, offering various educational opportunities for individuals interested in pursuing a career in this field. In the aviation sector, education plays an essential role in preparing new learners for a career of excellence. The electronic Centralized Aircraft Monitoring System, ECAM, used on Airbus aircraft for monitoring and displaying engine and aircraft information, is one of the focus areas.

2.1.2 Types of Institutions That Provide ECAM Program

Depending on the institution offering training courses, duration of the study, level of certification, and resources available, the cost of the Basic ECAM System Training Program in Malaysia may differ. Based on the real-time information, some institutions in Malaysia provide ECAM System training programs.

Table 2.1: Institutions Offering ECAM Program

Institution	Description
Figure 2.1: Malaysia Aviation Academy (MAvA) logo (MAvA, 2008)	MAvA offers several training courses including ECAM, which is recognized worldwide as an educational institution. It is in Sepang, Selangor, providing a wide range of training on aviation topics.
Figure 2.2: Canadian Aviation Electronics (CAE) (CAE, 2023)	CAE Kuala Lumpur offers initial and recurrent training to airline pilots on Airbus and Boeing platforms, cabin crew and ground training, and engineering. They may also provide ECAM training programs.
Figure 2.3: Universiti Kuala Lumpur (UniKL) (UniKL, 2002)	UniKL MIAT is the nation's premier aviation training institution established in 1997. UniKL MIAT became the first Maintenance Training Organization (MTO) to be recognized by the Department of Civil Aviation and later by Frost and Sullivan as the Asia Pacific Aviation Workforce Development 2008. They offer various aviation training programs, and they also provide ECAM training as well.

2.1.3 Types of ECAM Configuration

When it comes to understanding electronic centralized aircraft monitoring systems, hands-on experience is of paramount importance. While theoretical knowledge and an overview of how ECAM systems work can be obtained from YouTube and other web resources, students have the opportunity to use that knowledge in real-life scenarios. In modern aircraft, various systems and statuses are monitored in real-time and displayed centrally through the ECAM system. Depending on the manufacturer and model of the aircraft, there are various ECAM configurations.

Providing real-time monitoring, alerting, and display of various aircraft systems, the Airbus ECAM system is a vital component of Airbus aircraft. Firstly, the Airbus ECAM Engine/Warning Display (E/WD) is one of the primary screens where pilots can access critical information related to engine status, warnings, cautions, and system synoptics. The E/WD displays information such as engine parameters, fuel system status, hydraulic system status, and other important engine-related data. Next, the ECAM System Display (SD) screen complements the E/WD by providing detailed system information, status messages, and synoptic diagrams of various aircraft systems. The SD screen allows pilots to keep an eye on the condition of various systems, including the electrical, pneumatic, flight control, and environmental control systems. Besides, pilots are notified of anomalous conditions or malfunctions in the system by the ECAM system through color-coded alerts. The three colors used to indicate the severity and urgency of an alert are warnings (red), cautions (amber), and advisories (blue).

Furthermore, to ensure continuous monitoring and display of vital aircraft information, Airbus ECAM was designed with redundancy and reliability in mind. The system is equipped with backup capabilities to maintain functionality in case of failures or malfunctions. Moreover, ECAM includes interactive system synoptic diagrams that allow pilots to visualize the status of different aircraft systems in a graphical format. These synoptics assist pilots in locating faults, isolating systems, and acting appropriately in response to the information presented. In addition, ECAM is integrated with electronic checklists that guide pilots through standard operating procedures and emergency responses. Based on the identified problem, the system prompts the relevant checklist, helping the flight crew to effectively handle unusual circumstances.

In summary, the Airbus ECAM configuration enhances situational awareness for pilots by consolidating essential information, alerts, and system status into a user-friendly display. This system plays a crucial role in helping flight crews manage aircraft systems efficiently and respond to abnormal situations during flight.

2.1.4 Evolution of Airbus ECAM

The evolution of Airbus ECAM has been a significant development in aircraft technology. ECAM is a system that monitors the various functions of an aircraft and disseminates vital information to flight crews. It gives real-time information on engine performance, aircraft systems, and other crucial parameters. In the 1980s, as part of the A320 family of aircraft, ECAM was first introduced by Airbus. Since then, it's been incorporated into all modern aircraft models of Airbus. To improve its functionality, the integration of advanced display technology is one of the key developments in ECAM's development.

Old Airbus ECAM systems, while groundbreaking at the time of their introduction in the 1980s, featured more basic text-based displays and limited monitoring capabilities compared to their modern counterparts. These initial systems introduced essential information to the flight crew, but they did not have advanced graphics. Representations and a full monitoring system that is now common in modern ECAM systems. But Airbus has developed more advanced display screens, which provide a complete and understandable visual representation of the aircraft's status as technology evolves and efficiency, the system has been continuously developed and improved over time.

The development of ECAM's monitoring capabilities is another important factor in its evolution. The system now monitors a wide range of aircraft systems, including engines, fuel systems, hydraulic systems, electrical systems, and more. This detailed monitoring enables the flight crew to spot and resolve any possible problems or abnormalities as quickly as possible so that safety and efficiency can be ensured. In addition, Airbus has been working on improving the user interface and ergonomics of ECAM for some time now. The aim is to provide pilots with a user-friendly interface that enables easy access to critical information and efficient decision-making. The development of the ECAM system has led to a more easily accessible and simplified interface, reduced workload for flight crew as well as improved real-time awareness.

In summary, the evolution of Airbus ECAM has been a continuous process aimed at improving the monitoring and display capabilities of the system. Through advancements in technology, the integration of advanced displays, expanded monitoring capabilities, and improved user interface, ECAM has become an essential tool for flight crews, ensuring the safe and efficient operation of Airbus aircraft.

2.2 SPECIFIC LITERATURE REVIEW

2.2.1 Product Structure

2.2.1.1 Basic Design of Main Structure

Acrylic

Utilizing acrylic as a structural framework for an ECAM training kit offers several advantages that enhance its effectiveness and durability. The transparency and lightweight nature of acrylic provides a clear and manageable foundation for the training kit, allowing trainees to easily view and understand the internal components and systems, thus improving the learning experience. Additionally, acrylic's durability, resistance to shattering, and ability to withstand frequent handling ensure that the structure can endure the interactive nature of ECAM training, resulting in a longer lifespan for the training kit and minimizing the need for frequent replacements. Acrylic also offers stability and rigidity to maintain the integrity of the training kit, ensuring that all components remain securely in place during simulations, and creating a safe and conducive learning environment. Lastly, the versatility of acrylic allows for a customized and optimized design of the ECAM training kit, as it can be easily cut, shaped, and configured to meet specific requirements, accommodating various components and features of the training kit. Whether supporting static models, providing a framework for electronic displays, or integrating various interactive elements, the adaptability of acrylic facilitates a tailored design that aligns with the educational objectives of the ECAM training program.

LCD screen

Utilizing Liquid Crystal Display (LCD) screens as a core component of an ECAM training kit offers several advantages that enhance the effectiveness and longevity of the educational tool. The high resolution and clarity of LCD screens provide detailed and accurate displays, essential for understanding complex ECAM systems. This visual precision allows trainees to interact with realistic simulations and data, improving their learning experience and retention of information. Additionally, LCD screens are durable and can withstand frequent use, making them well-suited for the interactive nature of training environments. Their longevity minimizes the need for frequent replacements, enhancing cost-effectiveness. Moreover, the versatility of LCD screens allows for dynamic content presentation, enabling trainers to easily update and customize training modules to meet specific educational objectives. This adaptability ensures that the training kit remains relevant and effective, accommodating advancements in ECAM technology and evolving training needs.

2.2.2 Product Mechanisms

Button/Switches

1) Tactile Button

Tactile button switches provide numerous advantages, including exceptional durability, with a longer lifespan than traditional switches, making them a cost-effective solution for businesses. These durable switches are also space-saving, allowing for more creative freedom in product design and facilitating compact product design without sacrificing functionality.

2) Rotary knob

A rotary knob acts as a switch in this ECAM Training kit, allowing users to change the brightness of the lower and upper panel displays.

Power Source

1) Alternating Current

The ECAM Training Kits uses alternating current to power it by connecting the power cable to the socket. The power source operates like a Personal Computer (PC), there is no battery and in the event of a power outage, the device will not work. However, Alternating Current (AC) is the preferred choice for a majority of applications since it is more generally compatible with current electrical systems and equipment.

2.2.3 Software/Programming

2.2.3.1 About Raspberry Pi Boards & Programming Languages

The literature review explores the evolution and versatility of Raspberry Pi boards and programming languages commonly used for embedded system development. Raspberry Pi boards, introduced by the Raspberry Pi Foundation, have undergone significant advancements since their inception, with various models catering to diverse computational needs. Earlier models, such as the Raspberry Pi 2 and 3, offered adequate performance for basic applications, while newer iterations, like the Raspberry Pi 4 and Raspberry Pi 5, feature enhanced processing power, expanded memory options, and improved connectivity, making them suitable for complex and resource-intensive projects. These advancements underscore the suitability of Raspberry Pi boards as cost-effective platforms for prototyping and developing embedded systems, including training kits like the ECAM system.

In terms of programming languages, Python remains a dominant choice for Raspberry Pi projects due to its simplicity, extensive libraries, and strong community support, enabling efficient hardware interaction and rapid development. Other languages, such as C++ and Java, are often employed for applications requiring greater control or performance, although they demand more technical expertise. For GUI development, Python's frameworks, such as Tkinter and PyQt, are frequently used due to their ease of integration with Raspberry Pi systems. This review highlights the flexibility of Raspberry Pi boards and the adaptability of programming languages, affirming their combined potential to support innovative projects in training and simulation environments.

2.2.4 Accessories & Finishing

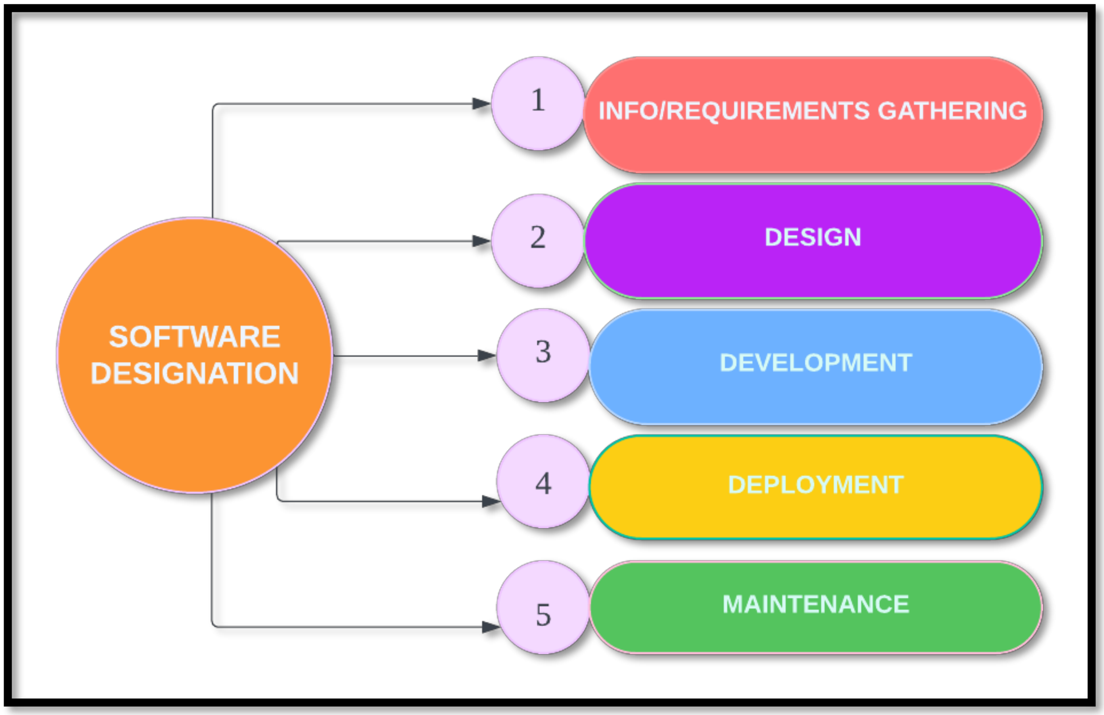


Figure 2.4: Software Designation Finishing

To be classified as software, several overviews need to be considered for the successful functioning of applications. Before assigning a software designation, we must get information about the applications we intend to create. Then, gather the information on the guidelines and technical requirements. In order to attract customers and users, it is therefore very important that designs are well designed in all applications. The purpose of design is to decide on the layout and construction of the system. From then on, the process of developing the apps involves understanding how to make them more user-friendly. The process of developing a system involves upgrading it or fixing bugs. Ensuring users can use the apps for additional learning is the next step in the deployment process. It is imperative to perform maintenance as errors may arise and difficulties must be resolved as necessary.

2.3 REVIEW OF RECENT RESEARCH / RELATED PRODUCTS

2.3.1 Related Patented Products

Table 2.2: Patent A product

2.3.1.1 Patent A	
Product	**Description**
 *Figure 2.5: Airbus MCDU Trainer (MCDU-100B) (ADF, 2020)*	The MCDU-100B is a training aid designed to help aircraft technicians understand how to perform tests and control aircraft systems. It allows students to print test results from a printer and understand the purpose of the Centralized Fault Display System (CFDS), which makes maintenance tasks easier by displaying fault messages in the system. The MCDU trainer is equipped with a laser printer and ADIRS panel and also comes with a plastic case for protection. It is also designed to help students learn about the BITE (Built-In Test Equipment) for each electronic system. Overall, the MCDU-100B is an effective training tool for aircraft technicians and students to learn about aircraft system testing and control.

Table 1.3: Patent B product

2.3.1.2 Patent B	
Product	**Description**
 *Figure 2.6: Avionic System Trainer (AV-100A) (ADF, 2020)*	This avionics trainer enables trainees to gain hands-on experience with original avionics equipment to develop practical skills and understanding in troubleshooting aircraft systems. The trainer is delivered plug and play and includes necessary equipment such as antennas, transmitters, receivers, wiring, and indicators. The design is tailored to customers' training needs, demonstrating a commitment to delivering customized and effective training solutions.

2.3.2 Recent Market Products

Table 2.4: Product A Recent Market

2.3.2.1 Product A	
Product	**Description**
 *Figure 2.7: Aircraft EFIS/EICAS Trainer (CBT-100D) (ADF, 2020)*	The Aircraft EFIS/EICAS Trainer (CBT-100D) is a highly functional and realistic flight simulator designed for aircraft maintenance training and demonstration. It includes essential flight, engine, and pitot-static instruments, creating a complete and immersive cockpit experience. This training set provides hands-on maintenance training while also functioning as a demonstration tool, allowing instructors to further enhance their lessons. The simulator demonstrates the principles of gyros, altimeters, and engine instruments, and can also be used to teach the removal and replacement of instruments.

