POLITEKNIK BANTING SELANGOR

THE AEROGUARD HELMET

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DEPARTMENT OF AIRCRAFT MAINTENANCE

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THE AEROGUARD HELMET

SESSION: 1 2025/2026

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

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ABSTRACT

Conventional safety helmets are limited to basic head protection and fail to address modern workplace hazards such as excessive noise, poor lighting, and accidental impacts. The purpose of this project is to develop a smart helmet that enhances worker safety in hangar and industrial environments. The AeroGuard Helmet (AGH) integrates noise detection, automatic lighting, impact and vibration alerts, and real-time monitoring through application connectivity, making it unique compared to traditional helmets. The project began with a survey to identify user needs, followed by research and sketching of the AGH design. A prototype was then fabricated using an microcontroller integrated with LDR, sound, and vibration sensors, and tested under simulated workplace conditions with user evaluations to assess practicality and performance. This innovation significantly enhances workplace safety by providing proactive hazard detection and immediate alerts, thereby reducing accident risks and delayed responses, with 85.1% of users recommending it. The AGH benefits both workers and supervisors by improving protection and situational awareness, while also showing strong potential for scalability and future application in various industrial sectors as next-generation personal protective equipment solution.

Keywords: Smart Helmet, Accident Prevention, Industrial Environment

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Presently, we are doing Diploma Engineering in Aircraft Maintenance here at Politeknik Banting Selangor. This innovative product, The Aeroguard Helmet, which we will be working on during my final year project, is designed to provide the workers in the hangar or any other environment where maintenance activities are performed with better safety.

Figure 1: Traditional Safety Helmet

Nevertheless, the conventional helmets worn in the aviation and industrial industries are only availed with passive protection. They are only meant to absorb physical force and would not help the user to feel potential hazards before an accident ensues. As maintenance work is becoming more

complicated, particularly in the case of the modern aircrafts with complicated avionics, composite materials and electrified systems, passive PPE is no longer adequate. Employees are now exposed not only to physical hazards, but the conditions in the workplace including high levels of noises, low visibility and vibrations or shocks that might be a sign of hazardous conditions (Niu & Salvendy, 2019).

The development of embedded systems, miniature sensors, and the Internet of Things (IoT) has become the new possibilities to turn the traditional PPE into intelligent and proactive safety equipment.The aeroguard helmet have come out to be a new solution to various industries that can sense any environmental risk in the surroundings, warn, and transmit safety data to managers. This helmet normally designed with light sensors, noise sensors, impact sensor, and wireless communication modules in order to provide better knowledge to the worker and minimize the risk of accidents. Such features are very important in aviation maintenance (Zhang, Li & Huang, 2020). Technicians may have to work in poorly illuminated places (belly or hangar of aircraft) or they may have a lighting that changes. Unexpected loud distortion due to aircraft engines, pneumatic instruments or composite repair equipment may surpass safe noise levels and result in temporary or permanent impairment of hearing. Moreover, effects or falls can be invisible in case the worker is alone or is not visible by the supervisor. These difficulties undermine the necessity of having a more developed safety system that would track the environmental hazards in real time and give instant feedback to the user and the supervisor.

Figure 2: Smart Safety Helmet

1.2 PROBLEM STATEMENTS

Workers in the maintenance sector of the aviation sector work under high-risk conditions that are prone to accidents and long term health problems, especially due to the high noise levels, poor lighting and lack of real time monitoring. Investigations show that aircraft maintenance workers are exposed to 70-91 dB(A) of noise on a daily basis, which at its highest point reach 119 dB(A) when riveting, working with pneumatic tools, or testing the engine, which are loud enough to cause permanent hearing loss should no precautions be taken or used (Smedje et al., 2011). Moreover, the auditory damage may also be worsened by the exposure to solvents and other chemicals that are usually used to maintain the aircrafts, including the damages to both the peripheral and the central auditory systems. Conventional safety helmets are merely passive in terms of protection against impact and fail to integrate any active monitoring systems that can notify users of hazards in the environment like sudden loud noise, bad visibility, or falls. This constraint is more pressing when the technicians are isolated or in limited areas since the supervisors cannot real time detect any emergencies. The lack of light in certain sections of the aircraft like landing gear bays, wing roots, tight compartments among others further impairs the performance and precision of the jobs by compelling the technicians to go through the handheld torches or external lighting, which is cumbersome and inefficient.

In addition to short-term safety issues, the long-term effect of high noise and stressful working conditions may be physiological and psychological stress, such as stress on the cardiovascular system and fatigue. All those challenges point to how ineffective traditional personal protective equipment is and the necessity of a proactive solution to those issues. Thus, there is a definite necessity to have an intelligent helmet which is not only capable of protecting against impact but also capable of elevating the level of safety by detecting the possible hazard in real-time, automatic notifications, adjustable lighting in situations when the visibility is low, hands-free communication and also remote monitoring. A solution of this kind would aid in the minimization of the risk of instant injury in aviation industry.

1.3 PROJECT OBJECTIVES

1.3.1 GENERAL PROJECT OBJECTIVES

- To design a smart safety helmet with essential safety features like an automatic light system, noise level detection, fit-in earmuff, and an inbuilt alert system.
- To develop a working model of the Aeroguard Helmet using microcontroller-based embedded systems and sensor technology for real-time environmental detection.
- To evaluate the performance of the smart helmet to minimize exposure to occupational hazards, improve workplace safety, and decrease potential risks and injuries.
- To enhance the process of safety monitoring by enabling support of Bluetooth or wireless communication between the helmet and a mobile application for real-time alerts, recording of data, and remote monitoring.

1.3.2 SPECIFIC INDIVIDUAL PROJECT OBJECTIVES

1.3.2.1   Product Structure
   (NANTHAKUMARAN A/L VASU)

- To design the product structure of The Aeroguard Helmet, the focus is on developing a comfortable and uniform safety helmet that integrates different safety features without compromising comfort. The helmet is constructed using Acrylonitrile Butadiene Styrene (ABS), a lightweight material with excellent strength that meets industrial safety standards and provides sufficient space to hold electronic components such as sensors, wiring, and power supply systems.

- To develop the internal framework, the integration of components such as the microphone sound sensor, light sensor, vibration sensor, and detachable earmuffs must be strategized. Each component will be positioned to optimize performance while ensuring even weight distribution and worker comfort.

- To evaluate the performance, the final product will be tested under controlled industrial conditions to assess reliability, comfort, and safety performance. Feedback will be gathered to facilitate optimization of component placement and overall design, which will optimize the process of safety equipment design for the aviation maintenance environment. Such enhancements will work to maximize protection and user compliance through smart design.

- To demonstrate the functionality, a fully functional prototype will be created to test and show the interaction between structural design and internal components. The light sensor will activate LED lights in low-light or confined spaces, the sound detector will alert the user when noise exceeds safe thresholds, the vibration sensor will detect impacts or falls, and the removable earmuffs will mitigate hazardous noise exposure.

1.3.2.2   Product Mechanism

(MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

- To continuously monitor ambient noise and alert the wearer when it exceeds a safe threshold, the Noise Detection System uses an embedded sound level sensor. When the noise exceeds the set threshold (e.g., 85 dB), the system triggers an alert using a mini alarm buzzer inside the helmet. The sensor input is processed by the microcontroller and the alarm is triggered if the unsafe noise level is detected.

- To provide immediate alerts for unsafe conditions the Alarm Triggers feature operates in conjunction with the microcontroller. On excessive sound levels or other parameters exceeding safety limits, the microcontroller activates an audio or vibrational alarm to immediately inform the wearer of likely hazards in the environment.

- To enhance visibility in low-light conditions, Automatic Lighting System uses a Light Dependent Resistor (LDR) on the helmet. Whenever the LDR detects low light, the system activates the high-lumen LED lights in front of the helmet. The microcontroller continuously monitors the light data and activates the LEDs if the light is not enough, improving nighttime visibility.

- To reduce noise exposure and prevent unwanted alarms, the Integrated Earmuffs feature offers two retractable noise-reducing earmuffs. If the earmuffs are extended, the system automatically mutes the alarm to prevent double notifications. The sensor tells the microcontroller that the earmuffs are extended, and the microcontroller ensures the alarm is muted for comfort when exposed to noise for an extended period.

1.3.2.3 Software /Programming

(THARSHAM MENAN A/L BALAKRISHNAN)

- To design the software architecture that coordinates the functionality of the Aeroguard Helmet, including sensor input processing, data analysis, alert triggering, and wireless communication.

- To develop the embedded systems programming using the Arduino IDE (C/C++) to enable automatic lighting, sound detection, and control of alert systems according to real-time sensor inputs.

- To evaluate the effectiveness of the software in responsiveness, reliability, and usefulness in improving the safety of users, while also attempting to reduce cost by using open-source development platforms.

- To enhance the hardware interfacing with the developed software, depicting how the sensor data is interpreted and acted upon via various output methods such as lights, vibration motors, and mobile notifications.

1.3.2.3   Accessories & Finishing

(DEVESH A/L THIYAGARAJAN)

- To design helmet accessories and finishing, the focus is on user comfort, safety, and durability. Each element is designed to enhance usability and maintain long-term performance in demanding aviation environments.

- To develop integration, accessories will complement the helmet's structural and mechanical systems. Detachable earmuffs allow noise reduction without affecting helmet balance, ergonomic padding enhances comfort, and protective coatings ensure resistance to wear.

- To evaluate performance, accessories will be subjected to durability, safety, and user-experience tests. Feedback from these tests will refine design placement, materials, and integration to maximize protection, comfort, and operational compliance.

- To demonstrate usability, prototypes will be used in practical simulations to show how all accessories function in harmony with the helmet's structural, mechanical, and software components. This includes testing ease of attachment/removal, comfort during extended wear, and effectiveness of protection and visibility enhancements.

1.4 PURPOSE OF PRODUCT

The Aeroguard Helmet is intended to be a smart, all-inclusive, and innovative in helping to provide aviation maintenance personnel with a variety of diverse protection features in one unified, wearable device. The Aeroguard Helmet is opposed to the conventional helmets that mainly offer impact protection and the Aeroguard Helmet is created to actively monitor any hazardous conditions and make workers safe by responding intelligently. It is characterized by automatic lighting system to support low-visibility operation, noise-detecting and noise-reducing system using built-in earmuffs, and impact or fall-detecting device using a vibration sensor, all of which are real-time activated to provide the user with the possible hazard warning. Besides protecting the individual, the helmet is also fitted with the ability to communicate wirelessly as well as monitor, thereby enabling the supervisor to know the safety of the technician in a restricted area, in a sheltered area where visibility is limited. This aspect provides the possibility of the immediate reaction to the incidents, minimizing the severity of accidents. Other ergonomic features like the perfect distribution of weight, comfortable padding and modularity are also incorporated in the product to guarantee long usage without any discomfort and fatigue.

The Aeroguard Helmet does not only reduce the risk physically like the head injuries caused by random impacts, the noise level, slips and falls but also helps in decreasing the efficiency of operations and the workforce productivity. Giving real-time feedback, and automated alerts, the helmet allows the maintenance personnel to be able to concentrate on their work with more awareness and confidence. Moreover, the information that is gathered by sensors of the helmet can be performed in safety analytics to determine the areas or tasks that are considered to be at high risk, streamline the maintenance processes, and improve the safety culture as a whole in organizations involved in aviation maintenance.

Finally, The Aeroguard Helmet is designed to make personal protective equipment (PPE) more of an active protection technology and combine advanced technology, ergonomics and pragmatic functionality into providing maximum protection, situational awareness and functional efficiency in the aviation maintenance work environment.

1.5 SCOPE OF PROJECT

1.5.1 General Project Scopes

This project will cover the entire project of production of the Aeroguard Helmet which will include conceptual design, mechanical and electronic development, prototyping, testing and evaluation. The project aims at developing a smart safety helmet that combines various protective and monitoring technologies, including automatic lighting in low-visibility conditions, noise detection and minimization using inbuilt earmuffs, impact sensing in case of falls or collisions and wireless monitoring to have a remote supervision. Here, the project consists of a functional prototype, close integration of electronics, sensors, microcontrollers and power supply systems into the helmet structure without affecting the comfort, ergonomics and structural integrity. Software development is also within the scope, which entails real-time sensor monitoring embedded programming with automated alerts and wireless data transfer to an automated web application to manage safety.