Table 2.5: Product B Recent Market

2.3.2.2 Product B	
Product	**Description**
 *Figure 2.8: A320 Touch Screen Maintenance Trainer (ECA Group, 2015)*	The A320 Touch Screen Maintenance Trainer offers a way to train students in a cockpit-like setting without the stress involved. This modular training tool enables the use of inexpensive, adaptable Touch Screen technology to perform an entire airplane simulation.

2.4 COMPARISON BETWEEN RECENT RESEARCH AND CURRENT PROJECT

2.4.1 Patent A vs Product A vs Our Product

Table 2.6: Comparison Table 1

Items	Purpose	Target users	Focus	Content	Price	Portability
 **Airbus MCDU Trainer (MCDU-100B) (ADF, 2020)**	Provides hands-on training for the Airbus Multifunction Control Display Unit (MCDU) operations.	Flight crews, avionics students, and maintenance trainees	Emphasizes understanding and operation of MCDU, including navigation and flight management systems.	Covers MCDU interfaces, flight plan entries, navigation data, and system diagnostics.	Higher cost due to specific avionics focus and detailed simulation capabilities.	Compact and portable, designed for individual or classroom setups.
 **Aircraft EFIS/EICAS Trainer (CBT-100D) (ADF, 2020)**	Provides interactive training on EFIS (Electronic Flight Instrument System) and EICAS (Engine Indicating and Crew Alerting	Pilots, flight engineers, and maintenance personnel.	Focuses on avionics operation and crew alert management training.	Includes EFIS/EICAS system operations, crew procedures, and fault management scenarios.	Higher cost due to advanced simulation capabilities and broader focus.	Limited portability: typically, a stationary unit used in training labs.

	System).					
ECAM Training System Kit 	Designed for hands-on training to simulate Airbus A320 ECAM systems.	Aviation students, cadet pilots, and aircraft maintenance trainees.	Emphasizes practical understanding of ECAM system functions, components, and troubleshooting.	Includes basic ECAM display functionality, button interaction, and basic hardware simulations.	Low-cost and budget-friendly for educational institutions and training programs.	Lightweight, compact, and easily transportable due to plywood and PVC construction.

2.4.2 Patent B vs Product B vs Our Product

Table 2.7: Comparison Table 2

Items	Purpose	Target users	Focus	Content	Price	Portability
 **Avionic System Trainer (AV-100A) (ADF, 2020)**	Provides comprehensive training in avionics systems and their integration.	Avionics students, maintenance trainees, and technicians.	Covers multiple avionics systems, including navigation, communication, and autopilot systems.	Features modules on system diagnostics, integration, and fault isolation.	High cost due to advanced modules and integration capabilities.	Limited portability; designed for use in labs or stationary setups.
 **A320 Touch Screen Maintenance Trainer (ECA Group, 2015)**	Offers hands-on maintenance training with an interactive touch-screen interface for A320 systems.	Aircraft maintenance engineers, technicians, and aviation students.	Focuses on A320 aircraft systems, troubleshooting, and maintenance procedures.	Includes detailed A320 system components, fault scenarios, and maintenance workflows.	Expensive, reflecting its advanced technology and comprehensive training capabilities.	Stationary unit with limited portability due to integrated hardware and touch screens.
ECAM Training System Kit	Designed for hands-on training to	Aviation students, cadet pilots, and	Emphasizes practical understanding	Includes basic ECAM display functionality,	Low-cost and budget-friendly for educational	Lightweight, compact, and easily

	simulate Airbus A320 ECAM systems.	aircraft maintenance trainees.	of ECAM system functions, components, and troubleshooting.	button interaction, and basic hardware simulations.	institutions and training programs.	transportable due to plywood and PVC construction.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 PROJECT BRIEFING & RISK ASSESSMENT

3.1.1 Utilisation of Polytechnic's Facilities

Resources at the Polytechnic played an instrumental role in the successful development of the ECAM Training System Kit since it provided access to specialized tools, workshops, and modern equipment. Within the Aircraft Maintenance Department (JPP) Hangar itself, Engineering Workshop 1 (EW1) was used to treat and refine the plywood. Treatment and refinement meant measuring, cutting, and **enhancing** the material to exact specifications with tools such as steel rulers, hacksaws, files, and grinding machines. Using these tools, was a guarantee that the plywood was strong and matched the kit's structural design, thereby increasing the integrity and reliability of the structure.

Engineering Workshop 2 (EW2), also housed in the JPP Hangar, supported the assembling of PVC panels and electrical components. Measurement and cutting of the PVC panels had to be very precise using measuring tools such as steel rulers, L-shaped rulers, utility knives, and pliers. The workshop facilities were also needed for the wire cutting, an important process in creating the electrical connections assembly for the kit. This area enabled the very accurate and quality preparation of major materials needed for the functional interface of the ECAM system.

Additionally, the 3D Printing Laboratory in the Mechanical Engineering Department—JKM provided complicated technological support for the project. This laboratory allowed the designing and manufacturing of custom buttons specifically designed to suit the functional and aesthetic requirements of the kit. Using 3D modeling software coupled with precision printers, the buttons were produced to fit seamlessly into the overall system and ensure a professional look while being compatible with the interactive functions of the kit. The facilities allowed for the effective execution of the projects by availing all the resources necessary to complete each phase of the development process. Workshops in use for manual operations, amidst state-of-the-art 3D printing technology, ensured the ECAM Training System Kit was of high quality. The facilities also epitomized the importance of bringing together academic resources with practical, industry-related projects that encourage innovation and skill-building among the team.

3.2 OVERALL PROJECT GANTT CHART

Table 3.1: Project Overall Gantt Chart 1

SEMESTER 4		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Final-Year Project (FYP) Introduction	P															
	I															
Idea Discussion	P															
	I															
Project Discussion	P															
	I															
Assignment Task	P															
	I															
Pre-Proposal	P															
	I															
Chapter Write-Up	P															
	I															
Final Proposal	P															
	I															

Table 3.2: Project Overall Gantt Chart 2

SEMESTER 5		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Material Acquisition	**P**															
	I															
	P															
	I															
	P															
	I															
	P															
	I															
Product Construction & Presentations	**P**															
	I															
	P															
	I															
Aeromech & Thesis Write-up	**P**															
	I															

P = Planning

I = Implementation

3.3 PROJECT FLOW CHART

3.3.1 Overall Project Flow Chart

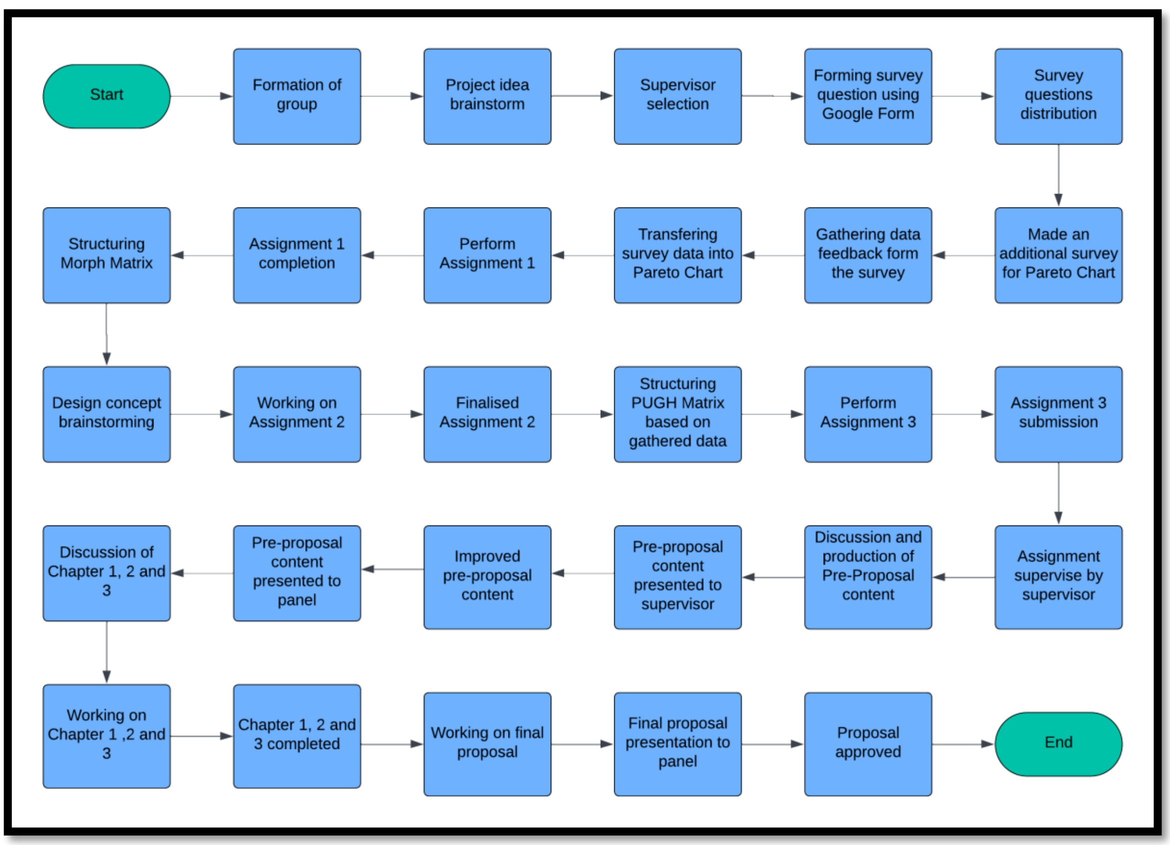


Figure 3.1: Group project flowchart.

3.3.2 Specific Project Design Flow/Framework

3.3.2.1 Product Structure

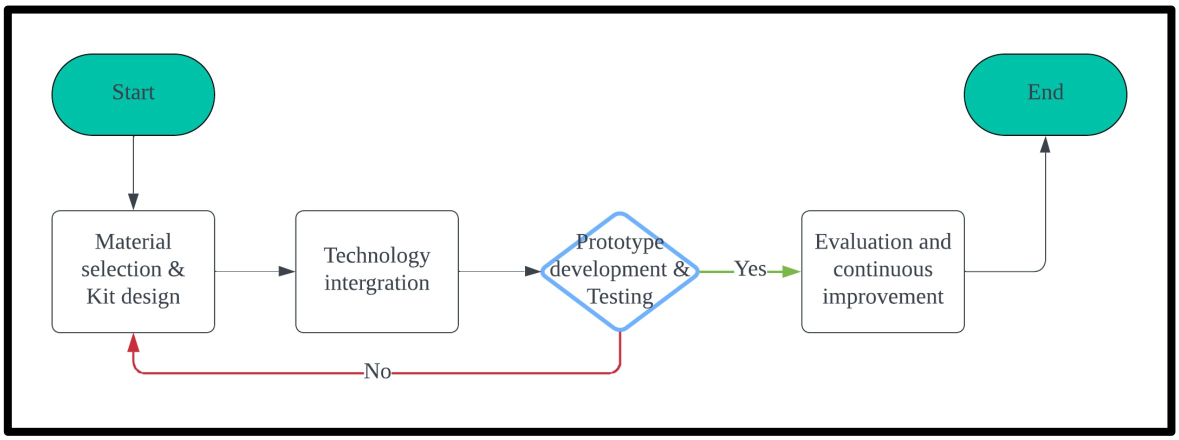


Figure 3.2: Product Structure Flowchart

3.3.2.2 Product Mechanisms

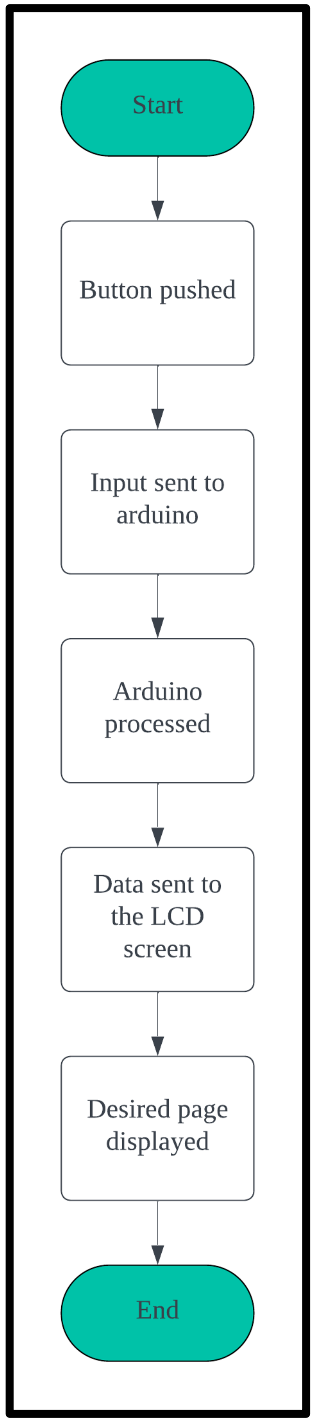


Figure 3.3: Product Mechanism Flowchart

3.3.2.3 Software / Programming

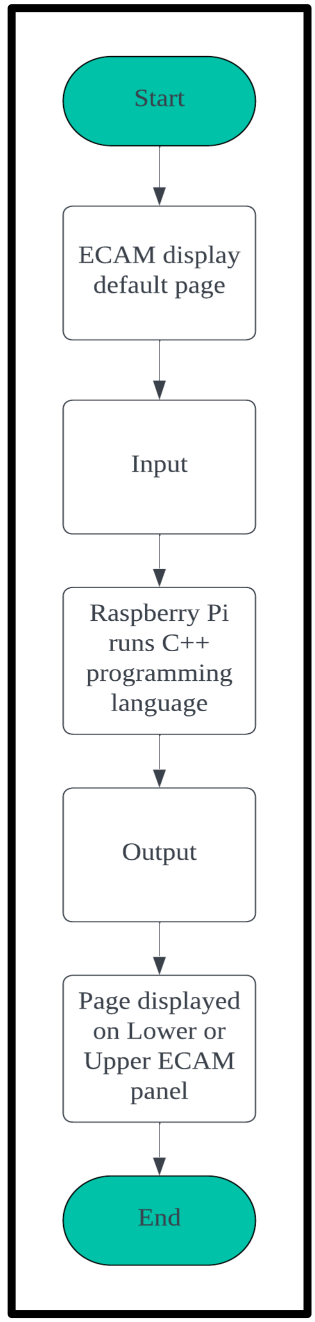


Figure 3.4: Software/Programming Framework

3.3.2.4 Accessories & Finishing

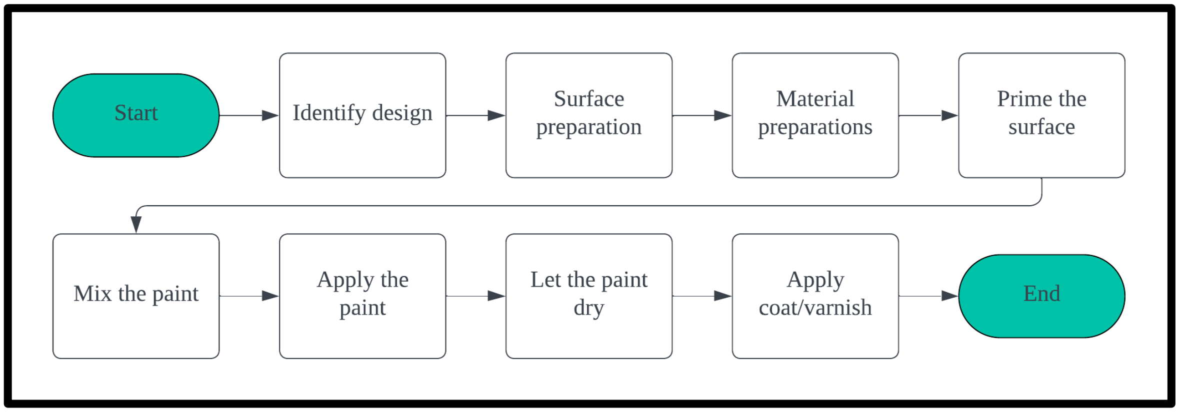


Figure 3.5: Accessories & Finishing Flowchart

3.4 DESIGN ENGINEERING TOOLS

3.4.1 Design Requirement Analysis

At the initial stages of our Final-Year Project (FYP), the first step was to create and conduct a survey questionnaire that could gather information from the target audience (maintenance students, trainees, and personnel) about their knowledge and understanding of ECAM and aircraft avionics systems. The questionnaire contains closed-ended questions to help gather quantitative data. The questionnaire was then sent out to a random sample of students in aviation training schools and institutions using Google Forms. It was distributed via social media platforms. Once data was collected, it was evaluated using statistical methods and relevant software such as Microsoft Excel to identify patterns and trends. The data was analyzed to determine the level of knowledge and understanding of ECAM among the target audience and to identify any specific areas where additional training and support were needed. After receiving satisfactory responses, the survey results were validated through a group discussion to ensure that the data collected was accurate and reliable.

3.4.1.1 Questionnaire Survey

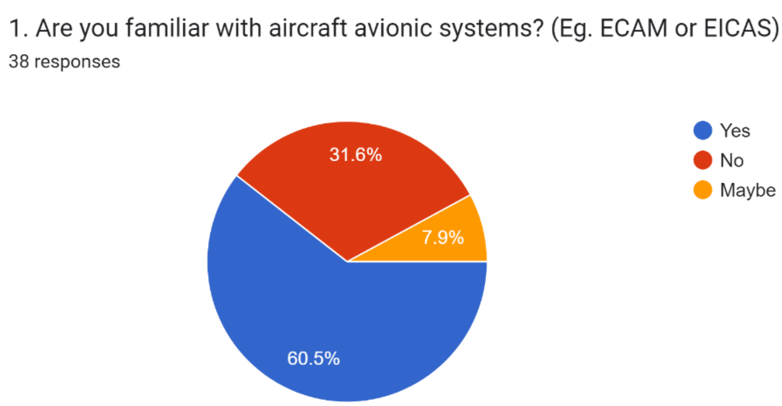


Figure 3.6: ECAM familiarity chart response.

1. Based on a small sample size of thirty-eight responses, in terms of the respondents' knowledge regarding aircraft avionics systems, 32.6% answered that they are not familiar with them, while 60.5% answered that they are familiar with them. The remaining 7.9% answered that they are somewhat familiar with them.

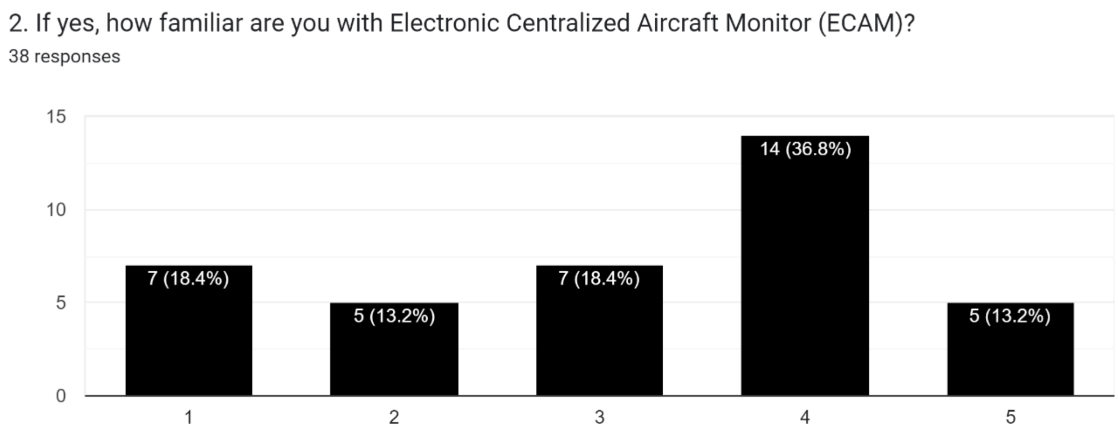


Figure 3.7: ECAM Familiarity graph.

2. From these proportions, we can see that the majority of respondents are somewhat familiar with ECAM (Level 4), with approximately one-third of respondents being very familiar (Level 5). On the other hand, more respondents are less familiar with ECAM (Levels 1 and 2), accounting for nearly half of the responses.

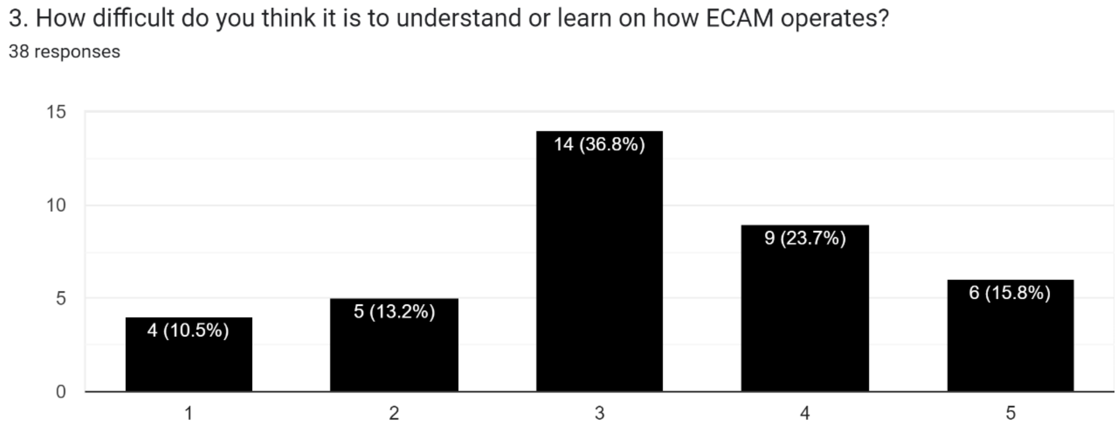


Figure 3.8: ECAM operation difficulty bar graph.

3. From these proportions, we can see that approximately one-third of respondents find ECAM to be somewhat difficult to operate (Level 3), with smaller proportions of respondents finding it to be very difficult (Level 4) or easy to operate (Level 5). On the other hand, more respondents find ECAM to be less difficult to operate (Levels 1 and 2), accounting for approximately 20% of the responses.

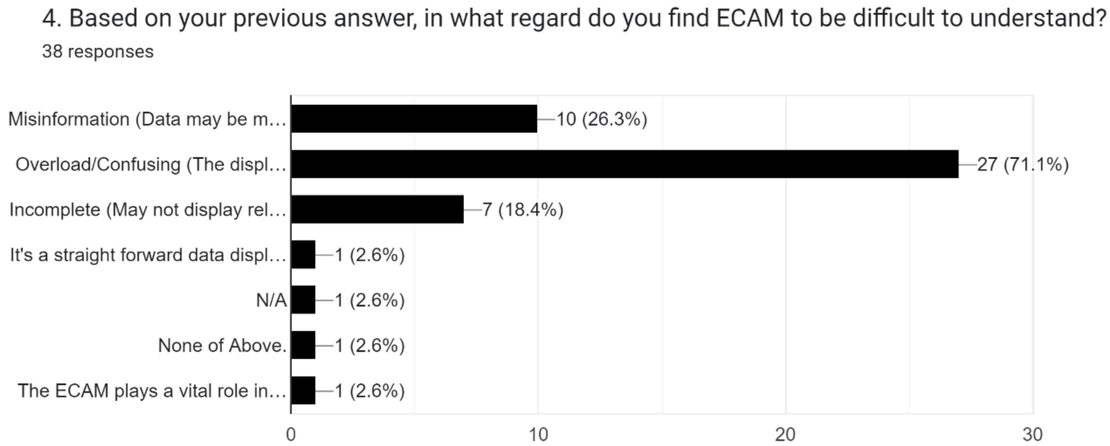


Figure 3.9: Difficulty aspects of ECAM bar graph

4. We can see that many respondents reported that ECAM can be confusing due to the display of too much information (Overload/Confusing), with about one-quarter of respondents reporting that ECAM can be misinterpreted due to misinformation (Misinformation) and a smaller proportion reporting that ECAM may not display relevant or complete information (Incomplete). There is also a small proportion of responses that do not fit into any of the listed categories (Other).

   An inference that can be made from the analysis of the given data is that most of the respondents find ECAM to be overloaded and confusing because of the display of too much information. This could be due to some possible factors such as the complexity of the information displayed, and the overwhelming display of information and data.

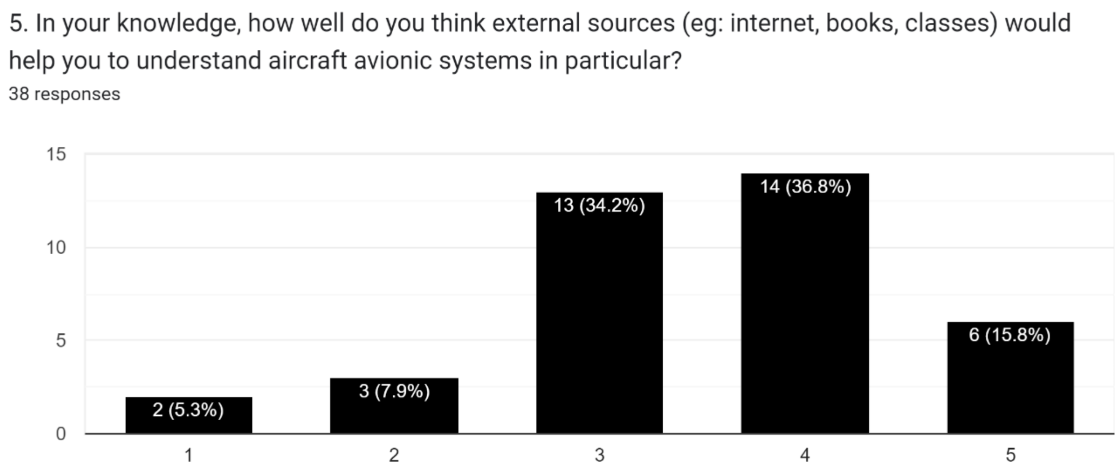


Figure 3.10: External sources helpfulness graph.

5. From these proportions, we can see that a small percentage of respondents (5.3%) do not think that external sources would help them to understand ECAM (Levels 1 and 2), while a majority of respondents (94.74%) think that external sources would either somewhat (Level 3), very much (Level 4) or completely (Level 5) help them understand ECAM. This indicates that most respondents believe that external sources, such as books, classes, and training, can help them learn how to operate ECAM.

   However, some respondents may not find external sources useful or may have different methods of learning that work best for them. It is essential to take individual learning preferences and needs into account when considering training and educational methods.

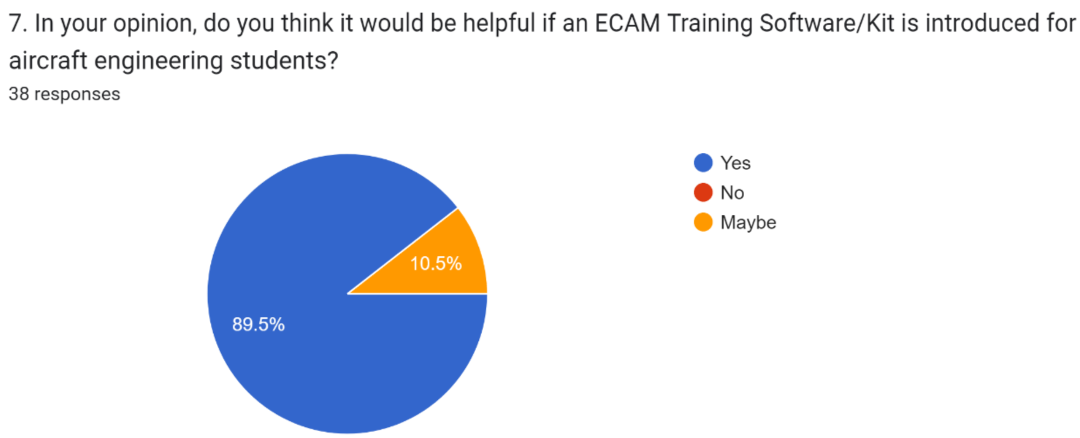


Figure 3.11: Helpfulness of project chart.

6. Based on the data provided, the respondents overwhelmingly agreed that an ECAM Training Kit would be helpful, with 34 out of 38 respondents answering "yes" and only 4 answering "maybe", indicating that an ECAM Training Kit System could be a valuable learning tool for users of the system.

   This suggests that there is a strong demand for training resources that can help users effectively understand and operate ECAM and that a well-designed training software and kit could be a valuable resource for users seeking to improve their skills and knowledge related to ECAM. It is important to consider the needs and preferences of users when designing training resources, as different learners may have different learning styles, levels of experience, and training needs.