Evaluation and testing constitute an important scope of the project. The helmet will be subjected to simulated conditions of hangar and maintenance environment to determine the effectiveness of lighting, noise alert, impact detection, and communication system. Sensors accuracy, response time, durability, and ergonomic comfort are some of the performance metrics that will be documented and analyzed. Furthermore, the user feedback will be held with the potential end-users to understand the usability, comfort and practicality of the design and will aid in the iterative improvement of the design.

The scope also focuses on the adherence to the current standards of personal protective equipment (PPE) in the aviation maintenance field so that the helmet should not only satisfy the safety standards but also make workers more efficient and more aware. Lastly, the project would entail documentation of design procedures, testing guidelines, testing outcomes, recommendation on how this can be implemented in industries, which would form a basis of future improvements in smart PPE in aviation safety.

1.5.2 SPECIFIC INDIVIDUAL SCOPES

1.5.2.1 Product Structure

(NANTHAKUMARAN A/L VASU)

The scope of the project is on structural design and physical shape of a smart helmet to be used by hangar workers working in risk environments. The helmet will be ergonomic, streamlined in shape that promises extreme comfort and head safety over long periods of use. Its outer casing will be aerodynamically contoured in shape with a view to reducing air resistance while providing complete protection against potential impacts. (NIOSH, 2022)

The helmet will be constructed of Acrylonitrile Butadiene Styrene (ABS), an engineering polymer specifically chosen for an ideal combination of strength, wearability, and lightness. The body inside will be hand-built to a shape uniquely designed to endure comfort and wearability, incorporating molded areas of padding curving around the contour of the human head, allowing natural ventilation along with stability. (3M, n.d.; PubChem, n.d.)

The design will also include sleek lines and integrated contours that allow space for additional features such as earmuff compartments, chin straps, and light features without sacrificing the helmet's sleek, compact shape. The overall look prioritizes functionality and aesthetics, adhering to modern safety gear fashion while providing effortless mobility and day-long wear in industrial settings.

1.5.2.2   Product Mechanisms

(MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

The Aeroguard Helmet seeks to enhance safety and operational efficiency for hangar, workshop, and industrial maintenance personnel, resolving problems of poor visibility, noise hazards, and the need for real-time safety monitoring. The Automatic Lighting System uses a Light Dependent Resistor (LDR) to detect low-light levels and activate high-lumen LED lights, which enhance visibility and reduce the likelihood of accidents (Texas Instruments, 2020). The Noise Detection System has a built-in sound level sensor that continuously monitors the noise, triggering a mini alarm buzzer when levels exceed (e.g., 85 dB), and Integrated Earmuffs reduce noise exposure and silence the alarm automatically upon being put on, ensuring comfort and minimizing auditory fatigue. Additionally, the helmet incorporates environmental and safety sensors such as an accelerometer to detect falls or impacts, with the microcontroller processing the data and forwarding it for immediate alert (Daniellsson et al., 2011). Supervisors can also monitor real-time noise levels, helmet status, and sudden impacts of critical parameters, enabling fast response to emergencies and improving workplace safety (García et al., 2011; Singh & Jain, 2020). With such features, Aeroguard Helmet is focused on boosting productivity by minimization of workplace noise-related dangers, loss of vision, and workplace-related safety threats. The project also focuses on monitoring and improving worker's conditions of safety, reducing accident rates, and verifying industry standards compliance related to safety.

1.5.2.3   Software/Programming

(THARSHAM MENAN A/L BALAKRISHNAN)

The individual scope of the project deals with the software and programming aspect of the Aeroguard Helmet. The responsibilities include the design and programming of the embedded system that is in charge of the intelligent aspects of the helmet. This involves coding and debugging the microcontroller using the Arduino IDE (C/C++) to operate the automatic light system, noise-level sensor, vibration alarms, and the fit-in earmuff mechanism (Arduino, 2023). Various sensors such as the Light Dependent Resistor (LDR), impact and sound sensor will be installed and configured for accurate real-time monitoring. Decision-making logic will be coded for reading sensor input and activating relative output components (Arduino, 2023). A web application will also be developed using tools such as MIT App Inventor for developing Bluetooth communication, enabling real-time data transfer and alert notifications to the user's smartphone (MIT App Inventor, 2023). The software will be developed for low power consumption and small memory footprint, appropriate for wearable devices (Digi-Key, 2023). Exhaustive testing and debugging will be carried out to ensure system performance and reliability, and documentation of code structure, logic flow, and interface operations will be supplied to enable evaluation and future development (Arduino, 2023).

1.5.2.4   Accessories & Finishing
(DEVESH A/L THIYAGARAJAN)

The scope assigned under accessories and finishing involves the design, placement, and performance validation of external components that directly support the Aeroguard Helmet's smart safety functions.

A key feature within this scope is the development of detachable earmuffs, engineered to minimize high-decibel noise exposure while maintaining comfort for prolonged use (NIOSH, 2022; HSE UK, 2023). These earmuffs are constructed from noise-dampening material and attached with a modular mechanism that allows easy attachment or removal based on user needs (3M Safety Division, 2020).

In addition to auditory safety, the scope includes mounting a robust LED lighting module on the helmet's front section, providing focused illumination that activates automatically in low-light conditions through sensor control. This improves visibility during maintenance work under aircraft structures or in dim hangar areas without the need for handheld lighting (Ergodyne, 2019)

The exterior finish will be treated with a weather-resistant, industrial coating that protects the helmet from impact, moisture, UV exposure, and thermal degradation. Additional tasks include incorporating branding decals, warning signs, and comfort pads, ensuring the helmet is not only safe but also user-friendly and visually professional (ANSI/ISEA, 2014). This scope ensures that all external elements of the Aeroguard Helmet are both technically reliable and appealing for aviation maintenance personnel working in dynamic, high-risk environments working in dynamic, high-risk environments.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL LITERATURE REVIEW

2.1.1 INTRODUCTION

The development of Industry 4.0 created great innovation in the domain of personal protective equipment (PPE) and turned the old safety equipment into the smart ones, which are able to perceive, analyze, and react to environmental threats. The workers in most sectors of the industry like the aviation maintenance industry, construction, and heavy manufacturing are subjected to various hazards like low-light conditions, high-noise, and unexpected impacts or falls of the tools, equipments and structural barriers. The traditional safety helmets are physically protective and cannot identify or alert the workers of a dangerous situation. The limitation has led to the creation of the so-called smart helmets, allowing the combination of sensors, microcontrollers and wireless communication devices to ensure situational awareness and provide better safety in the workplace. The latest technological progress proves that the smart helmets have been developed to incorporate the functions of gas detection, temperature regulation, impact-detection, and the IoT-based alert. As an example, Lee et al. (Arduino, 2023) have emphasized the development of multimodal sensing in the contemporary helmets, and numerous recent studies are focused on the impact detection to prevent accidents, vibration sensors to warn on a collision, and light-based systems to increase the visibility. Nevertheless, even with such developments majority of available smart helmets are designed to work in general industry or to help safeguard a motorcyclist and

many are designed to perform only one of the functions which include collision detection or environmental sensors. Very few studies offer multi-functional helmets that can take into consideration visibility, noise exposure and also the impact related hazards. This distance is further highlighted in areas such as aircraft maintenance engineering where employees often work in dark environments, near noisy machinery and in places where accidental slips, falls or impacts of tools can be experienced at any moment. Aviation environment tasks include inside cabin inspection, undercarriage inspection, avionics troubleshooting among others, and all these activities demand proper lighting, sensitivity to noise exposure, and impact resistance. The current system of smart helmet fails to meet these requirements in full, so a more focused safety solution has to be created. The AeroGuard Helmet is able to fill this technological gap by incorporating three fundamental safety features that are specific to the industrial maintenance and aviation maintenance setting: Automatic Lighting: The helmet will have an LDR module that activates an LED light when in low-light environments so that workers do not have to carry handheld lighting to improve visibility. Noise Detection: The system measures the level of ambient noise and reminds when its level goes above 85 dB, preventing the development of hearing impairment in the long run and keeping people within the safety range. Sudden Impact or Fall Detection: The helmet has a vibration sensor (SW-420) that detects strong impact or sudden falls and issues notifications that can be connected to a monitoring system to react to them. The AeroGuard Helmet is a multi-sensor solution (when compared with existing smart helmets which usually focus on one hazard at a time- e.g. impact only or lighting only), and that is directly related to the day to day activities of aircraft maintenance personnel. Its ability to combine real-time lighting control, hearing protection alerts and fall/impact monitoring helps to make the working environment safer and is a significant step towards the future of smart PPE systems. The AeroGuard Helmet brings a convenient, scalable, and industry-relevant addition to the safety of workers by utilizing important features without any unnecessary complexity. Not only does it address a gap in the literature in terms of research, but it also contributes to the real-world application in hangars, workshops and industrial facilities.

Smart Safety Helmets But With Automatic lighting.

Occupational safety significantly depends on the light, particularly when carrying out detailed inspection work or even work in dark or enclosed areas. Automatic lighting smart helmets have attracted interests since they eliminate the use of handheld flashlights, and enhance efficiency in operation. Studies of sensor-based illumination indicate that Light Dependent Resistors (LDRs) have been extensively applied in ambient light sensing because LDRs are cheap, quick and easy to incorporate with microcontrollers [Arduino, 2023]. A number of studies prove the efficiency of automatic lighting systems in enhancing the convenience and visibility of workers. Indicatively, Bhatt and Shah (2020) developed an automatic helmet lighting system, which switches on LEDs when the environment is low-light and thus it requires no manual operation (Open Source Initiative, 2023). On the same note, the IoT-driven illumination systems have been implemented in the industrial safety to uphold the brightness levels in the environment where the illumination systems are installed at all times (Arduino, 2023). Regardless of these improvements, the majority of lighting capable helmets concentrate on the visibility of the motorcyclist and not assisting the technical maintenance operations in the dark or other limited areas. AeroGuard Helmet is an example of such concepts as it attaches a sensor of LDR that tracks the presence of poor light and turns on an LED light automatically. This is convenient especially to aircraft maintenance engineers who need to perform inspections in the fuselage compartments, undercarriage structures or equipment bays where light is sometimes insufficient. The AeroGuard Helmet is efficient and safe because it gives motorcyclists visibility that is not hands-free.

Noise Detection and Hearing Protection in Industrial Wearables.

The most common and well documented industrial hazard and significant contributor to occupational hearing loss is excessive noise exposure. Studies indicate that a sustained exposure to noise levels over 85 dB may severely impair hearing and hence real-time noise monitoring of the workplace is of great importance in the high-risk working environment. The wearable systems that combine sound sensors and noise alert systems have been developed in order

to enable workers to be aware of the dangerous sound levels and apply suitable safety precautions. Recent researches discuss wearable sound monitoring devices that can identify unusual noise signals and provide safety warnings. Nagatomo et al. (Components101, 2023) have shown that head-mounted sensors are effective to record acoustic data to be processed in real-time, and the idea of incorporating sound detection using microphones into wearable gadgets is viable. According to other studies in industrial safety systems, noise-level detection module and alerting devices can lessen the risks associated with hearing in the long term and increase adherence to safety standards (Arduino, 2023). AeroGuard Helmet has a sound sensor with which it can monitor the ambient noise and send alert when its level surpasses 85 dB. This is under international safety guidelines and it endorses the aviation maintenance employees who often work around engines, pneumatic tools, and heavy machinery. The helmet allows users to take protective measures since they can give instant feedback to adjust the equipment distance or use ear-muffs.

Smart Helmet Impact and Fall Detection.

Smart helmets have also assumed the role of detecting impacts and falls, which can be used in response to an accident. Accelerometers and vibration sensors (e.g. SW-420) are often utilized to detect sudden shocks, high vibrations, or drops. These systems are also crucial when the risk of accidental contact of hard surfaces, falling objects, or structural barriers is present to the workers. The article by Patel and Sharma (MIT App Inventor, 2023) proposed an IoT-based impact detector system to fall detection based on the vibration sensor. On the same note, wearable collision detectors have been proven to be dependable in sending notification in the event of sudden shocks or hits (Digi-Key, 2023). These papers affirm that the use of simple, low-power vibration sensors can be an effective instrument in monitoring accidents in wearable safety gadgets. The AeroGuard Helmet is fitted with the SW-420 vibration sensor which is used to identify falls or sudden impacts.Impact detection assists in minimizing the consequences of accidents and also enhances the response time to emergencies by alerting the users and possibly the supervisors.

Determined Research Gaps and Applicability to the AeroGuard Helmet.

Though the current studies have gone a long way in coming up with smart helmets, various kinds of gaps still persist-gaps which the AeroGuard Helmet fills. First, most of the published prototypes concentrate on individual functionality usage which could be a fall detector, noise detector or light booster application in isolation. Not many studies record systems that integrate all three functions all at the same time, particularly in a manner that does not compromise the ergonomics, low power consumption and comfort of the user. This has a loophole in multi-hazard PPE that is applicable in situations where workers are exposed to multiple risks at once. However, the AeroGuard Helmet bridges this with the combination of automatic lighting, noise alert detection, and impact detection via vibration into a single design. A second significant research gap is the industry-specific applicability.

A lot of literature on smart helmet is addressed to general construction, mining or motorcyclist safety. The aviation maintenance conditions, in which the technicians are forced to work inside small aircraft segments, undercarriages, and on high-rise platforms, introduce a distinctive set of hazards that is not widely covered by the available prototypes. Lack of aviation-specific designs in the scientific literature indicates that customized helmets in this regard will have an opportunity. AeroGuard Helmet is a direct result of this necessity since it targets illuminated areas in low-light, extreme intermittent engine and tool noise, and impact-prone aircraft environment. The third gap is associated with the fact that sensors have to be practically implemented into a small comfortable helmet.

The common problems associated with the operation of the existing studies include wiring discomfort, errors in the positioning of sensors, and unstable work of microcontrollers when a number of sensors are operated at the same time. The AeroGuard Helmet is specifically designed to address these issues by streamlining internal wiring design, positioning sensors in the optimal location that is sensitive to detecting objects and also by making sure that the sensors work without causing interference with each other. This is a direct response and consideration of issues that have been raised in various research

publications on smart PPE design (Arduino, 2023). The fourth gap is real time monitoring and management of worker safety. Most smart helmet designs are autonomous, meaning they do not have a connection with supervisors or safety managers to track hazards offsite.

AeroGuard Helmet eliminates this shortcoming since it incorporates a web-based monitoring application. With this app, the supervisors can be informed about the instant alert in case an impact is observed, see whether the workers are wearing hearing earplugs in a place where the sound is not less than 85 dB, and the state of the lighting system in the helmet. This kind of monitoring can help to identify the personnel servicing in dark places as well as adherence to safety measures ensuring the improved safety in the workplace of the aviation maintenance setting.

Lastly, literature always observes that there has to be a balance in complexity and usability between systems. The helmets might be too technologically advanced and might overload its users or it might demand a lot of power resources or the systems might be too simple and cannot meet the necessary safety requirements. AeroGuard Helmet achieves this trade-off by specializing in three very pertinent yet lightweight sensing features- lighting, noise, and impact sensing and provides convenient web-based monitoring. This focused solution also makes sure that the solution is practical, affordable and consistent with the aviation maintenance workflow in the real world.

2.1.2 Smart Safety Helmets Trend and Demand

In recent years, there has been a growing trend towards intelligent PPE solutions in the majority of high-risk industries. Intelligent safety helmets are being applied extensively across construction, oil and gas, manufacturing, and aircraft maintenance industries (Ergodyne, 2023). The majority of the increasing demand is because of the need to improve hazard detection, increase worker awareness, and enable remote monitoring.

Figure 3: Automatic Illumination & GPS

Employers are seeking helmets with features such as noise level sensors, GPS, automatic illumination, and Internet of Things (IoT) capabilities. Such systems allow for real-time monitoring of worksite conditions and worker safety, allowing organizations to ensure regulatory adherence and reduce the number and severity of workplace incidents (OSHA, 2022). Smart helmets are not only improving safety outcomes but also productivity because they enable faster response times and greater communication between workers and managers.

2.1.3 Development of Industrial Helmets

The development of safety helmets has revolutionized tremendously in the past few decades. Initially, helmets were purely mechanical equipment that would take in and dissipate impact through composite or hard plastic shells. As technology advanced, microelectronics, sensor technology, and wireless communication enabled the current helmets to achieve a massive number of active functionalities. The shift away from passive protection to interactive, real-time safety systems is a paradigm shift in occupational safety culture from reacting to incidents only after they happen, to pre-emptive measures that find and rectify risks beforehand before injuries are inflicted. The shift is the reflection of the growing realization that safety in the workplace is more than mere compliance but also leveraging technology to enhance worker's well being.

2.1.4 Aeroguard Helmet Specifications

The Aeroguard Helmet is an advanced smart safety helmet, specifically designed for use in aviation maintenance environments. It is created based on the need to reduce the most common and life-threatening hazards to ground crew and technicians. The key features of the Aeroguard Helmet are:

Noise Level Detection Sensor: The helmet has a calibrated sound sensor built into it, which activates an alarm if the ambient noise level exceeds a safe threshold, typically 85 dB. This alerts the user to the danger of hearing loss and reminds them to wear ear protection (HSE UK, 2023).

Integrated Alarm System: The helmet issues an physical and visual alert when immediate hazards are detected, such as sudden ambient noise spikes or mechanical shocks. This feature increases situational awareness and allows the worker to take evasive action in a timely fashion.

Automatic Lighting: An ambient light sensor built into the helmet activates low-light conditions and activates built-in LED lights to assist technicians in maintaining visibility. This is especially useful in aircraft underbellies, maintenance pits, or night operations (Components101, 2023).

Earmuff Integration: Smart earmuff are integrated into the helmet and can be inserted into the ears to automatically disable alarms and reduce sound exposure. This two-function approach provides warning and noise attenuation.

Remote Monitoring Sensor: The helmet has IoT-enabled sensors that transmit environmental and biometric data to a central monitoring system. Supervisors can track the worker's location, exposure to danger, and helmet usage in real time using a mobile or desktop application. This enables faster response to emergencies and safety adherence .

Fall Detection System: The helmet has a vibration sensor installed in it to record the occurrence of sudden impact or sudden deceleration which is an indication of a fall. Notifying supervisors about an incident in the system is automatic, required by the detection of a fall, which is sent through the web app and the supervisor can react to the incident regardless of whether the worker is unconscious or unable to call an ambulance (B.Alper, 2020).

These improved specifications are specifically aimed at enhancing the safety, performance, and health of aviation maintenance personnel. By incorporating a number of protective technologies within a single wearable system, the Aeroguard Helmet significantly reduces the risk of injury, enhances emergency preparedness, and supports a culture of preventive safety.

2.2 SPECIFIC LITERATURE REVIEW

2.2.1 Product Structure (NANTHAKUMARAN A/L VASU)

2.2.1.1 Basic Design of Main Structure
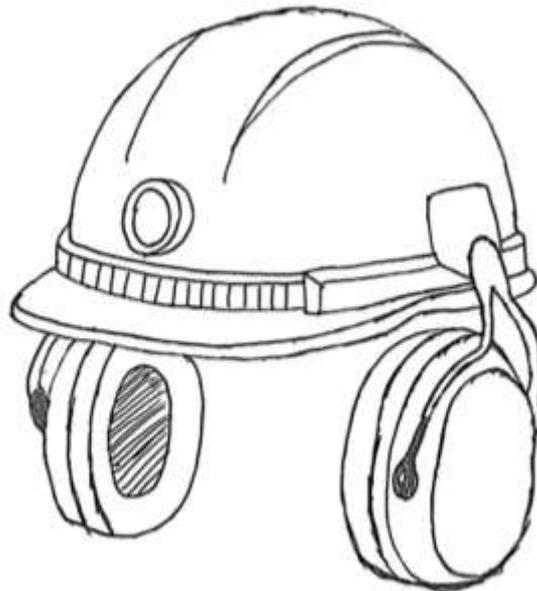
Figure 4: Product Design Overview

The Aeroguard Helmet is made of nonmetallic materials, specifically Acrylonitrile Butadiene Styrene (ABS), due to its high impact resistance, excellent strength-to-weight ratio, and ease of embedding electronic components. This thermoplastic is used extensively in the industrial safety market and meets general safety and structural requirements for protective gear for harsh environments such as aviation maintenance hangars. (PubChem, n.d)

Just as plastic moldings used in aircraft cabins are required to meet FAR 25.853 flammability standards when used in "high-risk" zones, the Aeroguard Helmet's outer shell has flame-resistant properties to facilitate safe use in environments where electrical components represent a less severe fire concern. The casing of safety helmets with embedded electronic systems has to be made from robust yet lightweight material and the most appropriate is ABS, which is a commonly used polymer in the field of aerospace, especially in the manufacture of interior components such as trim strips, control housing, and covers. (PubChem, n.d)

Internally, the helmets feature a modular configuration for sound, light, and vibration sensors and a Li-Po rechargeable battery integrated into the ABS structure. This design allows for even weight distribution without compromising user mobility or comfort. Furthermore, earmuffs that can be removed fulfill technical and ergonomic roles by reducing noise exposure while also allowing extended wear, as in design roles similar to light, composite airframe seat structures. (PubChem, n.d)

Similarly, carbon composites and lightweight alloy structures are explored in aircraft seating to minimize weight without compromising strength (Lyon R.E, 2008), The Aeroguard Helmet adheres to the same principle by prioritizing a light form factor with multi-functional safety features thereby maintaining user comfort as well as adhering to safety standards in aviation maintenance.

2.2.1.1.1 Evolution Of Safety Helmet

Safety helmet evolution has progressed significantly throughout the decades as a reaction to mounting concern for workplace safety and material science innovations. Early industrial helmets were made of metal or dense fiberglass, with the sole aim of protecting the head from impact by falling objects. These early models were bulky, uncomfortable, and featureless for protection against electrical hazards or environmental annoyances.

The revolution in the design of helmets began with the application of thermoplastic materials like polycarbonate and Acrylonitrile Butadiene Styrene (ABS) that offered superior impact resistance, lightness, and simplicity of production. The materials enabled designers to create better ergonomic and wear-comfortable helmets for long durations, paving the way for smart protective gear. (3M, n.d; Pubchem, n.d)

1919

The OG. Based on the doughboy helmet from WWI, the first hard hat was made from steamed canvas, glue, a leather brim and black paint.

1930s

Aluminum becomes the gold standard, but with one shocking drawback - aluminum is a great conductor of electricity. So aluminum gave way to Bakelite plastic and then fiberglass helmets.

TODAY

Today's hard hats are made from lightweight, supremely durable HDPE, and are more comfortable than ever. Options like vents, flexible suspensions with wicking pads, plus accessory slots keep workers comfortable all day.

Figure 5: Evolution of Safety Helmet

In the US, OSHA adopted helmet standards based on ANSI Z89.1, which classified helmets based on impact type (Type I and II) and class of electrical protection (G, E, and C). Standardization enabled manufacturers to create helmets for specialized work environments such as construction, utility work, and aircraft maintenance.

There has been the creation of smart safety helmets in recent years through the integration of digital technologies like sensors, communication modules,

and augmented reality displays. This creation is within the trends of Industry 4.0 and the market demand for proactive safety solutions in high-risk industries. According to NIOSH, integrating real-time monitoring technologies, i.e., fall detection and noise exposure monitoring, can significantly reduce workplace injuries as well as improve workers' response time (NIOSH, 2022). (TechTarget, n.d)

The Aeroguard Helmet is the latest step in this evolution, combining a durable ABS outer shell with embedded sensors (vibration, light, and sound), LED light systems, and detachable earmuffs. The integration of electronics into the helmet's framework answers both age-old safety concerns and emerging dangers to which aircraft maintenance technicians are subjected, offering an intelligent, ergonomic, and regulation-compliant head protection system. (AviationPros, n.d; PubChem, n.d)

2.2.1.1.2 Standard Weight, Dimension, And Structural Strength Of Safety Helmet

Industrial and aviation safety helmets need to meet strict weight, fit, and especially structural strength requirements in order to offer proper protection against falling objects, impacts, and electrical shock.