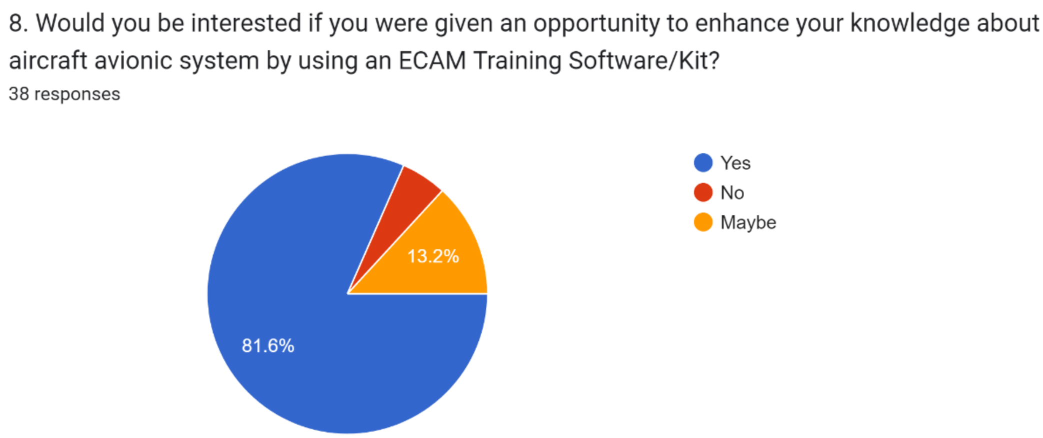


Figure 3.12: Knowledge enhancement interest chart.

7. Based on the data provided, an overwhelming majority of respondents (31 out of 38) expressed their interest in enhancing their knowledge of aircraft avionics systems by using an ECAM Training Kit System. This suggests that providing appropriate training resources such as the software can be beneficial to users who want to learn more about avionics systems.

   However, it is important to note that not all users may be interested in using such training resources and may prefer other methods of learning, such as classes or training programs. Therefore, when designing training resources for avionics systems, it is essential to consider the preferences and needs of users and provide a diverse range of learning options.

In the final section of the questionnaire, data was gathered on important aspects and features that will be required to develop the project.

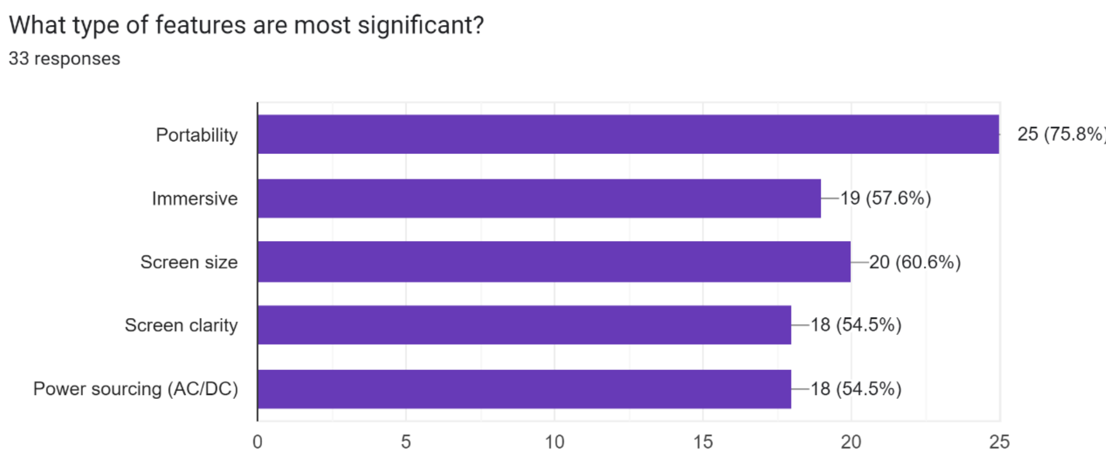


Figure 3.13: The project features a significance bar graph.

8. The data analysis based on the given respondent details suggests that portability, immersion, screen size, screen clarity, and power sourcing are all significant factors that respondents feel should be considered when developing an ECAM Training Software/Kit.

   For portability, 25 out of 33 respondents felt that portability is important, suggesting that users would prefer a training kit that can be easily transported and used on the go. For immersion, 19 out of 33 respondents thought immersive features were important, indicating that users would like the training software/kit to mimic the actual ECAM system as closely as possible. For screen size, 20 out of 33 respondents deemed screen size an important feature, suggesting that users would appreciate training software/kit with a sufficient display size to properly view the information presented. For screen clarity, 18 out of 33 respondents felt that screen clarity is important, indicating that users would want a training software/kit with high clarity and visibility for optimal learning. Lastly for power sourcing, 18 out of 33 respondents thought that power sourcing is important, suggesting that users would prefer a training software/kit that can be easily charged and used without the need for a constant power source.

3.4.1.2 Pareto Diagram

Table 3.3: Pareto Data

FEATURES	Frequency	Percentage	Cumulative %	Pareto Baseline%
Effectiveness	20	60.61%	61%	80%
Performance	9	27.27%	88%	80%
Strength	2	6.06%	94%	80%
Reliability	2	6.06%	100%	80%
Marketability	0	0.00%	100%	80%
TOTAL	**33**			

Based on the data collected and recorded in a table, the project will prioritize the effectiveness of the ECAM Training Kit System due to respondents' demands.

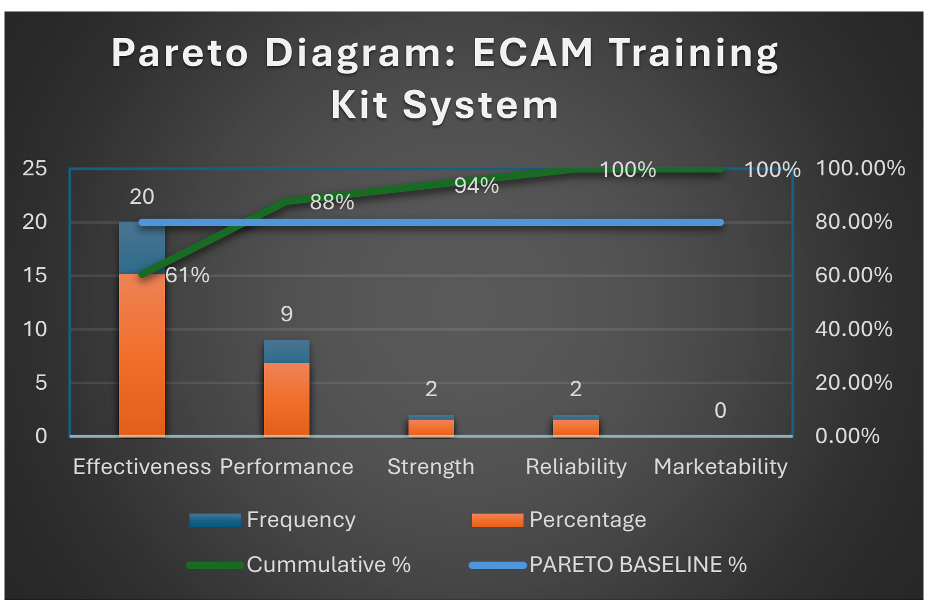


Figure 3.14: ECAM Training Kit System Pareto Diagram

3.4.2 Design Concept Generation

3.4.2.1 Function Tree

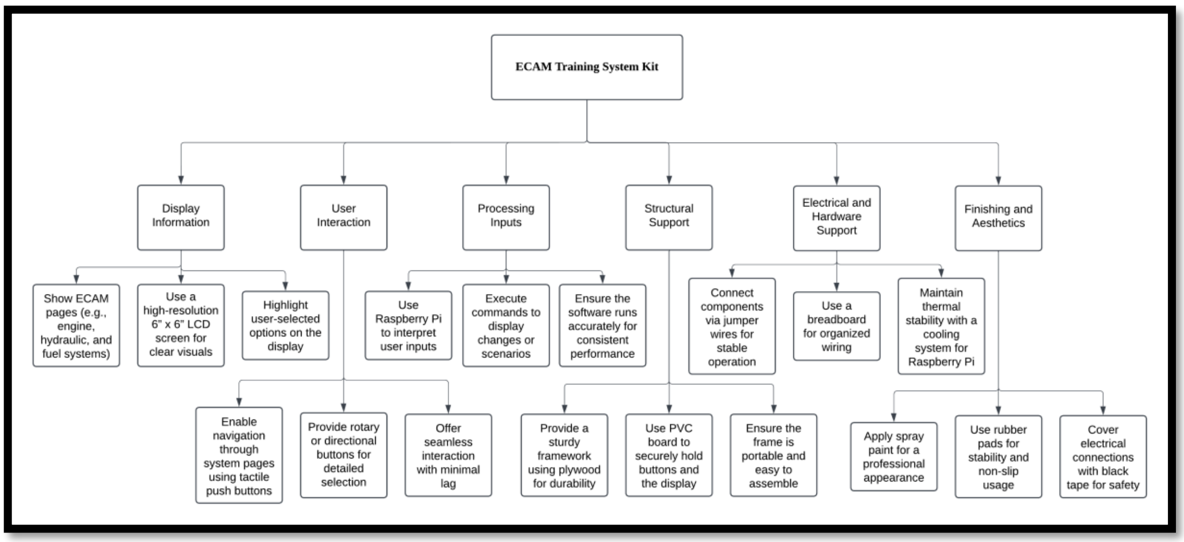
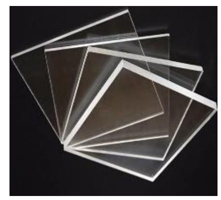
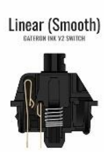


Figure 3.15: Function Tree

3.4.2.2 Morphological Matrix

Table 3.4: Morphological Matrix Table

FUNCTIONS	IDEA 1	IDEA 2	IDEA 3	IDEA 4
Material (Type)	Polypropylene plastic 	High-grade plastic 	Acrylic 	Stainless steel 
Program Language	C++/C#	Java	JavaScript	Python
Microprocessor	Arduino 	Esp 	Raspberry Pi 	Raspberry pi 
Component 1 (Screen type)	Liquid Crystal Display (LCD) Screen 	Backlight 	LCD Screen 	Organic LED (OLED) 
Component 2 (Mechanical switch type)	Linear switches 	Tactile switches 	Momentary Push Buttons 	Tactile switches 

3.4.2.3 Proposed Design Concept 1

Table 3.5: Concept 1 Design

FUNCTION	CONCEPT 1	JUSTIFICATION
Material (Type)	 Polypropylene plastic	• Lightweight • Durable • Inexpensive • Widely available
Program Language	C++/C#	• Wide range of programming capabilities • Easy hardware and software integration
Microprocessor	 Arduino	• Cost-effective • Reliable
Component 1 (Screen type)	 Liquid Crystal Display (LCD) Screen	• High-quality display • High-resolution images and text
Component 2 (Mechanical switch type)	 Linear switches	• Comfortable input method • Reliable input method

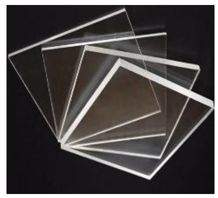
3.4.2.4 Proposed Design Concept 2

Table 3.6: Concept 2 Design

FUNCTION	CONCEPT	JUSTIFICATION
Material (Type)	High-grade plastic 	• Versatile • Chemical resistance • Strong and durable
Program Language	Java	Independent platform Its ability to move easily from one computer system to another
Microprocessor	Esp 	Highly efficient and low-cost microprocessor that is ideal for embedded applications
Component 1 (Screen type)	Backlight 	Improves image quality
Component 2 (Mechanical switch type)	 Tactile switches	A cost-effective solution. Traditional switches

3.4.2.5 Proposed Design Concept 3

Table 3.7: Concept 3 Design

FUNCTION	CONCEPT	JUSTIFICATION
Material (Type)	Acrylic 	It is a lightweight material that is easy to fabricate, durable, customizable to resemble cockpit panels, and affordable.
Program Language	JavaScript	It can run directly in web browsers without requiring users to install additional software.
Microprocessor	Raspberry Pi 	It's powerful enough to run realistic simulations and affordable.
Component 1 (Screen type)	 LCD Screen	good visibility, sharp image quality, and the ability to display detailed graphics and text.
Component 2 (Mechanical switch type)	Momentary Push Buttons 	standard size and shape, similar to those found on aircraft control panels.

3.4.2.6 Proposed Design Concept 4

Table 3.8: Concept 4 Design

FUNCTION	CONCEPT	JUSTIFICATION
Material (Type)	Stainless steel 	Corrosion-resistant, affordable, and long-lasting material.
Program Language	Python	Easy to use, straightforward, flexible, and intuitively readable.
Microprocessor	Raspberry Pi 	Small and affordable single-board computers that can carry out essential computing tasks.
Component 1 (Screen type)	Organic LED (OLED) Screen 	Uses light-emitting diodes and works without a backlight, provides better picture quality, consumes less power, and has almost perfect viewing angles.
Component 2 (Mechanical switch type)	 Tactile switches	Has a compact design, is reliable, and can withstand repeated use (durable).

3.4.2.7 Accepted vs. Discarded Solution

Accepted Solution: Concept 1

Reason:

1. Obtainable material
2. Affordable
3. User-friendly
4. Easy installation

Overall, after conducting thorough research and comparison among the 4 design concepts. We have selected Concept 1 as our final-year project design. However, polypropylene will be replaced with PVC board, which is a material not proposed in any design concept, Python programming language instead of C++, and Raspberry Pi 5 will replace Arduino as the microprocessor, LCD screen as the screen type, and linear switches as the mechanical switches are a solid design choice that offers a range of benefits that will make the device an effective and efficient solution for its intended purpose.

The materials and resources for the accepted solution are easily acquired and affordable in the market. In addition, the easy installation of the parts will provide a user-friendly way of building the project from scratch.

Discarded Solution: Concepts 2,3,4

Reason:

1. Unobtainable material
2. Expensive
3. Inconvenient

Apart from the accepted replacement material from design concept 3, other resources proposed from other concepts are costly, making the materials unobtainable. This is an inconvenience as the costs will be more than the expenditure budget.

3.4.3 Evaluation & Selection of Conceptual Design

3.4.3.1 Pugh Matrix

CONCEPT EVALUATION: CONCEPT 1 AS DATUM

Table 3.9: Pugh Matrix Concept 1 Datum

CHARACTERISTICS	FACTOR	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4
PORTABILITY	0.2	**D A T U M**	2	3	1
IMMERSION	0.2		3	1	2
POWER SOURCE	0.1		2	1	3
STRENGTH	0.1		3	2	1
RELIABILITY	0.1		1	2	1
PERFORMANCE	0.3		1	3	2
TOTAL SCORE	1.0		1.9	2.2	1.7
RANKING			2nd	1st	3rd

SCORE LEGEND: 3(+), 2(=), 1(-)

The table illustrates a concept evaluation using the Pugh matrix, with Concept 1 serving as the datum (baseline) for comparison against three other concepts based on key characteristics: portability, immersion, power source, strength, reliability, and performance. Weighted factors are applied to each characteristic, influencing the total score. Concept 3 achieved the highest score (2.2) and is ranked first, indicating its superior overall performance in meeting the evaluation criteria. Concept 2 follows with a score of 1.9, demonstrating strong performance but slightly lower than Concept 3.

Concept 4 ranks third with a score of 1.7, reflecting moderate alignment with the desired characteristics.