Weight and Dimensions:

According to ANSI Z89.1-2014 and EN 397, the standard weight of safety helmets ranges from 350 g to 450 g with a maximum of 500 g. The helmets should fit head sizes ranging from 52 cm to 64 cm with internal padding and adjustable straps for ease and security of wear. The standards also require a gap of 20–50 mm between the helmet shell and the head to dissipate impact energy. (ANSI/ISEA, n.d)

Structural Integrity and Aviation Safety Regulations:

Structural integrity refers to the ability of the helmet to absorb shock without degrading or breaking. To OSHA 29 CFR 1910.135 and ANSI Z89.1, however, alteration of any type to a helmet drilling holes, painting, or applying stickers— vitiates certification and makes the shell liable to degradation. In aviation maintenance systems, especially in a regulatory environment like the Civil

Aviation Authority (CAA) and FAA regulations, helmets with any structural modifications made to their structure are completely banned as they compromise on the safety of the users. (OSHA, n.d)

In our project, while The Aeroguard Helmet requires sensors and wires for smart functionality, drilling holes in the ABS shell to accommodate these components could reduce its impact resistance. This compromises its ability to protect the wearer from dropped tools or debris, which is a critical danger in aircraft hangars and workshops. (PubChem, n.d)

Accordingly, to ensure the end product meets aviation safety standards, another mounting solution will be designed e.g., by utilizing internal fastening clips, industrial-rated adhesive mounts, or non-penetrating modular sensor enclosures. This will maintain the original integrity of the helmet and ensure full conformity with safety standards.

By correcting this structural flaw, the Aeroguard Helmet will meet both objectives of smart functionality and the strict non-modification regulation existing in the aviation maintenance workshops. (Aviation Maintenance Magazine, n.d)

2.2.1.2 Type Of Material For Product Structure

Aviation conditions demand that materials are not only light but also highly impact-resistant and safe. The Aeroguard Helmet achieves this through nonmetallic materials. The main shell of the helmet is made from Acrylonitrile Butadiene Styrene (ABS), which is highly regarded for its high strength-to-weight ratio, shock resistance, and resistance to chemicals and heat. ABS is used extensively in industrial safety gear due to its toughness and easy molding characteristics, allowing for the inclusion of embedded sensor slots without compromising exterior aerodynamics or user ergonomics.

The internal structure also includes light-energy-absorbing foams that mold themselves according to the user's head for increasing the contacting surface and facilitating comfort—akin to ergonomic aviation seats designed on the basis of human body outlines. The Aeroguard Helmet also involves modular layers that enable sensors and electronics to be installed, such as the Max4466 sound sensor, SW-420 vibration sensor, and LEDs, without hampering the configuration as a whole. (Arduino Project Hub, n.d; SparkFun, n.d)

For providing structural stability, utmost precautions are taken while placing sensors. Since drilling holes into the helmet would compromise it, all items inserted inside are placed into pre-molded spaces in the ABS helmet. This allows for the integration of intelligent technology without breaching workshop norms restricting modified safety gear. (PubChem, n.d)

Acrylonitrile Butadiene Styrene (ABS)

The outer shell of The Aeroguard Helmet is made from ABS, a lightweight but highly durable thermoplastic with excellent impact resistance, strength, and moldability. ABS is widely used in helmets and protective gear due to its ability to absorb and distribute impact energy well, reducing the risk of head injuries. It also meets industrial safety regulations, ensuring the helmet complies with aviation and workplace safety regulations. (PubChem, n.d)

Figure 6: Acrylonitrile Butadiene Styrene (ABS)

Flame-Retardant Coatings

To ensure that the helmet is fire-resistant, the materials, especially those used in the inner linings and sensor housings, are treated with flame-retardant coatings. These coatings prevent the spread of flames and ensure that the helmet remains safe and functional even in the case of exposure to high temperatures or fire.

Figure 7: Flame-Retardant Coatings

2.2.2 Product Mechanism
(MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

2.2.2.1 Noise Level Detection Sensor

The noise level detection system is a significant feature integrated into the smart helmet to protect workers from prolonged exposure to hazardous sound levels, which are common in aircraft hangars. The system utilizes a sound detection module, such as the Max4466 sound sensor or an electret microphone with analog output, that can detect sound pressure levels in real time (Components101, 2023). When the noise level exceeds a predetermined threshold (e.g., 85 dB), the sensor produces a signal to the Arduino controller, which triggers two key responses. One, the flat motor vibrator is activated to signal the worker with a strong sound. Two, a wireless module (Bluetooth HC-05 or Wi-Fi ESP8266) sends a message to the monitoring app, where the system flags the worker as being in a high-noise area. This enables supervisors to track real-time exposure to hazards and make safety decisions accordingly (Texas Instruments, 2020).

2.2.2.2 Vibration alarm system

The smart helmet employs a 400Hz Rectangular Mini Vibrating Mechanical Buzzer, a piezo transducer vibrator for small applications where silent but effective notifications are required. Instead of making sound, this vibrator generates a vibration frequency of approximately 400Hz, which is physically felt by the user, and is especially useful in noisy environments where audible notifications will be useless (CDC/NIOSH, 2023).

This vibration-based warning system is activated when any of the onboard sensors for example , noise level sensor pick up a signal indicating a perilous condition. The vibrator is activated through the Arduino Uno microcontroller, which executes real-time data and activates the vibrator by implementing logic embedded in the Arduino IDE (Arduino Project Hub, 2023).

2.2.2.3 Integrated Earmuff Deactivation System

The Integrated Earmuff Deactivation System requires some essential components to function smoothly. These are called as limit switch whose purpose is to identify earmuffs through the detection of physical contact. The conductive contacts must be suitably fitted into the earmuffs that these sensors can figure out appropriately whether it's connected or not. A microcontroller, such as an Arduino UNO , is required to interface the sensor signals and control the system (OSHA, 2022). An internal vibrator module has been added to provide warning signals when hearing protection is not in use. Wires to attach, mounting hardware, and an adequate power source, such as a battery or rechargeable module, are also required to allow for continuous use. Last but not least, embedded software logic needs to be programmed into the microcontroller for processing the sensor input and buzzer on-off control based on this (Texas Instruments, 2020).

2.2.2.4 Automatic Lighting System (Darkness Detection)

The Automatic Lighting System in the smart helmet usesr an LDR (Light Dependent Resistor). The LDR is a simple, analog sensor with dropping resistance as surrounding light increases, and is therefore suitable for use in simple light sensing purposes. The sensors are connected to an Arduino Uno microcontroller, which decodes the light intensity information. Upon the light intensity falling below a set threshold, the Arduino activates an integrated LED light module mounted on the helmet (Texas Instruments, 2020).

2.2.2.5 Fall Detection System

To protect workers from undetected falls, the helmet has a two-stage safety feature for impact and fall detection. When a sudden change or drop that appears to be a fall is detected, the system sends a "FALL DETECTED" notification to the supervisor monitoring application.

It is because, the helmet is fitted with a SW-420 Vibration Detector to sense impact (Components101, 2023). Upon a significant impact such as a collision of the head or a fall of the helmet , the SW-420 sensor detects the vibration and provides a definite signal to the Arduino.The SW-420 detects by identifying patterns of vibration exceeding a predetermined threshold. When such an impact is detected, it activates the microcontroller, which raises an independent warning labeled "HELMET IMPACT DETECTED" through the monitoring system .

2.2.3 Software/Programming

(THARSHAM MENAN A/L BALAKRISHNAN)

The Aeroguard Helmet relies mostly on embedded system programming, and the primary development environment is the Arduino IDE [Arduino,2023]. The software dictates how the sensors, display units, and security systems of the helmet respond to various environmental stimuli.

2.2.3.1 ARDUINO IDE

The Arduino Integrated Development Environment, or IDE, is the central software environment that is used to develop and upload code into the electronic parts of the Aeroguard Helmet (13). It is an open-source program with a simple interface that allows for the writing, compiling, and uploading of code into boards that have microcontrollers such as the ESP32 (Espressif, 2023). The IDE includes essential features such as text editor, compiler feedback space to show messages, toolbar of often used commands, and serial monitor for live interaction between the helmet and the computer it is plugged into. The Arduino IDE also supports the utilization of libraries and therefore can simply incorporate sensors such as the MAX 4466 microphone, LDR module, and SW-420 vibration sensor . In the Aeroguard Helmet, Arduino IDE is the gateway to controlling the system functionality from sensing environmental data to initiating alarms, lighting, or wireless notifications (Arduino Project Hub, 2023).

Figure 8: Arduino IDE

2.2.3.2 Progamming C++

The C++ programming language is used in the Arduino IDE to define the logical operations and behaviors of the Aeroguard Helmet's smart features (Arduino, 2023). C++ allows developers to program code to scan for input from the sensors of the helmet and define accompanying outputs or actions based on certain conditions (Electronics Hub, 2023). For example, if the Max4466 detects a noise level beyond the safety threshold, an if statement in C++ can turn on a buzzer or play a Bluetooth alarm using the ESP32. Likewise, the light sensor can initiate automatic lighting when there is low light. The SW-420 vibration sensor, upon triggering, can turn on alert messages or store movement data. C++ provides the capability of controlling timing precisely, reading sensor inputs in real-time, and controlling outputs such as displays, lights, and communication modules effectively (Random Nerd Tutorials, 2023). Its modular-style syntax and support for writing modular code make it ideal for controlling multiple Aeroguard Helmet subsystems, allowing the device to operate smoothly, securely, and responsively in all environments.

Figure 9: C++ Programming

Typical Features Used in Aeroguard Helmet Code:

1) Sensor Reading & Processing

- Reading sound levels from Max4466
- Reading brightness values from LDR module
- Detecting movement using SW-420 vibration sensor

```
// Sensor Reading & Processing
int soundValue = analogRead(A0);
int lightLevel = analogRead(A1);
int vibrationState = digitalRead(2);
// Basic processing
bool noiseExceeded = soundValue > 850)
bool lowLight = lightLevel < 300)
bool impactDetected = vibrationState
== HIGH)
```

Figure 10: sensor reading & processing code

2) Conditional Alerts

- Triggering alerts if noise exceeds safe levels
- Turning on lights if the environment is too dark

```
// Conditiional Alerts
if (noiseExceeded)
  triggerAlert(NOISE);
}

// Turning on lights if the environment
is too dark
if (lowLight)
  digitalWrite(LED_PIN, HIGH)
```

Figure 11: condition alert code

3) Display Integration

- Showing values or warning messages on an OLED/LCD

```cpp
display.setCursor(0,0);
display.print("Noise: ");
display.print(soundLevel);
```

Figure 12: Display integration code

4) Connectivity (ESP32 Only)

- Sending real-time data to a WEB app
- Wifi-based alerts or logs

```cpp
SerialBT.begin("GuardianHelmet"); // Bluetooth setup
SerialBT.println("Noise level alert!");
```

Figure 13: connectivity code

2.2.4 Accessories & Finishing

(DEVESH A/L THIYAGARAJAN)

In the domain of personal protective equipment (PPE), accessories and finishing are not merely cosmetic additions but serve critical functional and ergonomic roles, especially in safety helmets used in industrial and aviation maintenance settings (NIOSH, 2022). For smart safety helmets like the Aeroguard Helmet, accessories such as detachable earmuffs, integrated lighting systems, and protective coatings significantly contribute to both user safety and device reliability.