The rankings suggest that Concept 3 excels particularly in immersion and power source attributes, which likely contributed significantly to its top ranking. In contrast, Concept 4's weaker performance in portability and immersion may have led to its lower score. The analysis highlights the importance of balancing key characteristics with the assigned weights to ensure optimal concept selection.

CONCEPT EVALUATION: CONCEPT 3 AS DATUM

Table 3.10: Pugh Matrix Concept 3 Datum

CHARACTERISTICS	FACTOR	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4
PORTABILITY	0.2	3	2	DATUM	1
IMMERSION	0.2	3	3		2
POWER SOURCE	0.1	3	2		3
STRENGTH	0.1	1	3		1
RELIABILITY	0.1	2	1		1
PERFORMANCE	0.3	3	1		2
TOTAL SCORE	1.0	2.7	1.9		1.7
RANKING		1st	2nd		3rd

SCORE LEGEND: 3(+), 2(=), 1(-)

The table presents a Pugh matrix evaluation using Concept 3 as the datum (baseline) for comparison. Concept 1 emerges as the highest-performing alternative with a total score of 2.7, achieving first place in the ranking. This indicates that Concept 1 surpasses Concept 3 in most of the evaluated characteristics, particularly in portability, immersion, and performance. Concept 2 scores 1.9, placing second, while Concept 4 scores 1.7, ranking third.

Concept 1's superior performance is likely attributed to its ability to balance portability, immersion, and overall performance effectively. In contrast, Concept 4's lower score can be linked to its weaker evaluation in portability and immersion, which hold significant weight in the analysis. The comparison underscores the importance of aligning design priorities with the weighted factors to optimize concept selection and achieve the desired outcomes for the system.

CONCEPT EVALUATION: MARKET PRODUCT AS DATUM

Table 3.11: Pugh Matrix Market Product Datum

CHARACTERISTICS	FACTOR	EFIS/EICAS TRAINER	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4
PORTABILITY	0.2	D A T U M	3	2	3	1
IMMERSION	0.2		3	3	1	2
POWER SOURCE	0.1		3	2	1	3
STRENGTH	0.1		1	3	2	1
RELIABILITY	0.1		2	1	2	1
PERFORMANCE	0.3		3	1	3	2
TOTAL SCORE	1.0		2.7	1.9	2.2	1.7
RANKING			1st	3rd	2nd	4th

SCORE LEGEND: 3(+), 2(=), 1(-)

The table evaluates different concepts using the Pugh matrix, with the EFIS/EICAS Trainer serving as the datum (baseline). Concept 1 secures the highest total score of 2.7 and ranks first, demonstrating superior performance across key characteristics such as portability, immersion, and performance. Concept 3 follows in second place with a score of 2.2, while Concept 2 scores 2.0, placing third. Concept 4 ranks last with a score of 1.7, indicating the least alignment with the evaluated criteria.

Concept 1's strong ranking reflects its well-rounded balance across critical attributes, particularly its superior portability and immersion, which hold significant weighting in the evaluation. In contrast, Concept 4's weaker scores in portability and performance contributed to its lower ranking. This analysis highlights Concept 1 as the most viable option for addressing the market and technical requirements, showcasing its potential to outperform the baseline product in terms of overall effectiveness.

3.5 PRODUCT DRAWING/SCHEMATIC DIAGRAM

3.5.1 General Product Drawing

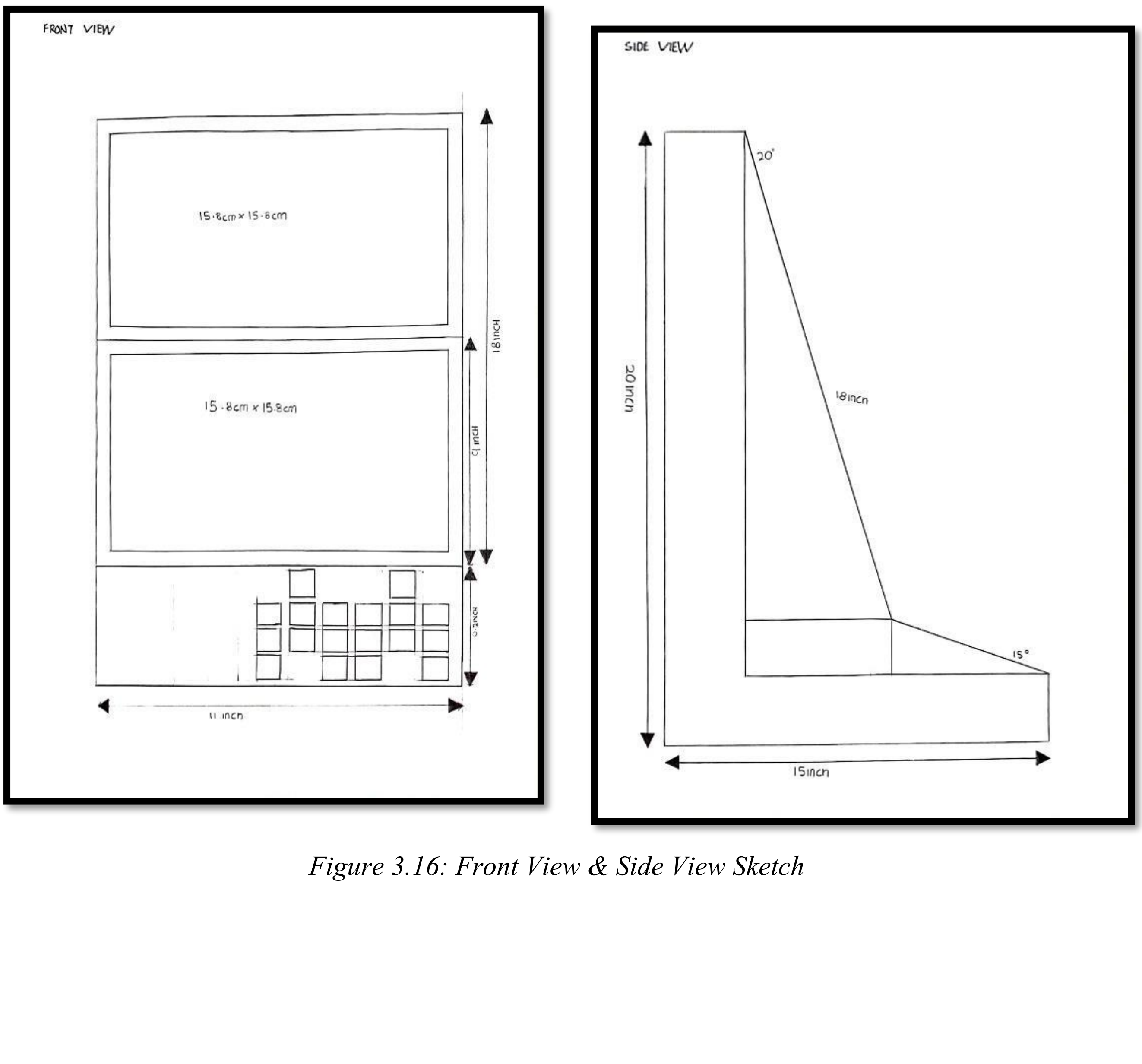


Figure 3.16: Front View & Side View Sketch

3.5.2 Specific Part Drawing / Diagram

3.5.2.1 Product Structure

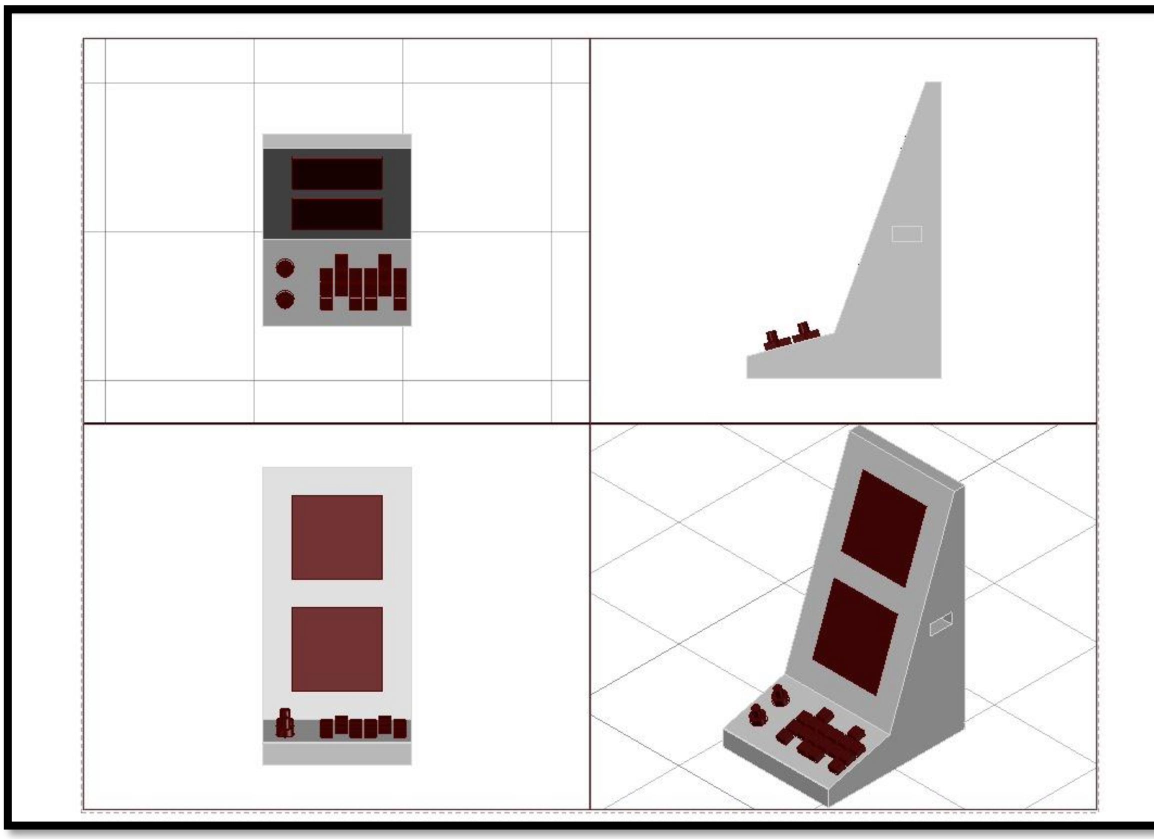


Figure 3.17: Orthographic View Product Drawing

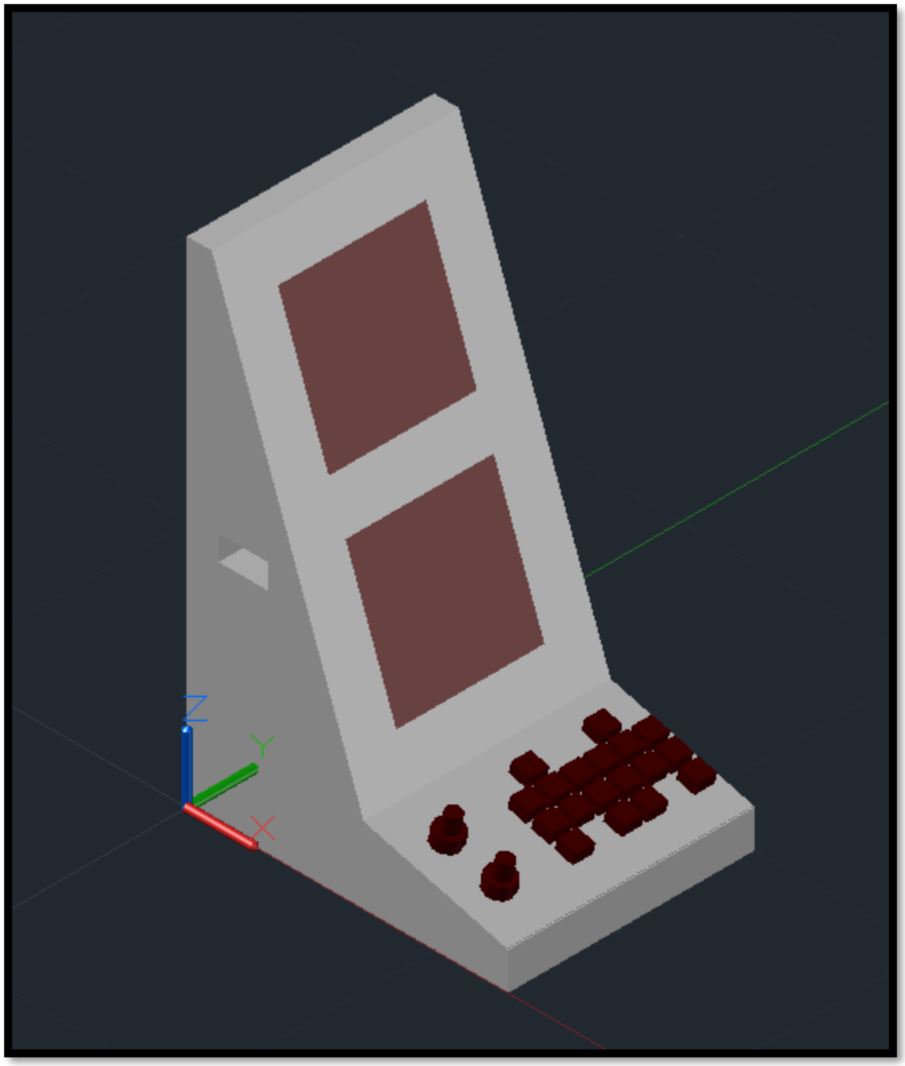


Figure 3.18: AutoCAD ECAM Product Structure

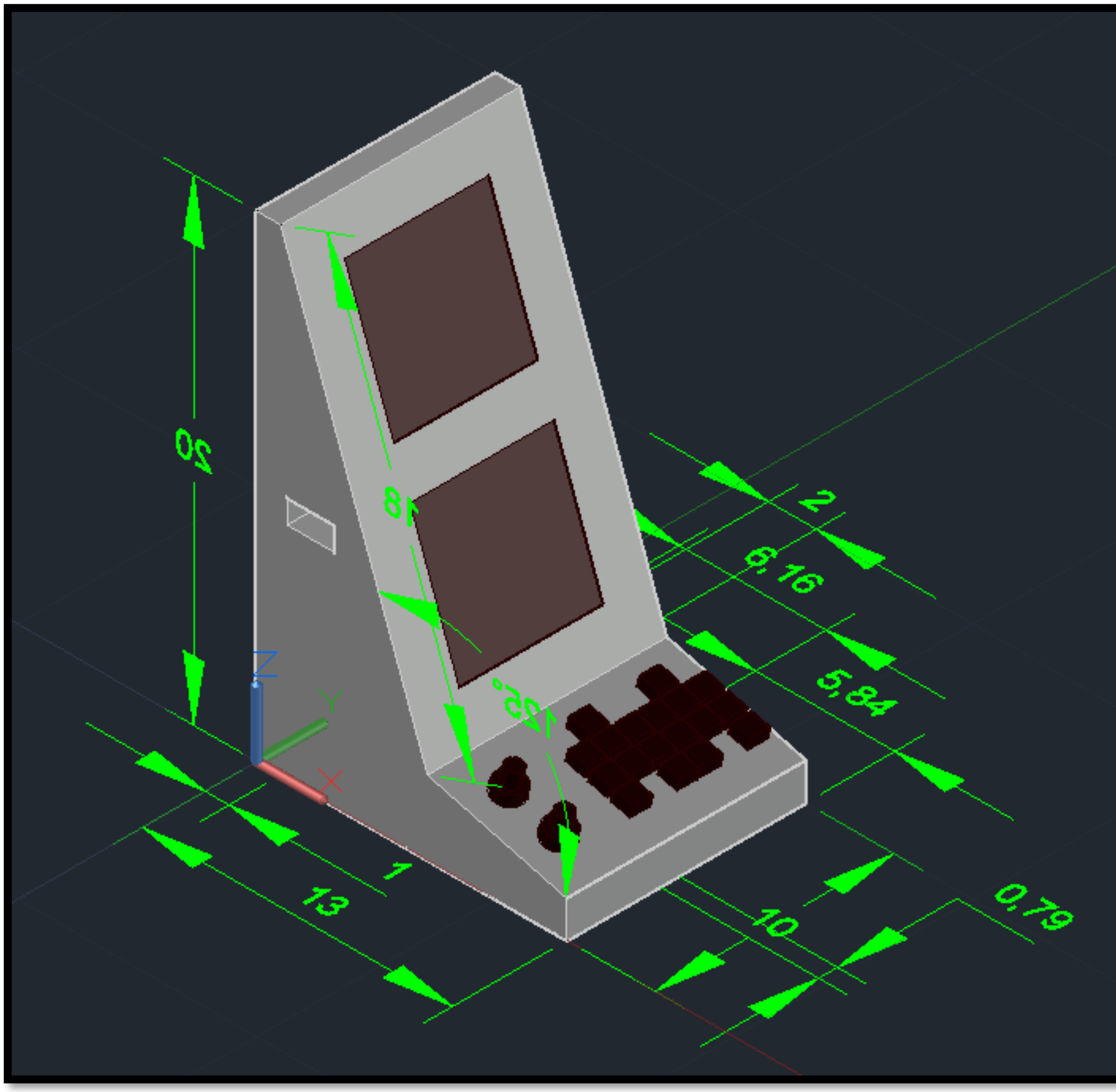


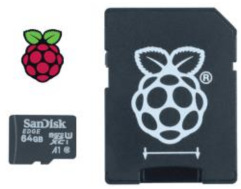
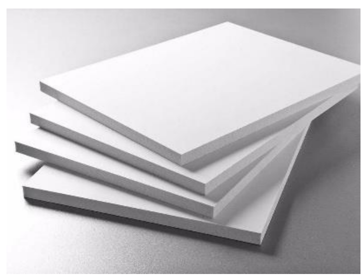
Figure 3.19: AutoCAD product dimensions.

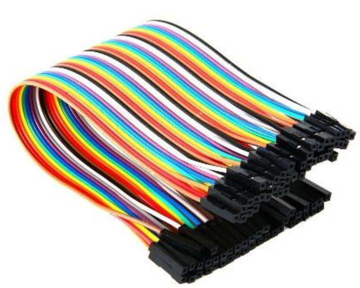
3.6 DEVELOPMENT OF PRODUCT

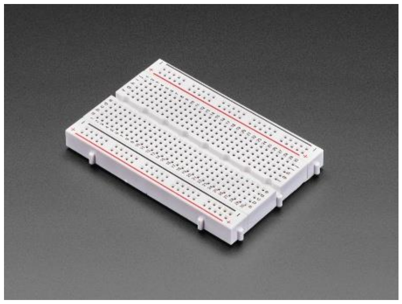
3.6.1 Material Acquisition

Table 3.12: List of Material Acquisition

No.	Materials	Quantity	Acquisition
1.	Raspberry Pi 5 Computer with 4GB RAM 	1	Cytron
2.	Raspberry Pi USB-C PD (Power Delivery) 27W PSU - UK - Black 	1	Cytron
3.	Micro-HDMI to Standard HDMI Cable 	1	Cytron

4.	64GB Micro SD Card Preloaded with Raspberry Pi OS 	1	Cytron
5.	PVC Board 	5	Shopee
6.	6” x 6” LCD Screen Panel 	2	Shopee
7.	Tactile push buttons 6x6 mm 	20	Shopee

8.	HDMI L-Shape 90 degree 	2	Shopee
9.	M-M Jumper Wire Cable 	1	Shopee
10.	M-F Jumper Wire Cable 	1	Shopee
11.	F-F Jumper Wire Cable 	1	Shopee

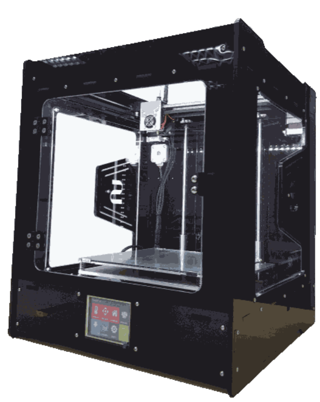
12.	Breadboard 	1	Shopee
13.	Cooler Raspberry Pi 5 	1	Shopee
14.	Rubber pad 	1	Mr DIY
15.	Hot glue stick 	1	Mr DIY

16.	Spray paint 	4	Kit Seng Hardware Trading
17.	Black electrical tape 	1	Kit Seng Hardware Trading
18.	Door hinge 	1	Kit Seng Hardware Trading
19.	Plywood 	1	Kit Seng Hardware Trading

3.6.2 Machines and Tools

Table 3.13: List of Machines and Tools Usage

No.	Machines & Tools	Quantity	Acquisition
1.	Steel rule 	2	Engineering Workshop 1
2.	L-shape ruler 	1	Engineering Workshop 2
3.	Files 	2	Engineering Workshop 1
4.	Cutter knife 	1	Engineering Workshop 2

5.	Cutter 	1	Engineering Workshop 2
6.	Plier 	1	Engineering Workshop 2
7.	Grinder 	1	Tools Crib
8.	3D Printing Machine 	1	3D Printing Lab

9.	Hot glue gun 	1	Mr. DIY

3.6.3 Specific Project Fabrication

3.6.3.1 Phase 1 (Base Structure)

Phase 1 involves fabricating the foundational structure of the ECAM Training System Kit in a precise manner and robustness. First, the plywood for the frame is cut to size, then measured and chopped, creating a stable and decent base for the process to take place. Once the tools such as steel rulers, hacksaws, and grinding machines are used, in preparation for mounting of LCD and the buttons, the PVC board is then prepared. Assembly with attention to alignment and stability takes place to support the base structure of all functional components well and a good deal of portability and ease of use.

3.6.3.2 Phase 2 (Accessories & Mechanisms)

The Airbus ECAM Training Kit System includes a range of accessories designed to replicate the essential functionalities of the actual aircraft system while providing an accessible learning platform. The simulated display panels, consisting of Upper and Lower screens, are key components that visually emulate the ECAM interface. These high-resolution monitors or touchscreens provide real-time alerts, system schematics, and procedural steps. Control input devices, such as keypads, switches, or touch-sensitive overlays, allow trainees to interact with the system, mimicking the controls available in the cockpit. Fault trigger tools enable instructors to introduce simulated failures, such as hydraulic or electrical faults, using toggle switches or software-based inputs. Complementing these are indicator lights and sound modules that replicate auditory and visual alerts, enhancing the sensory realism of the training experience. The computing hardware, such as a PC or microcontroller, acts as the system's brain, seamlessly integrating these accessories to deliver an interactive and immersive environment.

The mechanism of the Airbus ECAM Training Kit System mirrors the logic of the real aircraft system while simplifying operations for educational purposes. Predefined or instructor-activated fault scenarios are processed as virtual data inputs, simulating the behavior of onboard sensors in an actual aircraft. This data is evaluated by the central processing unit, which uses programmed algorithms to detect anomalies and categorize them by priority. Alerts, categorized as critical, cautionary, or informational, are dynamically generated and displayed on the Upper Display, while the Lower Display provides supplementary system diagrams and corrective procedures. The prioritization ensures critical faults are highlighted first, reflecting the real ECAM logic. The system also offers interactive troubleshooting guidance, allowing trainees to follow corrective steps in response to alerts. Additionally, built-in feedback mechanisms assess trainee responses, providing immediate evaluation and reinforcing learning outcomes. Together, this mechanism integrates simulation, feedback, and instructional features to effectively teach the principles of aircraft system monitoring.

3.6.3.3 Phase 3 (Finishing)

Table 3.14: Phase 3 Process

No	Process	Description
1.	 *Figure 3.20: Paint Coating Process*	Multiple layers of spray paint are used to apply the desired color to the panels, resulting in an improved texture and consistency of the finishing.
2.	 *Figure 3.21: Structure Assembly*	The mainframe is assembled and reinstalled with the painted panels to accomplish the product's main structure.
3.	 *Figure 3.22: Wire Installation Process*	The wires are installed and adjusted at the frame before the project is assembled.

3.7 PRODUCT TESTING / FUNCTIONALITY TESTS

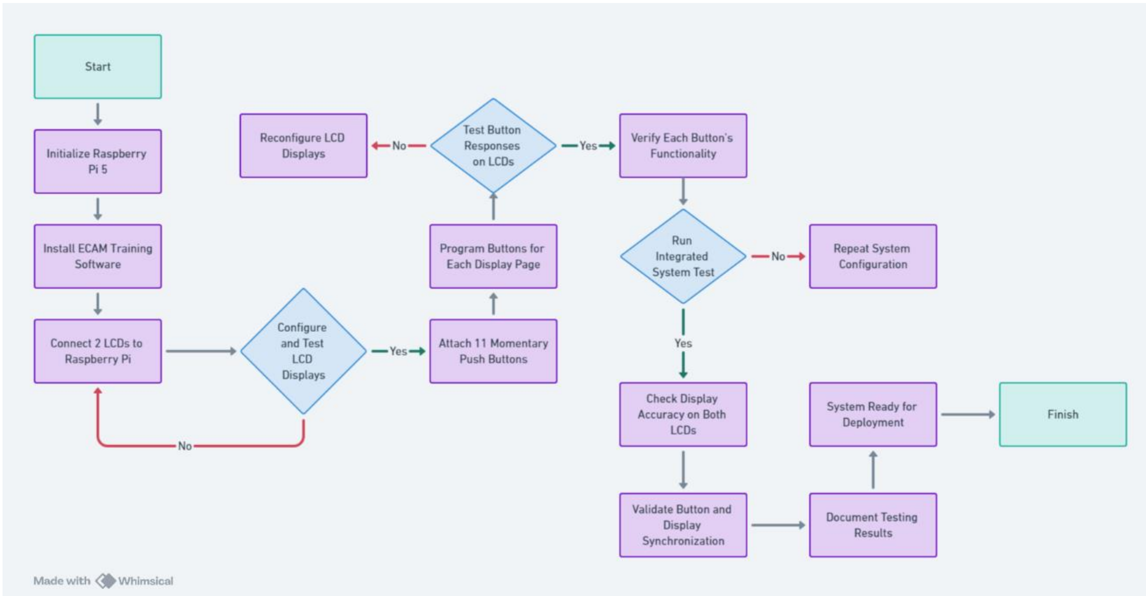


Figure 3.23: ECAM Training Kit System Functionality Test Flowchart

3.8 LIST OF MATERIALS & EXPECTED EXPENDITURES

Table 3.15: Budget Expenditures

3.8.1 Product Structure				
No.	**Item Details**	**Unit**	**Price/Unit**	**Total (RM)**
1.	**PVC Board**	**5**	**23.90**	**119.50**
2.	**Door hinge**	**2**	**0.60**	**1.20**
3.	**Plywood**	**1**	**15.00**	**15.00**
3.8.2 Product Mechanism				
No.	**Item Details**	**Unit**	**Price/Unit**	**Total (RM)**
1.	6” x 6” LCD Screen Panel	**2**	**117.69**	**235.38**
2.	Tactile push buttons 6x6 mm	**20**	**1.50**	**30.00**
3.	Raspberry Pi 5 Computer with 4GB RAM	**1**	**279.00**	**279.00**
4.	Cooler Raspberry Pi 5	**1**	**35.98**	**35.98**
5.	M-M Jumper Wire Cable	**1**	**3.39**	**3.39**
6.	M-F Jumper Wire Cable	**1**	**2.89**	**2.89**
7.	F-F Jumper Wire Cable	**1**	**2.49**	**2.49**
8.	Breadboard	**2**	**3.90**	**7.80**
3.8.3 Software / Programming				
No.	**Item Details**	**Unit**	**Price/Unit**	**Total (RM)**
1.	64GB Micro SD Card Preloaded with Raspberry Pi OS	**1**	**62.00**	**62.00**
3.8.4 Accessories & Finishing				
No.	**Item Details**	**Unit**	**Price/Unit**	**Total (RM)**
1.	Raspberry Pi USB-C PD (Power Delivery) 27W PSU UK - Black	**1**	**60.00**	**60.00**
2.	Micro-HDMI to Standard HDMI Cable	**2**	**15.00**	**30.00**
3.	HDMI L-Shape 90 degree	**2**	**1.90**	**3.80**
4.	Rubber pad	**1**	**2.00**	**2.00**

5.	Hot glue gun	**1**	**6.00**	**6.00**
6.	Hot glue stick	**1**	**2.00**	**2.00**
7.	Spray paint	**4**	**12.00**	**48.00**
8.	Black electrical tape	**1**	**1.50**	**1.50**
			GRAND TOTAL	**947.93**

CHAPTER 4

RESULT AND DISCUSSION

4.1 PRODUCT DESCRIPTION

4.1.1 General Product Features & Functionalities

Figure 4.1: ECAM Training System Kit

The ECAM Training System Kit provides a training device capable of simulating the essential functions of the Airbus ECAM system, affording aviation students hands-on experience in navigating and monitoring the system. It has a high-resolution LCD and user-friendly control buttons, powered by a Raspberry Pi. They will allow students to become familiar with navigating through the ECAM system pages and interacting with the display in much the same manner as they would in the actual aircraft. Its compact and portable design makes it ideal for classroom settings and an affordable solution for aviation schools and technical training centers.