Detachable earmuffs are an essential accessory that addresses one of the most prevalent hazards in aviation hangars, excessive noise. Aircraft engine run-ups, pneumatic tools (HSE UK, 2023), and auxiliary systems often generate noise levels exceeding 85 dB, which can lead to permanent hearing damage if unprotected. Traditional earmuffs offer sound insulation but lack flexibility. In contrast, detachable earmuffs provide dual benefit, they offer effective noise suppression during operation and allow users to remove or replace them as needed for hygiene, maintenance, or operational convenience. This modular design is especially beneficial in shared PPE environments or long-duration tasks that require intermittent communication or breaks (3M Safety Division, 2020).

Another key finishing element is the integrated LED light, mounted on the front of the helmet to assist in low-light conditions. This feature becomes crucial when technicians are required to work under aircraft fuselages, in dim hangars, or during night shifts (Ergodyne, 2019; Lin & Huang, 2020). Unlike external flashlights or handheld torches, built-in LED lighting ensures hands-free operation, improves task precision, and reduces the likelihood of accidental slips or errors caused by poor visibility (Ergodyne, 2019).

From a materials and durability perspective, industrial-grade finishing is vital to preserve the functionality of embedded electronics and maintain the helmet's structural integrity. The Aeroguard Helmet employs heat-resistant, waterproof, and anti-scratch coatings on its Acrylonitrile Butadiene Styrene (ABS) shell, a

thermoplastic polymer known for its toughness and impact resistance. Such coatings prevent environmental damage from moisture, temperature fluctuations, and abrasive contact conditions commonly found in maintenance workshops, airfields, and mobile repair units (R.E Lyon, 2008).

Additionally, modern helmet design incorporates weather-resistant decals, reflective strips, and ergonomic padding that not only improve aesthetics but also enhance usability and visibility.

For instance, reflective labels improve worker visibility in low-light areas, and ergonomic pads reduce pressure points during extended use (ANSI/ISEA z89, 2014; MSA Safety, n.d). These finishing features transform the helmet from basic safety gear into a multifunctional, user centred wearable device.

In summary, accessories and finishing features in smart helmets are essential elements that elevate the practicality, safety, and comfort of PPE systems. For the Aeroguard Helmet, these elements are not optional, they are integrated intentionally to meet the complex demands of modern aviation maintenance and industrial operations (NIOSH, 2021). They ensure the helmet complies with safety regulations, enhances worker experience, and withstands environmental stressors while remaining modular and visually appealing.

2.3 REVIEW OF RECENT RESEARCH / RELATED PRODUCTS

2.3.1 RECENT MARKET PRODUCT

2.3.1.1 PRODUCT A (NANTHAKUMARAN A/L VASU)

Table 2.3.1.1: Comparison with MSA V GARD 930 SAFETY HELMET

NO	MARKET PRODUCT	PRODUCT SUMMARY
3	**Figure 14: MSA V GARD 930 SAFETY HELMET**	**Product Name:** MSA V-Gard 930 Safety Helmet with Fas-Trac III Straps **Published Date:** [Date Not Specified] **Manufacturer:** MSA Safety **Model Number:** V-Gard 930 **Description:** MSA V-Gard 930 Safety Helmet is designed for use in industrial workplaces, offering a light and comfortable design. It has the Fas-Trac III suspension system to ensure comfort and adjustability. The helmet provides impact and penetration protection to meet ANSI/ISEA Z89.1-2014, Type I, Class E requirements. It features a UV indicator that will show when it's time to replace the helmet due to sun exposure. **Source:** RS Malaysia

2.3.1.2 PRODUCT B (THARSHAM MENAN A/L BALAKRISHNAN)

Table 2.3.1.2: comparison with Vented Hard Hat

NO	MARKET PRODUCT	PRODUCT SUMMARY
2	**Figure 15: Vented Hard Hat**	**Product Name :** Vented Hard Hat with Light, Cap Style, Ratchet Suspension, Class C, Ergodyne Skullerz 8972LED Orange **Published Date:** August 9, 2019 **Manufacturer:** Ergodyne **ASIN:** B07W4XFRZC **Description:** The Skullerz 8972 Class C Cap-Style Hard Hat + LED Light with 4-point suspension is heavy-duty, yet lightweight and comfortable head protection built to protect the top of the head from falling objects or bumping into stationary objects. A padded, moisture-wicking and odor-resistant sweatband and top pad lines the sides, forehead and top interior and is removable for easy replacement.This cap-style brim can be worn backwards to improve upward visibility or forward to keep sun and rain away from the eyes.The open frame design in combination with the adjustable venting offers the best of both worlds: a cooler hard hat in the heat and a dry hard hat in the rain. Customize the size with the easy-to-adjust 4-point premium ratcheting suspension (Ergodyne, 2023).

2.3.1.3 PRODUCT C (MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

Table 2.3.1.3: Comparison with Bullard Classic C30

NO	MARKET PRODUCT	PRODUCT SUMMARY
3	 **Figure 16: Bullard Classic C30**	**Product Name:** Bullard - Classic C30 - Hard Hat Safety Helmet 6 Point Suspension - Color: 6pt Ratchet Hi-Viz Orange. **Published Date:** May 23, 2014 **Manufacturer:** Bullard **ASIN:** B00KJ21UJY **Description:** Bullard Classic Series Hi-Viz Orange Polyethylene Hard Cap with Full-Brim And 6 Point Flex-Gear Ratchet Suspension is perfect for most applications. It features a replaceable cotton brow pad and 1" wide seamless nylon crown straps for comfort. It has Yes fluorescent colors which heighten visibility with front, side and rear vertical height adjustments. Cap meets or exceeds ANSI/ISEA Z89.1-2009, Type I Class E and G and CSA Z94.1-2005 standards.(Bullard, n.d).

2.3.1.4 PRODUCT D (DEVESH A/L THIYAGARAJAN)

Table 2.3.1.4: Comparison with MSA V-GARD Safety Helmet

NO	MARKET PRODUCT	PRODUCT SUMMARY
3	 **Figure 17: MSA V-GARD Safety Helmet**	**Product Name:** MSA V-Gard® H1 Trivent Safety Helmet **Published Date:** [Date Not Specified] **Manufacturer:** MSA Safety Incorporated **Model Number:** 10194783 **Description:** : The MSA V-Gard H1 Trivent Safety Helmet is purpose-built for workers operating at height, offering an ideal blend of comfort and technical functionality. Unlike traditional hard hats, this helmet is engineered for advanced head protection in dynamic environments such as construction, rescue operations, and industrial maintenance. The Trivent model specifically features three strategically placed ventilation openings to maximize airflow, helping to reduce heat buildup in hot climates. The non-contact foam liner improves hygiene and comfort by creating space between the head and shell, and a removable, moisture-wicking headband ensures all-day wearability. The 4-point chinstrap includes a built-in whistle for emergency signalling and ensures the helmet stays securely fastened, even in active situations. (R.E. Lyon, 2008).

2.3.2 COMPARISON BETWEEN RECENT RESEARCH AND CURRENT PROJECT

2.3.2.1: MSA V-Gard 930 Safety Helmet vs.The Aeroguard Helmet (PRODUCT A)

Table 2.3.2.1 MSA V-Gard 930 Safety Helmet vs.The Aeroguard Helmet

Feature	MSA V-Gard 930 Helmet	The Aeroguard Helmet
Main Idea	High-end industrial safety helmet offering passive head protection with high comfort and visibility.	Intelligent safety helmet integrating physical protection with smart features like lighting, noise sensing, and mobile connectivity.
Key Features	ABS shell, Fas-Trac III suspension system, integrated visor, ventilation slots, ANSI/ISEA Z89.1 compliance.	Auto-activating LED lighting, real-time noise level detection, alert notification system, ergonomic design, and app-based data interface.
Innovation	Enhanced helmet with greater comfort and optional eye protection, but no active safety features.	Enhances conventional helmet design with active safety features that actively detect environmental threats.
Limitation	Lacks electronic capabilities or environmental sensitivity; only available as physical protection equipment.	Dependent on batteries; more complexity and cost; requires periodic maintenance for electronic components.

2.3.2.2 :Ergodyne Skullerz VS The Aeroguard Helmet (PRODUCT B)

Table 2.3.2.2 : Ergodyne Skullerz VS The Aeroguard Helmet

Aspect	Ergodyne Skullerz	The Aeroguard Helmet
Main Idea	A rugged, light industrial hard hat for all-round industrial wear. Provides head protection and includes a basic LED light for illumination.	A smart safety helmet designed for aviation maintenance, combining physical protection with smart features like sensors, alarms, lighting, and remote monitoring.
Key Features	- 4-point ratcheting suspension - Moisture-wicking sweatband - Adjustable vents - Internal LED light - Forward and backward wear	- Automatic light sensor LED light - Alarm system noise level detection - In-built earplugs - Remote monitoring using app - Adjustable and comfortable fit
Innovation	New fundamentals with integrated LED and venting adjustability for comfort.	State-of-the art features like intelligent lighting, sound detection, real-time alerting, and cellular connectivity for worker safety and supervisor monitoring.
Limitation	Lacks advanced features like sensors, alarms, or smart integration. Not approved for aviation or noisy/dark environment maintenance.	Could require higher cost due to technology, presently still in development stage (prototype or pilot model), and may need further testing for full certification in industrial environments.

2.3.2.3: Bullard C30 Hard Hat vs. The Aeroguard Helmet (PRODUCT C)

Table2.3.2.3: Bullard C30 Hard Hat vs The Aeroguard (PRODUCT C)

Aspect	(Bullard C30 Hard Hat)	(The Aeroguard Helmet)
Main Idea	Basic, lightweight hard hat providing passive protection from impact and falling objects.	Smart helmet combining impact protection with built-in lighting, noise detection, alert systems, and mobile app integration.
Key Features	HDPE shell, four-point suspension, accessory compatible (earmuffs, face shields), no internal electronics.	Integrated LED lights, noise exposure tracking, alert warnings, ergonomic design, app connectivity, potential add-ons like environment or gas sensors.
Innovation	Traditional design focused solely on passive safety; relies on external add-ons for extra functions.	Advances traditional helmets by integrating smart, active safety features, improving situational awareness and worker protection.
Limitation	No electrical functionality; cannot detect dangers; only capable of offering physical protection; accessories will need to be manually installed.	Needs electricity and maintenance via batteries; higher cost; increased complexity to standard hard hats.

2.3.3.4 :MSA V-Gard H1 Trivent Safety Helmet vs. The Aeroguard Helmet (PRODUCT D)

Table 2.3.3.4 :MSA V-Gard H1 Trivent Safety Helmet vs. The Aeroguard Helmet (PRODUCT D)

Aspect	MSA V-Gard H1 Trivent Safety Helmet	(The Aeroguard Helmet)
Main Idea	Premium industrial helmet for height work, rescue, and confined spaces, focusing on comfort, airflow, and standard safety compliance.	A next-generation smart safety helmet integrating PPE with real-time monitoring, lighting, and communication for proactive safety with integrated detachable earmuffs and LED lighting for enhanced safety and visibility.
Key Features	- Tri-vent airflow design for cooling - Fas-Trac® III ratchet suspension - 4-point chinstrap with whistle - Integrated accessory rails and light clips	- Detachable earmuffs for noise protection - Front-mounted LED strip for illumination - Rechargeable lithium battery power
Innovation	- Tool-free accessory system - Reflective striping standard - Lightweight HDPE shell with no-contact foam liner - Mountaineering helmet certification (EN 12492)	- Fall detection & SOS alert system - Multi-function lighting integration - Modular ear protection - Custom electronics integration using Arduino
Limitation	- No built-in lighting - No integrated hearing protection - Higher cost - Limited customization for electronics	- Still in prototype stage - Requires certification to ANSI/EN standards - Requires electricity (battery dependent) - Slightly higher cost due to smart features - Needs occasional maintenance for electronic

CHAPTER 3

RESEARCH METHODOLOGY

3.1 PROJECT BRIEFING & RISK ASSESSMENT

3.1.1 Utilisation of Polytechnic's Facilities

AeroGuard Helmet project development was done with the facilities and equipment that Politeknik Banting Selangor offered. During the project period, several laboratories were used such as electronics lab, mechanical workshop, CAD lab, and prototyping room, hence making sure that the due engineering processes would be safe and efficient. Availability of these facilities allowed developing structural parts, sensor testing, ESP32 microcontroller programming and the prototype assembly.