4.1.2 Specific Part Features

4.1.2.1 Product Structure

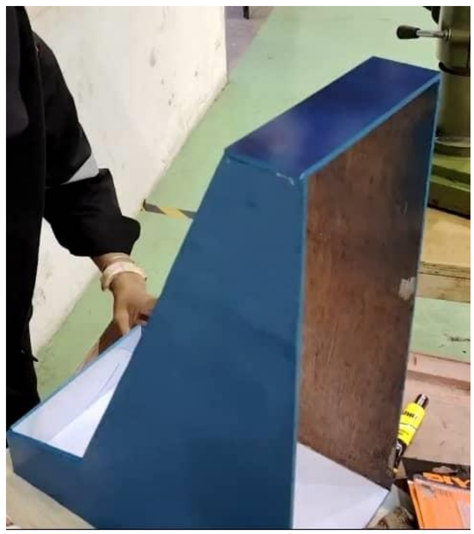


Figure 4.2: Combination of plywood and PVC board in structure

Plywood: It gives a strong and stable base for the kit to provide structure to many of the components like the LCD. Since plywood won't warp and can withstand continued use, plywood makes a great training tool for an item you use a lot.

PVC Board: The surface layer provides a smooth and clean finish, making the kit look better and easier to work with. Additionally, PVC is lightweight, and cutting or molding is easy.

4.1.2.2 Product Mechanisms

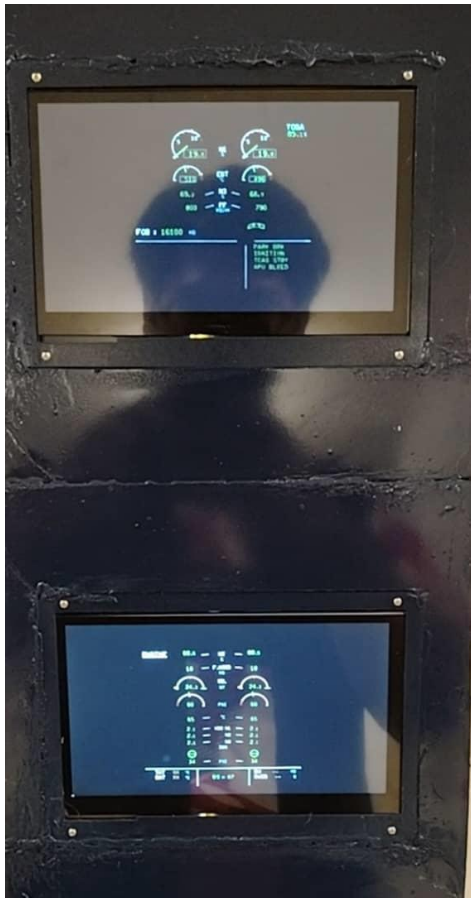


Figure 4.3: Upper and Lower ECAM display

ECAM Display Features

1. Engine/Warning Display (E/WD)

- Primary Function: Displays critical engine parameters and alert messages.
- Content:
    - Engine performance data (e.g., N1, N2, EGT).
    - Warning alerts for immediate crew action (Level 3 failures).

    - Caution alerts requiring attention (Level 2 failures).
- Colour Coding:
    - Red: Immediate action is required.
    - Amber: Attention needed but not immediate action.
    - Cyan: Indicates actions to be taken.

2. System Display (SD)

- Primary Function: Provides synoptic diagrams and status messages for various aircraft systems.
- Content: Displays up to 12 system pages, including:
    - ENG: Secondary engine parameters.
    - BLEED: Air bleed system status.
    - ELEC: Electrical power status.
    - FUEL: Fuel system information.
    - HYD: Hydraulic system status.
    - APU: Auxiliary Power Unit data.
    - Additional pages for air conditioning, doors, wheels, and flight controls.
- Status Page: Offers an operational summary after a failure has been displayed.

4.1.2.3 Software/Programming

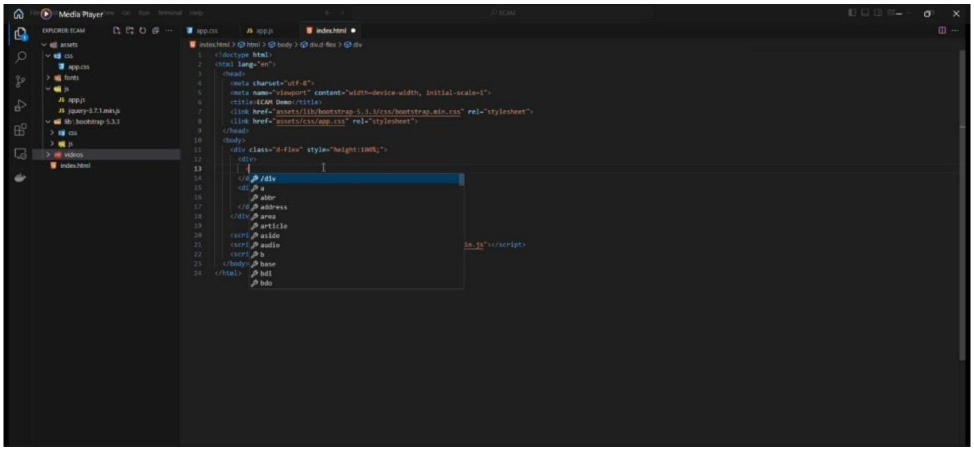


Figure 4.4: VSC Workspace running Python programming language

This section will delve into the specific software features integrated into the ECAM Training Kit, focusing on components developed using Python programming. Python's versatility and simplicity have allowed for efficient development and high adaptability, enhancing the kit's interactivity and functionality.

User Input Handling and Response

To provide an interactive experience, the ECAM Training Kit features Python code that responds to user inputs, such as button presses or touch-screen interactions. Input handling functions monitor user actions and trigger appropriate responses, such as changing display screens.

Data Processing

The ECAM Training Kit simulates data processing for various aircraft parameters. Raspberry Pi 5 processor's threading capabilities are employed to handle data streams, such as engine temperature, hydraulic pressure, and fuel levels. The system continuously processes these inputs, updating the display with live values, which closely resemble the real ECAM’s functionality.

4.1.2.4 Accessories & Finishing

The Electronic Centralized Aircraft Monitoring (ECAM) System Learning Kit is covered in blue spray paint as the outcome of the project. During the spray process, each part of the plywood and PVC board was sprayed separately before being assembled. Then, the structures are done according to planning and satisfaction. Besides that, the labels 'Upper ECAM Display', Lower ECAM Display', ECAM Control Panel', and the QR of theoretical notes information about ECAM were printed to ease the understanding and knowledge of students and users especially those who were not from the aviation background. By adding the QR code, users be able to scan and learn more about ECAM and refer to our project display as exact in the actual aircraft. Apart from that, the upper PVC board is separated at the back of the project and is used as a door with a hinge attached to the below PVC board. This allows trainers or students to troubleshoot or replace wires and accessories as needed without dismantling the entire kit.

4.1.3 General Operation of the Product

The ECAM Training System Kit operates by displaying standard ECAM system pages on an LCD screen to which students can interact with the control buttons. Users can move between various pages, for example, engine data or hydraulic systems, simulating the tasks of monitoring aircraft status from their RFE status page. It facilitates the practice of laying out and operating an ECAM interface, which resembles practical experience and provides support for theoretical learning.

4.1.4 Operation of the Specific Part of the Product

4.1.4.1 Product Structure

Plywood: The main structure of the kit, very durable and very stable, is plywood. This guarantees a kit that will stand up to frequent use in a training environment and is robust to handling and movement within sessions.

PVC Board: The LCD and buttons are held securely by the PVC board. This arrangement is a smooth and professional interface for the users to interact with the display and switch the controls without losing the structural integrity of the kit.

4.1.4.2 Product Mechanisms

Table 4.1: System Pages Operation

Button	System Page	Description
1	ENG	Displays secondary engine parameters, including oil pressure, fuel flow, and vibration indications for both engines.
2	BLEED	Shows the status of the bleed air system, including valve positions, temperatures, and pressures for engine and APU bleed air.
3	CAB PRESS	Provides information on cabin pressurization status, including altitude, differential pressure, and cabin altitude alerts.
4	ELEC	Displays electrical system status, including battery voltage, generator output, bus voltages, and power distribution.
5	HYD	Shows hydraulic system pressures, reservoir levels, and operational status of hydraulic components (e.g., pumps and accumulators).
6	FUEL	Provides details on fuel quantities in each tank, fuel distribution, consumption rates, and any fuel system faults.
7	APU	Displays the operational status of the Auxiliary Power Unit (APU), including temperature, RPM, and available bleed air.
8	COND	Shows the status of the air conditioning system, including temperature settings, airflow control, and environmental conditions in the cabin.
9	DOOR/OXY	Displays the status of cabin doors (open/closed) and oxygen systems (availability and pressure levels).
10	WHEEL	Provides information on landing gear status (up/down), braking system information, and ground spoiler deployment.
11	F/CTL	Displays information about flight control surfaces (elevator, ailerons,

		rudder) and their positions as well as any associated faults.
12	STATUS	Shows an overview of the aircraft's operational status after a failure has been displayed or acknowledged; provides summary information about systems in normal operation or degraded modes.

4.1.4.3 Software/Programming

The operation of the software components in the ECAM Training Kit System, designed using Python, plays a vital role in simulating aircraft monitoring and diagnostics for training purposes. This section provides a detailed description of how each software module operates to ensure an interactive, realistic, and efficient learning experience for students.

STARTING THE ECAM SYSTEM SIMULATION

The ECAM Training Kit system initializes with a Python script that loads the graphical user interface (GUI) and establishes necessary data connections for real-time simulation. Upon launching, the main display mimics an aircraft ECAM interface, presenting students with core data fields and system status indicators. The GUI, built using Python libraries such as tkinter or PyQt, is designed to be intuitive, allowing students to engage with the simulated environment immediately.

INTERACTING WITH SYSTEM DISPLAYS

The ECAM system features various display modes to allow students to inspect different aspects of the aircraft's simulated systems (e.g., engines, electrical, hydraulics). Using Python's event-handling capabilities, the software responds to user inputs, such as button presses or touchscreen commands. When a trainee selects a system view, the display updates to show relevant data. This operation is fundamental for training students on how to navigate through an aircraft's monitoring system efficiently.

RESETTING AND EXITING THE SYSTEM

At the end of each session, trainees have the option to reset the ECAM system to its initial state. Exiting the system is managed with a straightforward command that safely closes all processes. This functionality makes the ECAM Training Kit system efficient for repeated use in educational settings.

4.1.4.4 Accessories & Finishing

The finishing of the ECAM System Learning Kit uses several materials and equipment to meet the required project specifications. Firstly, the plywood functions as the main body structure as it is durable and very stable, which guarantees the kit will be able to be used in a training environment, with potable movement. Then, the PVC board functions to hold the LCD displays and buttons. This arrangement is a smooth and professional interface for the users to interact with the display and switch the controls without losing the structural integrity of the kit.

To elevate the visual appeal, spray paint has been applied to the structure, giving it a professional, polished finish. This not only improves aesthetics but also adds a protective layer, increasing the surface's resilience.

Finally, a hot glue gun is used to attach and secure all components, particularly the plywood and the PVC board structure, including the operational button on the control panel. This solution not only enhances the quick bonding time and versatility but also reduces the minimal mess at every side of the kit as it solidifies quickly and is easy to control, ensuring the kit maintains its integrity and withstands repeated use while offering both functional and aesthetic value.

4.2 PRODUCT OUTPUT ANALYSIS

Table 4.2: Product Output Analysis

No.	Parameters	Results	Remarks/Descriptions	Analysis
1.0	**Display Performance**			
1.1	**Display Clarity (Resolution)**	1080p	Provides high-definition visuals to simulate aircraft displays	Ensures that students can read system status and diagnostic data.
1.2	**Display Brightness**	300 nits	The maximum brightness level of the display screen.	Sufficient for indoor training environments.
2.0	**System Functions**			
2.1	**Display Simulation Accuracy**	90%	Accuracy in simulating messages is typically shown on actual ECAM systems.	A high accuracy rate provides realistic training, helping students familiarize themselves with common displays.
2.2	**Response to User Input**	Immedia te	Time taken for the system to respond to user actions (e.g. pressing buttons).	An immediate response ensures a seamless user experience, replicating real ECAM interaction.
3.0	**System Session Specification**			
3.1	**Max Operation Time**	2 h	Maximum operational time per session before reset or CPU overheat.	Sufficient time for a complete class session.
4.0	**Physical Specifications**			
4.1	**Weight**	1.5 kg	Total weight of the ECAM Training Kit System.	Lightweight and portable, making it easy to set up and transport between training locations.
4.2	**Dimensions**	20 in x15 in x8.5 in	Physical dimensions of the training kit.	The compact design fits so well on desks.
5.0	**Power Specifications**			
5.1	**Power Requirement**	27 W	Electrical power is needed to operate the system.	Low power requirement makes it cost-effective and easy to use in various locations with standard power outlets.

4.3 ANALYSIS OF PROBLEM ENCOUNTERED & SOLUTIONS

4.3.1 Product Structure

Plywood Hardness and Paint Adhesion:

- Problem: It was difficult to cut the plywood used for the main structure accurately, due to its hardness, making precise adjustments virtually impossible. Also, when spray painting and some types specifically, did not stick well to the plywood surface, the finish was uneven.

- Solution: To address this, specialized wood-cutting tools were employed to provide cutting precision. Regarding the paint issue, a form of spray paint specially designed for wood adhered well and finished smoother and harder.

PVC Board Fragility:

- Problem: In certain areas, the PVC board was just too soft and fragile and would crack or break under pressure. It is this fragility that constrained the LCD screen and buttons from being securely fastened.

Solution: The board was reinforced by an additional coating of PVC which added thickness and reinforced the board's strength. Plywood backing was also installed in areas where extra support was necessary such as around the screen and button panel to prevent breakage and extend a product’s durability.

4.3.2 Product Mechanisms

1. Cost Constraints

Issue: Budget limitations restricted access to high-quality hardware and materials.

Solution: Essential features that delivered the most value in training effectiveness were prioritized while keeping costs manageable.

2. Availability of Components

Issue: Certain desired components were difficult to source or had long lead times for delivery.

Solution: Research was conducted on alternative suppliers or equivalent components that could meet performance requirements without compromising quality.

3. Display Resolution

Issue: Low-resolution displays hindered the clarity of simulated data and made it difficult for trainees to read critical information.

Solution: Investment was made in high-resolution monitors that accurately replicated the look and feel of actual ECAM displays.

4. Processing Power

Issue: Insufficient processing power led to slow performance, lagging simulations, or an inability to run complex scenarios.

Solution: Hardware with adequate specifications (CPU, RAM) was selected to handle the demands of real-time data simulation and graphical rendering.

4.3.3 Software/Programming

Problem: Limited Processing Power for Real-Time Data Handling

Since the ECAM Training Kit requires real-time data processing to simulate alerts, warnings, and dynamic displays, the Raspberry Pi 5's processing capabilities posed a limitation. During testing, the system experienced noticeable lag when processing multiple data streams and running graphical updates simultaneously. This delay impacted the responsiveness of the training kit, which could detract from the user experience.