When undertaking any practical, strict compliance with the safety measures was observed. Safety goggles, anti-static wrist straps, and gloves were worn where necessary as a form of personal protective equipment (PPE). Soldering, circuit, and voltage calibration were done using electrical benches, whereas cutting, drilling and attaching components on the helmet were done using the mechanical benches. With the access to CAD computers, it was possible to create precise 2D and 3D drawings to be used in structural planning. Such facilities provided that the project implementation was conducted under controlled conditions and reduced the number of risks to the team members, not to mention that the tools and materials were properly handled

3.1.2. Project Collaboration/Transfer of Technology

The project has been built by teamwork and every member of team was given certain tasks based on their capabilities and abilities. The project supervisor was a source of unrelenting instructions at each stage of the project, as well as, engineering principles were put into proper practice. Sharing of knowledge was done frequently in the form of group discussions, peer demonstrations, technical briefing and prototype evaluation.

The transfer of technology was made possible by being exposed to programming tools, including Arduino IDE, IoT dashboards, and ESP32 communication protocols. Also, the experience of working with sensors like the LDR module, the MAX4466 sound sensor, and SW-420 vibration sensor were obtained practically. Technical capabilities like component assembly, wiring and structural support, and design were also exchanged between team members. Such cooperative atmosphere ensured the information flow, effective solving of problems, and orderly accomplishment of tasks.

PROJECT ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Project planning (Phase 1) • Give the AeroGuard Helmet idea to team members • Share the project requirements and expectations • Provide initial hardware and system design concepts	▓	▓	▓												
Trial Software & Hardware (Phase 2) • Test Arduino programming and sensor functionality • Identify and fix software or hardware issues • Implement necessary refinements and improvements				▓	▓										
Design Poster & Demonstration (Phase 3) • Review and gather feedback on the project poster • Prepare presentation slides and demonstration video • Review with supervisor					▓	▓	▓								
Project Progress Presentation (Phase 4) • Update logbook and progress reports • Final slide presentation and submission • Present the project to panel								▓	▓	▓					
Additional Achievements & Final Deliverables (Phase 5) • Participated in multiple innovation competitions to showcase the AeroGuard Helmet, including Aeromech Competition • Completed the full project thesis, ensuring all technical, analytical and experimental documentation met academic requirements and submitted it for evaluation. Handover the helmet to PBS.											▓	▓	▓	▓	▓

Chart 3.2 : overall project gantt chart

3.3 PROJECT FLOW CHART

3.3.1 Overall Project Flow Chart

Chart 3.3.1 : Overall project flowchart

A general workflow diagram was developed to show the most important steps in the project implementation. The flow chart was presented as a stepwise process beginning with the first identification of the problem that the industrial workers had and that was followed by literature review, analysis of survey, conceptual design, choice of design approach,prototype production, integration of sensors and electronics, testing methods, data collection, troubleshooting, simplification of improvements and final examination. This methodical stream of flow has made sure that all the phases of the project have been set in accordance with the appropriate engineering method.

3.3.2 Specific Project Design Flow / Framework

3.3.2.1 Product Structure

(NANTHAKUMARAN A/L VASU)
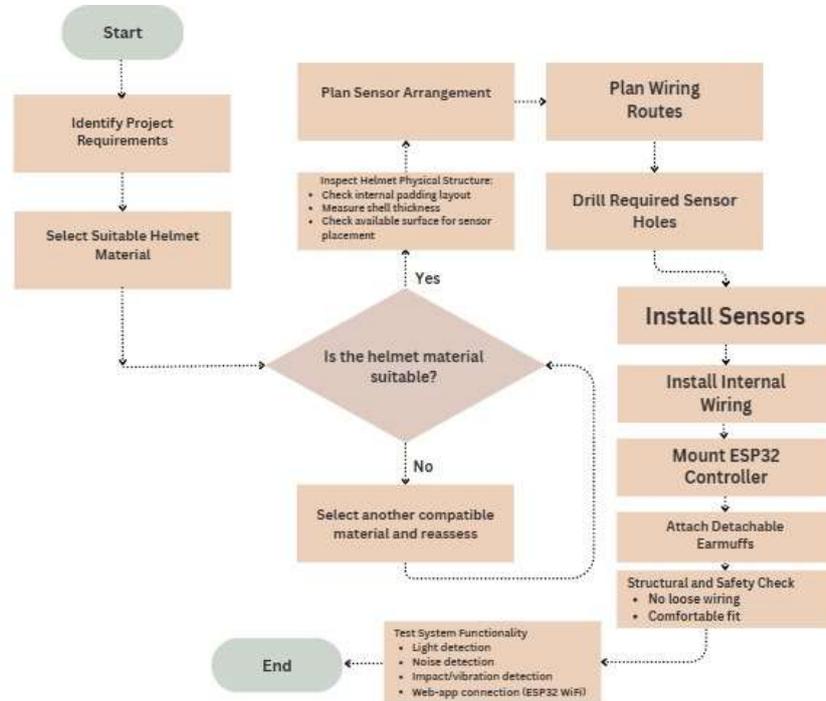
Chart 3.3.2.1 : Product structure's flow chart

The process of structural design involved the identification of the right type of helmet material. The use of ABS plastic was caused by the attributes of plastic, durability, strength, impact resistance and light weight. Preliminary drawings were done in order to see how the sensors would be placed, where the LEDs would be, where the battery compartment would be and where the internal wiring would be, in order to verify dimensions, ergonomics and integration of components. It created different versions of design to make it comfortable to the user, the optimal distribution of weight, and effective positioning of internal parts. The necessary structural reinforcements were also introduced so as not to cripple the electronic modules at the expense of the wearer in terms of comfort and safety.

3.3.2.2 Product Mechanisms
(MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)
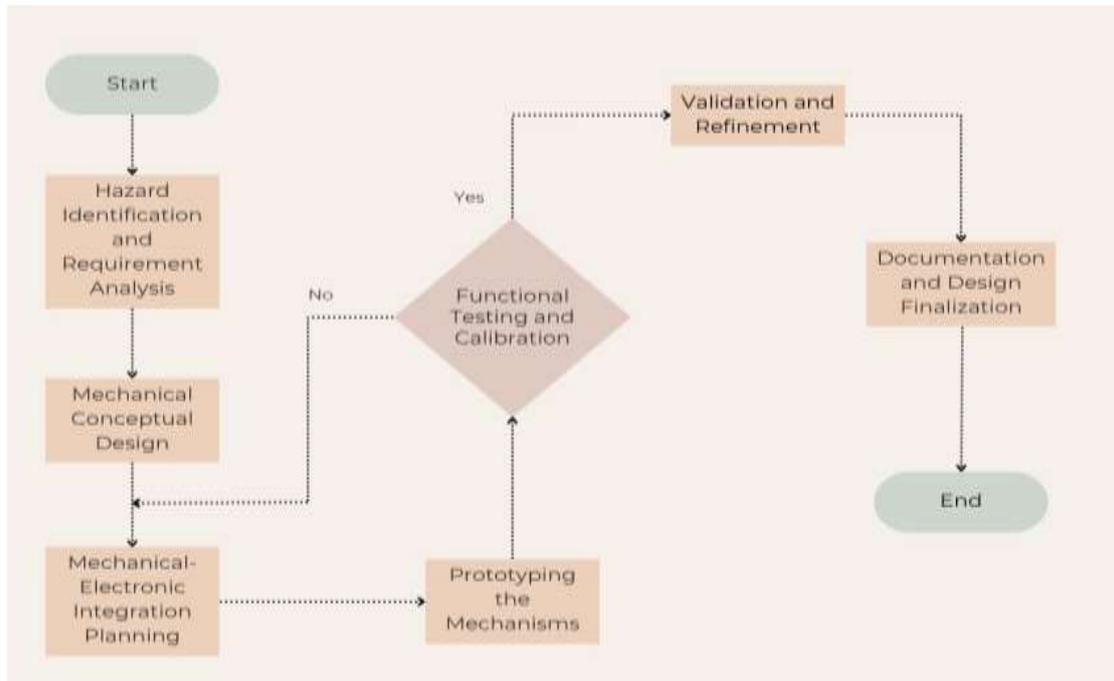
Chart .3.3.2.2 : Product mechanism's flow chart

Moving, removable, or movable parts were made to work well, and the mechanical mechanism was created in such a way that all the aforementioned parts worked properly. This also involved the incorporation of removable earmuffs, sensor bracket mounting, LED fittings, wire conduits, and board holders. Various prototypes were tested to ascertain the best point of location of the sensors to ensure maximum accuracy. The modifications were done to deal with such problems as internal space constraints, vibration interference, wiring discomfort, and sensor positioning. Every change was retested until optimum stability, durability, and functionality of the mechanical layout were obtained.

3.3.2.3 Software/ Programming
(THARSHAM MENAN A/L BALAKRISHNAN)
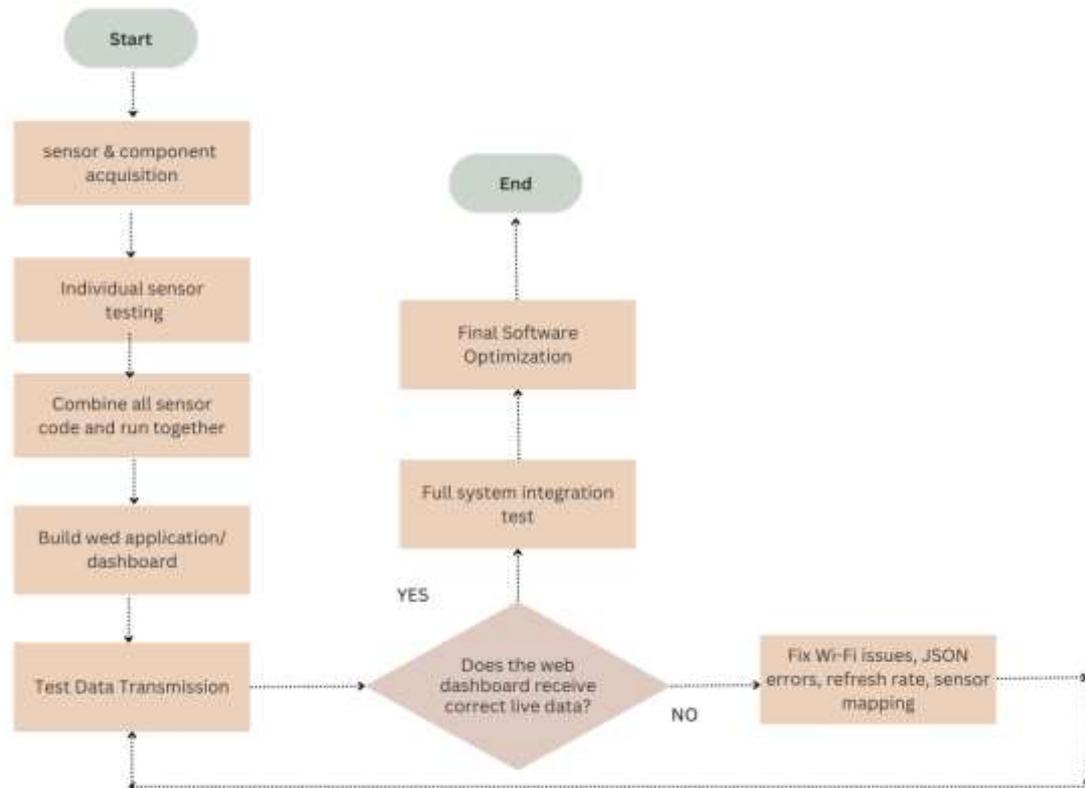
Chart 3.3.2.3 : Software/Programming's flow chart

The programming process began with the setup of ESP32 microcontroller. Sensor libraries were brought in and calibrated, individually, and include:

- ESP 32

- LDR for automatic lighting.

- Noise sensor microphone sensor ,MAX4466.

- SW-420 impact sensor (vibration sensor).

There was the use of conditional programming logic so that correct responses are given under different environmental conditions. The IoT connectivity were intended to be built with WiFi-enabled capabilities to obtain real-time information based on a web dashboard. To confirm wiring connections, power distribution, and input / output relationships, a block diagram and schematic circuit layout was generated. Several investigations on debugging were conducted to remove false triggers, sensor interference and unstable measurements.

75

3.3.2.4 Accessories and Finishing (DEVESH A/L THIYAGARAJAN)
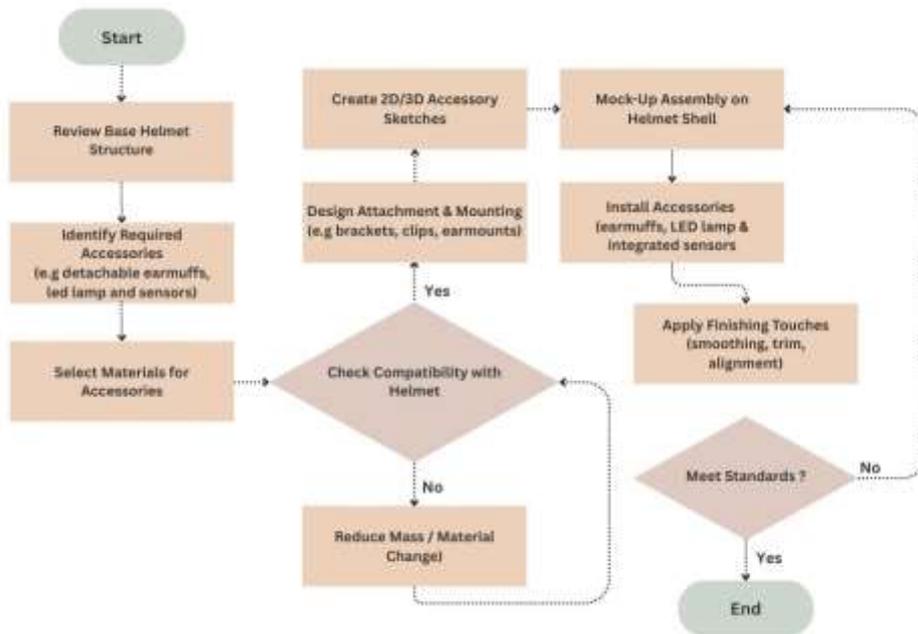
Chart 3.3.2.4 : Accessories and finishing's flow chart

The final process was to polish the appearance of the helmet on the outside and make sure that all the parts were covered. Internal padding was done using soft interiors, wire coverings, and surface finishing treatment to add comfort and beauty. Neat wiring paths were also given special consideration whereby internal cables were not to irritate the wearer. The finalisation of outside visual improvements like the alignment of LED strips, colour consistency and the location of accessories were done on the basis of ergonomics and safety. It was the last prototype which was polished to give a complete and professional look.

3.4 DESIGN ENGINEERING TOOLS
3.4.1 Design Requirement Analysis
3.4.1.1 Questionnaire Survey

A survey was sent to the selected participants such as aviation students, hangar workers and industrial personnel to provide information on the current safety helmet constraints. The feedback showed that there were problems with lack of smart features, low light, noise detection and Alerts of impact. The analysis of the survey was done to find out the expectation of the users which formed the basis of the design requirements of the project.

B1. ARE YOU SATISFIED WITH THE CURRENT SAFETY HELMET ?
84 responses
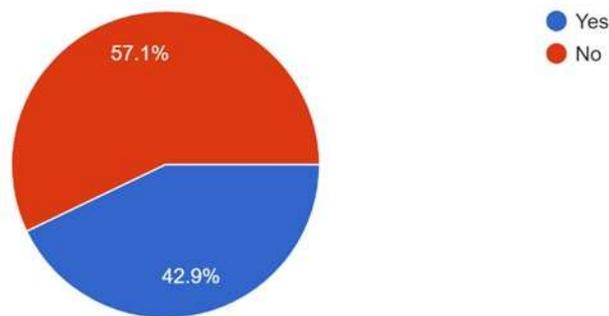
Figure 18 :satisfaction of current safety helmet

1)   Firstly, we begin the data analysis in the section B about their problem with basic safety helmet. The question which asks the user do they satisfied with the current safety helmet and majority of the user answer no which is 57.1 % (48 total) and yes answer is about 42.9 % (36 total).

B2. DO ALL EMPLOYEES WEAR CONSISTENTLY IN AREAS WHERE HEAD PROTECTION IS REQUIRED?

84 responses
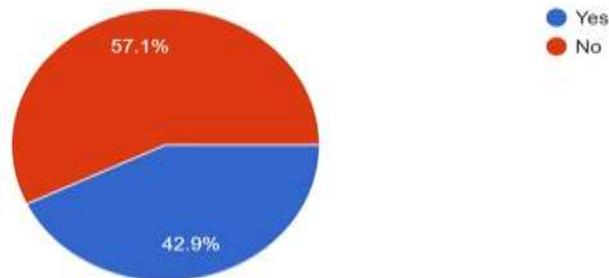
Figure 19 : how consistent they wear safety helmet

2)   We then ask the user do all employees wear consistently in areas where head protection is required and majority of the user answer no which is 57.1 % (48 total) and yes answer is about 42.9 % (36 total).

B3. ARE ALL EMPLOYEES PROVIDED WITH SAFETY HELMET THAT MEET THE REQUIRED SAFETY STANDARD ?

84 responses
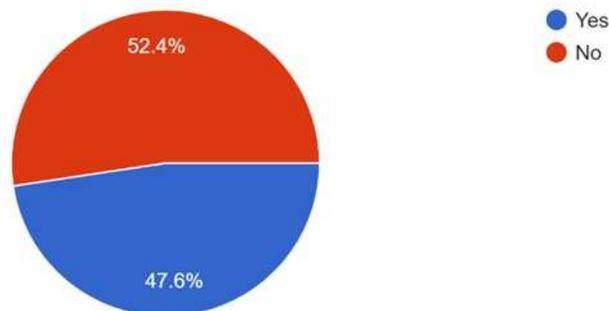
Figure 20 : availability of required safety helmet

3)   The next question does all employees are provided with safety helmet that meet the required safety standard and majority of the user answer no which is 52.4% (44 total) and yes answer 47.6% (40 total) at the hangar which they might be technician or engineer of aircraft maintenance or other potential user.

B4. IS THE HELMET EFFECTIVE AT PROTECTING AGAINTS SPECIFIC HAZARD RELATED TO THE WORK ENVIROMENT ? (e.g Falling object)

84 responses
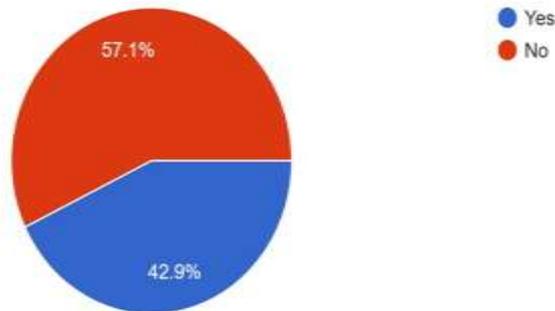
Figure 21 : Helmet Effectiveness

4)   The next question we ask the user is the helmet effective at protecting against specific hazard related to the work environment (Example falling object) and the majority of the user answer no which is 57.1% (48 total). There also same percentage on the answer yes which is at 42.9% (36 total).

B5. DOES THE HELMET PROVIDE PROPER CLEARANCE FOR HEARING PROTECTION OR OTHER PERSONAL PROTECTIVE EQUIPMENT (PPE) ?

84 responses
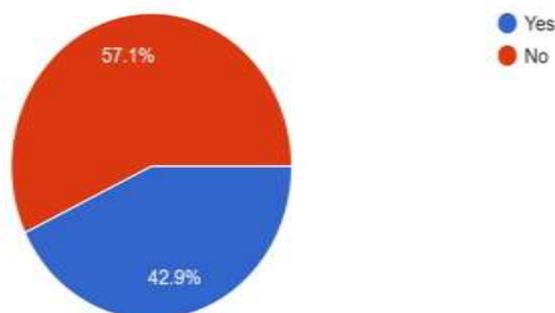
Figure 22 : Response about Clearance For Hearing Protection/ PPE

5)   Last question in section B, we then ask the user does the helmet provide proper clearance for hearing protection or other personal protective equipment (PPE) and majority of the user answer no which is 57.1% (48 total) and answer yes 42.9% (36 total).

C1. WOULD YOU FIND A FALL ALERT SYSTEM IN THE HELMET USEFUL ?
84 responses
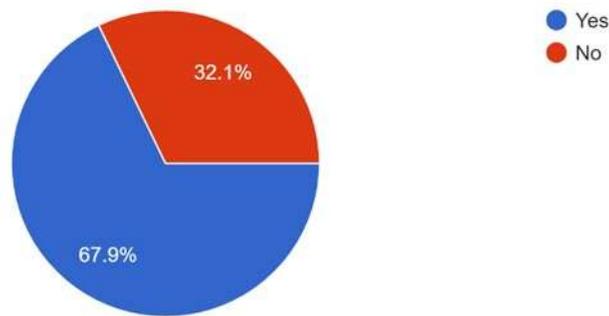
Figure 23: Usefulness Of Fall- Alert System

6) We then move to the section C, which ask the user if their find a fall alert system in the helmet useful and majority of the user answer yes which is 67.9% (57 total) and 32.1% (27 total) answer no.

C2. DO YOU THINK HELMETS CAN BE IMPROVED TO PROVIDE BETTER PROTECTION BY MONITORING SAFETY CONDITION VIA AN APP ?
84 responses
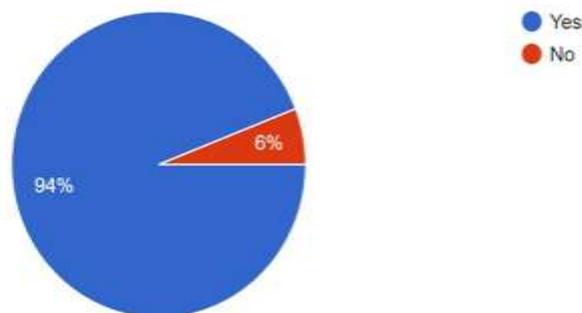
Figure 24: improvement of safety helmet via APP based monitoring

7) We then ask the user if their think safety helmets can be improved to provide better protection by monitoring safety condition via an app and majority of the user answer yes which is 94.0% (79 total) and 6.0% (5 total) answer no.

C3. DO YOU THINK A HELMET WITH SPECIAL ADVANCED SAFETY FEATURE WILL HELP
MAINTENNANCE PERSONAL AT THE WORKPLACE ?

84 responses

Figure 25 : Importance of advanced safety features

8)   We then ask the user if their think a helmet with special advanced safety
feature will help maintenance personal at the workplace and majority of the
user answer yes which is 96.4% (81 total) and 3.6% (3 total) answer no.

C4. HOW IMPORTANT IS A AUTOMATIC LIGHT IN A HELMET FOR A JOB IN DARK PLACES ? (Give a
rate 1-5)

84 responses
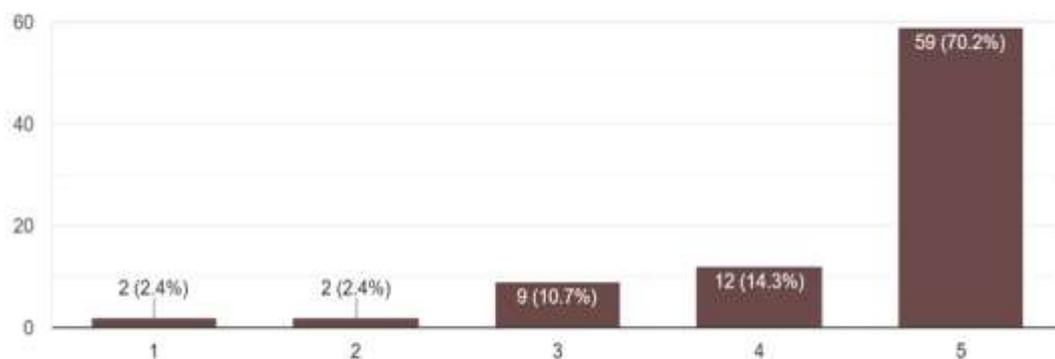
Figure 26: Importance of automatic lighting

9)   The next question we ask the user if the important is an automatic light
in a helmet for a job in dark places and majority give rate 5 (70.2%), rate 4
(14.3%), rate 3 (10.7%), rate 2 (2.4%) and for rate 1 (2.4%).