Solution:

To optimize performance, Python's threading module was utilized to manage multiple tasks concurrently, such as data processing and display updates. By offloading certain tasks to separate threads, the system could handle real-time processing more efficiently. Additionally, we reduced the data refresh rate to balance performance with real-time simulation needs, improving the system's responsiveness without compromising its functionality.

Problem: Inconsistent Response to User Inputs

The ECAM Training Kit requires real-time responsiveness to user inputs, such as pressing buttons to navigate between system displays. However, during testing, the system sometimes exhibited a delay or failed to register inputs accurately, likely due to Python's tkinter event handling and the Raspberry Pi's limited processing capacity.

Solution:

We implemented Python's queue module to manage input events, which allowed the system to handle inputs more consistently. This approach ensured that every input was processed in sequence, preventing skipped or delayed responses. Additionally, event debouncing techniques were introduced to prevent multiple triggers from a single button press, improving the user interaction experience.

Problem: Overheating of Raspberry Pi 5 During Prolonged Use

During extended use, the Raspberry Pi 5 would overheat due to the continuous processing load from running the ECAM Training Kit software. This led to automatic CPU throttling, which caused the system's performance to drop significantly, affecting both the GUI responsiveness and real-time data processing.

Solution:

To mitigate overheating, we added a small cooling fan and heat sink to the Raspberry Pi 5. Additionally, we implemented a temperature-monitoring function in Python that triggers an alert if the system temperature exceeds safe levels. This function allowed for proactive management of potential overheating issues, ensuring consistent performance during training sessions.

4.3.4 Accessories & Finishing

During the product's development, several problems arose, specifically in the accessories and finishing section. Firstly, the issue emerged during the attachment of buttons on the PVC board, in which the buttons were inadequate to fit the PVC board. To address this problem, the PVC board for the buttons was cut to a new one from the moment it cannot be supplied. This adjustment provided an aesthetically pleasing finish and functionality in the training kit.

Apart from that, another additional issue that arose was during the finishing looks of the plywood for the main structure, it was then found that the spray painting and some types specifically, did not stick well to the plywood surface which makes the finish uneven. To encounter this problem, a form of spray paint specially designed for wood adhered well and finished smoother and harder. This solution effectively improved the aesthetics of the kit.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 ACHIEVEMENT OF AIM & OBJECTIVES OF THE RESEARCH

5.1.1 General Achievements of the Project

Its primary objective of providing a cost-effective and practical training tool was successfully achieved with the ECAM Training System Kit and it replicates the ECAM interface used in Airbus aircraft. This project succeeded not only in designing and manufacturing a portable and user-friendly device to improve students' ECAM familiarity but also in creating a device to heighten students' understanding of how to interact with aircraft system pages realistically. The project also met its affordability goals, providing an affordable alternative to full-size simulators to present advanced training at more schools at a lower cost.

5.1.2 Specific Achievement of Project Objectives

5.1.2.1 Product Structure

The ECAM Training System Kit product configuration was designed using a combination of plywood, for the improvement of strength, and PVC board for the interaction of functionalities. Plywood was the main structure since it had to be strong and able to resist constant pushing and touching; PVC was used for mounting the LCD and buttons. Additionally, extra support was added to the structure in the places that needed more strength, to provide stability and make it durable. With this design, the objective of having a solid and reliable structure suitable for intense training environments was achieved, thus making the kit portable and durable enough for applications in practice.

5.1.2.2 Product Mechanisms

The ECAM training kit provided a comprehensive learning experience that bridged the gap between theoretical knowledge and practical application for both pilot and maintenance personnel trainees. By incorporating realistic simulations and scenario-based training, the kit allowed users to engage with complex aircraft systems in a controlled environment. This hands-on approach fostered critical thinking and decision-making skills, enabling trainees to respond effectively to real-world challenges. As a result, the training kit contributed to improved operational safety and efficiency, reinforcing the importance of thorough preparation in aviation.

5.1.2.3 Programming/Software

Given the limitations of the Raspberry Pi 5 in terms of processing power and memory, optimizing the system for this platform was a critical objective. Through careful coding and resource management, we reduced CPU load by using Python's asyncio for asynchronous tasks and simplifying the GUI's graphical elements. Additionally, the system was enhanced with cooling measures to prevent overheating. Meeting this objective ensured that the training kit runs efficiently on the Raspberry Pi 5, making it accessible, portable, and suitable for classroom use. We also aimed to design an intuitive and interactive user interface that mirrors the layout of an actual ECAM system. Using the Tkinter library, we created a GUI with various display modes, interactive buttons, and system status indicators. The interface allows students to navigate through different aircraft system views, such as engine, fuel, and electrical, providing an authentic training experience. This objective was achieved by optimizing the GUI for Raspberry Pi 5, ensuring smooth navigation and responsiveness, even with the hardware limitations.

5.1.2.4 Accessories & Finishing

The final version of the Electronic Centralized Aircraft Monitoring (ECAM) System Learning Kit has been developed to fully achieve each objective that was originally set out. Through careful action especially on the accessories and finishing section, we ensured that every goal and requirement for functionality and effectiveness has been met, resulting in a product that aligns precisely with our initial aims and expectations. Our market value of this product is user-friendly which implies users understand the display of each page of the product easily while learning the theory among it. Thus, the accessories and furnishing were prioritized in the outcome of the project to make sure we achieved the look that we had aimed for. This accomplishment reflects our commitment to delivering a learning kit that provides a comprehensive and reliable educational experience for users.

5.2 CONTRIBUTION OR IMPACT OF THE PRODUCT

By providing an interactive, hands-on tool that enhances students' understanding of ECAM systems, the ECAM Training System Kit finds key contributions to aviation maintenance training. An important aspect of this project is to bridge the gap between theoretical learning and practical usage, enabling students to become proficient in operating ECAM and understanding system layouts. The cost of the kit and its portability make it perfect as a supplement for aviation schools to help improve their course without straining such institutions' budgets. The ECAM Training System Kit in providing a realistic training experience, assists in improving the skills and confidence of future aviation technicians.

5.3 IMPROVEMENT & SUGGESTIONS FOR FUTURE RESEARCH

5.3.1 Product Structure

For future versions of the ECAM Training System Kit, acrylic could be a possible different material used for the structure. Acrylic is lightweight, strong, and provides great stability but is still easy to cut and shape for production and customization. It is also cheaper, which practically helps keep the kit affordable. In addition, the smooth surface of the acrylic gives a nice, professional look that is great for educational tools. This would also help in making repairs and upgrades of parts easier with its modular structure, using transparent acrylic panels that are easy to assemble and disassemble. Adding features like foldable stands or adjustable frames could also make the kit easier to carry and use in different training settings, which would be very handy for aviation education.

5.3.2 Product Mechanisms

Suggestions for Improvement

1. User-Centric Design Enhancements: Conduct regular user feedback sessions with pilots and maintenance personnel to gather insights on usability and functionality. This could lead to design improvements that better meet user needs.

2. Incorporation of Real-Time Data: Explore the possibility of integrating real-time data from actual aircraft systems during training simulations. This would provide trainees with a more authentic experience and help them understand how real-time data influences decision-making.

3. Cross-Platform Functionality: Ensure that the training kit is compatible across various platforms (PCs, tablets, simulators) to increase accessibility and convenience for users.

4. Continuous Updates and Content Expansion: Establish a process for regularly updating the scenario library and training content based on industry trends, regulatory changes, and technological advancements. This would ensure that the training remains relevant and effective.

5. Adaptive Learning Algorithms: Implementing adaptive learning algorithms could tailor training scenarios to individual trainee needs, adjusting difficulty levels based on performance. This personalized approach would help maximize learning efficiency and engagement.

5.3.3 Software/Programming

The ECAM Training Kit System, as a project designed to simulate aircraft monitoring and alert functions, offers a promising tool for educational purposes. However, there are several areas for improvement and potential enhancements that could increase its effectiveness, functionality, and relevance in the field of aircraft maintenance training. By addressing these areas, future research could create a more advanced and realistic training experience, benefiting students and instructors alike. This section outlines key suggestions for improving the software and programming aspects of the ECAM Training Kit, specifically considering the limitations of the current Python-based system on the Raspberry Pi 5 platform.

Firstly, one of the primary areas for improvement is the optimization of real-time data processing and visualization. While Python's threading and asyncio modules were used to manage simultaneous tasks, the processing power of the Raspberry Pi 5 still poses a constraint. Future research could explore more efficient programming languages or hybrid programming approaches to reduce CPU and memory usage further. For example, implementing performance-critical sections in a lower-level language such as C or C++ while keeping Python as the main language could significantly enhance processing speed and efficiency. This hybrid approach could improve the responsiveness of the system, ensuring a smoother and more realistic simulation experience.

In addition to optimizing performance, expanding the scope of fault simulation is another area worth considering. The current system simulates basic faults using predefined parameters; however, a more sophisticated fault generation mechanism would add greater realism to the training experience. Future research could introduce a fault library with a broader range of scenarios based on real-world aircraft systems, including complex, multi-layered faults that affect multiple subsystems simultaneously.

Another suggested improvement involves data logging and user analytics. Although the current system records basic user interactions, future research could expand this feature to capture more detailed analytics. Implementing a comprehensive analytics dashboard could allow instructors to analyze student performance in depth, identifying common areas of difficulty and providing personalized feedback. Furthermore, using cloud storage and real-time data synchronization could enable remote monitoring and assessment, allowing instructors to review student progress outside the classroom environment and enhancing the accessibility of training records.

The system's hardware limitations also present opportunities for future enhancement. The Raspberry Pi 5, while compact and cost-effective, has inherent constraints regarding processing power, memory, and temperature management. Future research could experiment with alternative hardware, such as more powerful single-board computers or even dedicated microcontrollers for handling specific tasks. Alternatively, the current system could be integrated with external processing units that handle complex calculations, such as a GPU module or a secondary processing board dedicated to real-time data visualization. By offloading demanding tasks into additional hardware, the main Raspberry Pi processor could focus on managing essential operations, ultimately enhancing the system's overall stability and performance.

5.3.4 Accessories & Finishing

For the refinement of ECAM System Learning Kit accessories and finishing, firstly the product would like to change the blue color to the actual color of the cockpit to visualize to users the real color of the ECAM body on aircraft. Other than that, an improvement on the QR code will also be taken as we plan to put more information and notes with different types of Airbus ECAM. The QR code then will also be printed out and pasted beside the display panel.

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APPENDIX A: DECLARATION OF TASK SEGREGATION

SUB-CHAPTERS	DESCRIPTION
MUHAMMAD AMIRUL HAKIMI BIN MOHD RAFIQ	
1.3.2.1	Specific Individual Project Objectives: Product Structure
1.5.2.1	Specific Individual Scopes: Product Structure
2.2.1.1	Product Structure: Basic Design of Main Structure
2.3.1.1	Related Patented Products: Patent A
3.3.2.1	Specific Project Design Flow/Framework: Product Structure
3.4.2.3	Design Concept Generation: Proposed Design Concept 1
3.5.2.1	Specific Part Drawing / Diagram: Product Structure
3.6.3.1	Specific Project Fabrication: Phase 1 (Base Structure)
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
5.1.2.1	Specific Achievement of Project Objectives: Product Structure
5.3.1	IMPROVEMENT & SUGGESTIONS FOR FUTURE RESEARCH: Product Structure
AFIQ ZAFRI BIN AZUHARI	
1.3.2.2	Specific Individual Project Objectives: Product Mechanisms
1.5.2.2	Specific Individual Scopes: Product Mechanisms

APPENDIX A: DECLARATION OF TASK SEGREGATION

2.2.2	**SPECIFIC LITERATURE REVIEW: Product Mechanisms**
2.3.1.2	**Related Patented Products: Patent B**
3.3.2.2	**Specific Project Design Flow/Framework: Product Mechanisms**
3.4.2.4	**Design Concept Generation: Proposed Design Concept 2**
3.6.3.2	**Specific Project Fabrication: Phase 2 (Accessories & Mechanisms)**
4.1.2.2	**Specific Part Features: Product Mechanisms**
4.1.4.2	**Operation of the Specific Part of the Product: Product Mechanisms**
4.3.2	**ANALYSIS OF PROBLEM ENCOUNTERED & SOLUTIONS: Product Mechanisms**
5.1.2.2	**Specific Achievement of Project Objectives: Product Mechanisms**
5.3.2	**IMPROVEMENT & SUGGESTIONS FOR FUTURE RESEARCH: Product Mechanisms**
IMRAN HYDIR BIN ABDUL HALIM	
1.3.2.3	**Specific Individual Project Objectives: Software/Programming**
1.5.2.3	**Specific Individual Scopes: Software/Programming**
2.2.3.1	**Software/Programming: About Raspberry Pi Boards & Programming Languages**
2.3.2.1	**Recent Market Products: Product A**
3.3.2.4	**Specific Project Design Flow/Framework: Software / Programming**
3.4.2.5	**Design Concept Generation: Proposed Design Concept 3**

APPENDIX A: DECLARATION OF TASK SEGREGATION

4.1.2.3	**Specific Part Features: Software/Programming**
4.1.4.3	**Operation of the Specific Part of the Product: Software/Programming**
4.3.3	**ANALYSIS OF PROBLEM ENCOUNTERED & SOLUTIONS: Software/Programming**
5.1.2.3	**Specific Achievement of Project Objectives: Programming/Software**
5.3.3	**IMPROVEMENT & SUGGESTIONS FOR FUTURE RESEARCH: Software/Programming**
FARAH IRDINA BINTI MOHD HAIRUL IZAM	
1.3.2.4	**Specific Individual Project Objectives: Accessories & Finishing**
1.5.2.4	**Specific Individual Scopes: Accessories & Finishing**
2.2.4	**SPECIFIC LITERATURE REVIEW: Accessories & Finishing**
2.3.2.2	**Recent Market Products: Product B**
3.3.2.4	**Specific Project Design Flow/Framework: Accessories & Finishing**
3.4.2.6	**Design Concept Generation: Proposed Design Concept 4**
3.6.3.3	**Specific Project Fabrication: Phase 3 (Finishing)**
4.1.2.4	**Specific Part Features: Accessories & Finishing**
4.1.4.4	**Operation of the Specific Part of the Product: Accessories & Finishing**
4.3.4	**ANALYSIS OF PROBLEM ENCOUNTERED & SOLUTIONS: Accessories & Finishing**
5.1.2.4	**Specific Achievement of Project Objectives: Accessories & Finishing**

APPENDIX A: DECLARATION OF TASK SEGREGATION

5.3.4	**IMPROVEMENT & SUGGESTIONS FOR FUTURE RESEARCH: Accessories & Finishing**

APPENDIX B: SUMMARY OF SIMILARITY REPORT (TURNITIN)

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