81

C5. WOULD YOU FIND IT USEFUL IF A HELMET HAD NOISE DETECTION AND AN ALARM SYSTEM ?
(Give a rate 1-5)

84 responses
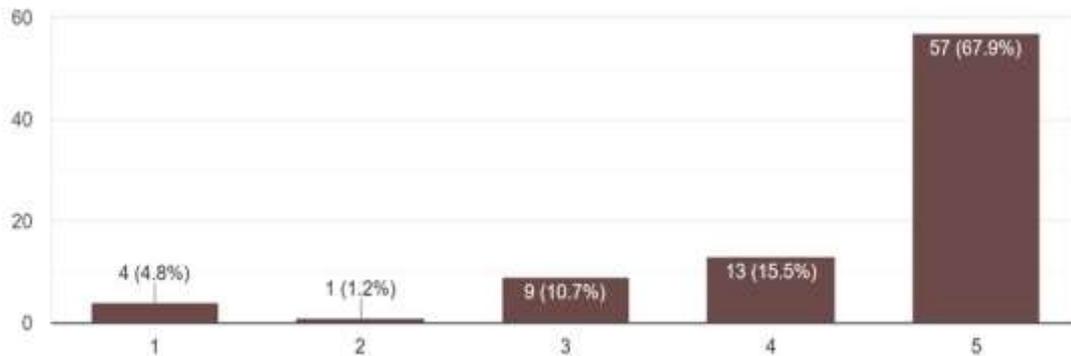
Figure 27: Usefulness of noise detection with alert system

10)   Last question in section C, we ask the user if their find it useful if a helmet had noise detection and an alarm system and majority give rate 5 (67.9%), rate 4 (15.5%), rate 3 (10.7%), rate 2 (1.2%) and for rate 1 (4.8%).

D1. IF A NEW SMART SAFETY HELMET DESIGN DEVELOPED , PLEASE RATE THE IMPORTANCE OF THE FOLLOWING DESIGN CRITERIA BASED ON YOUR PREFERENCE.
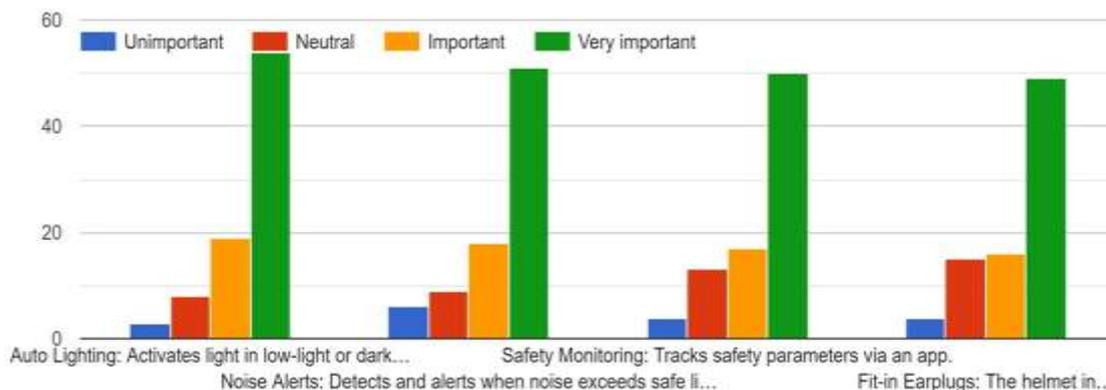
Figure 28: Rating of smart safety features

11)   Then we move to section D, we ask there if a new smart safety helmet design developed, please rate the importance of the following design criteria based on their preference. The majority of users agree with the auto lighting that activates light in low-light or dark during maintenance in the aviation industry, around 54 total answer is very important.

82

Figure 29: Importance of safety criteria

12)   Next, we ask there is important are the following features in a helmet designed for maintenance personnel's safety, considering factors such as reliability, strength, safety, efficiency, flexibility, and durability. Our respondent agreed the most important is safety of the helmet includes features to protect workers from risks such as high noise levels, impacts, or accidents in hazardous environments, around 54 total.

D3. DO YOU FEEL CONVINCED THAT THE FEATURES OF THIS HELMET (INCLUDING AUTOMATIC LIGHTHING SYSTEM, NOISE LEVEL DETECTOR, F...PROTECTION AND IMPROVE YOUR WORK SAFETY?"
84 responses
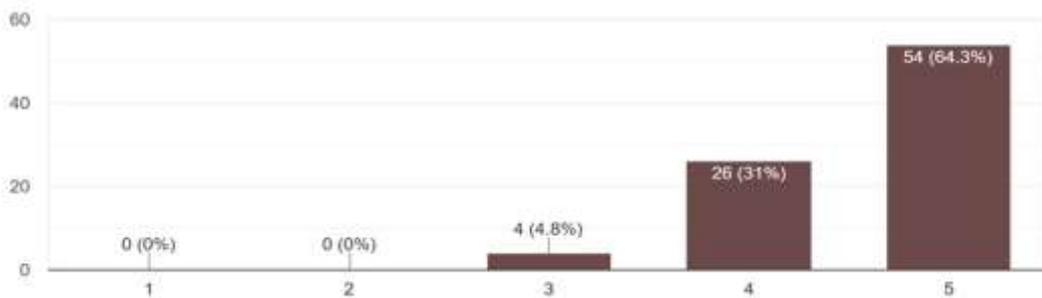
Figure 30: Response of smart safety helmet features

13)   Last question in section D, we ask the user if their feel convinced that the features of this helmet (including automatic lighting system, noise level detector, fit-in earplug and safety monitoring) would provide adequate protection and improve your work safety and majority give rate 5 (64.3%), rate 4 (31.0%), rate 3 (4.8%), rate 2 (0%) and for rate 1 (0%).

3.4.1.2 Pareto Diagram

Table 3.4.1.2 : Datas of Pareto Diagram

FEATURES	FREQUENCY	CUMMULATIVE	TOTAL PERCENTAGE	CUMMULATIVE PERCENTAGE	PARETO BASELINE
Reliability	356	**356**	17.22%	17.22%	80%
Strength	325	**681**	15.72%	32.95%	80%
Safety	371	**1052**	17.95%	50.90%	80%
Flexibility	329	**1381**	15.92%	66.81%	80%
Durability	321	**1702**	15.53%	82.34%	80%
Efficiency	365	**2067**	17.66%	100.00%	80%
Grand Total	2067	2067	100.00%	100.00%	
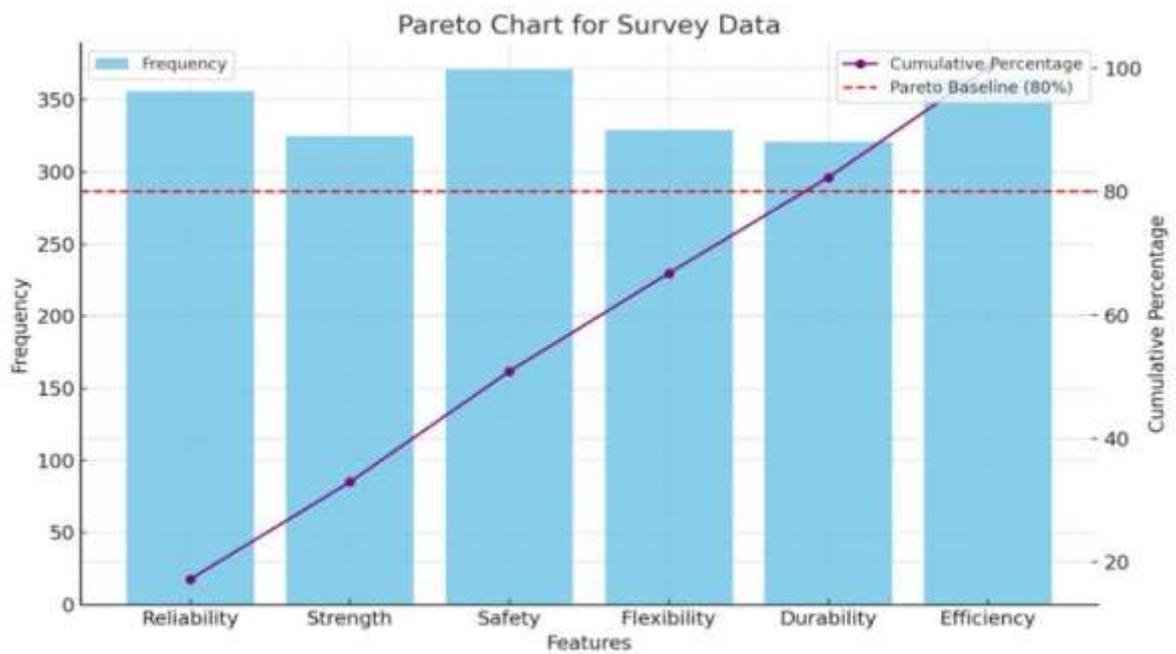
Chart 7 : Pareto chart

- **The highest vote: Safety (371 votes)**

- **The lowest vote: Durability (321 votes)**

- **Baseline Pareto: 80%**

84

3.4.2 Design Concept Generation

3.4.2.1 Function Tree
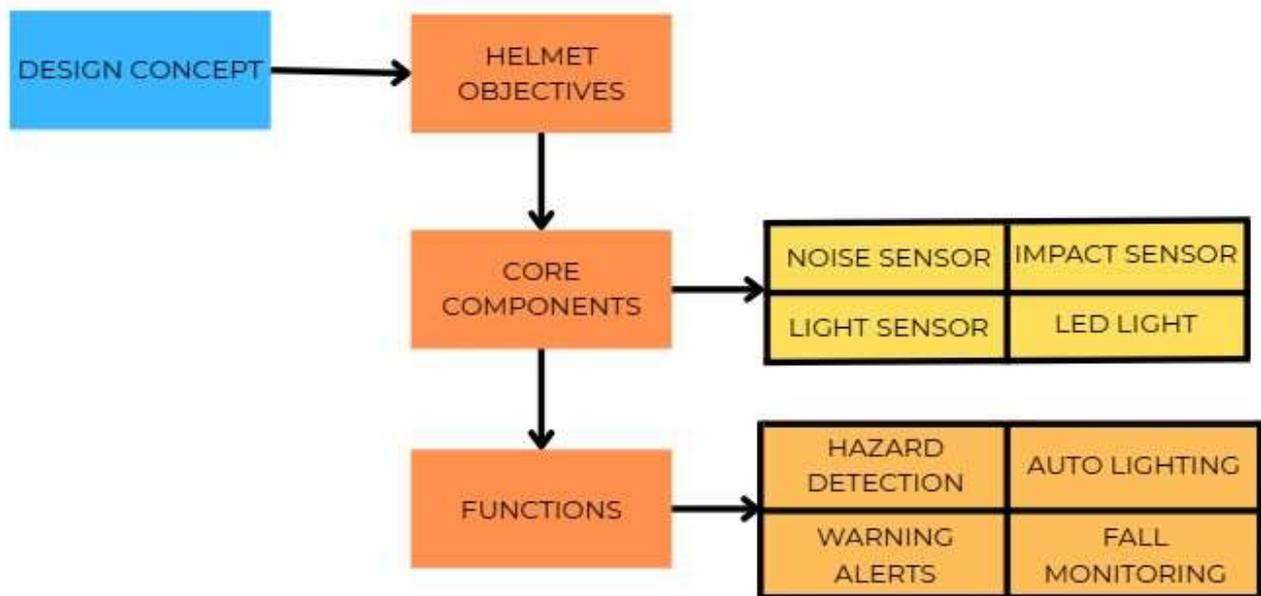
3.4.2.2 Morphoogical Matrix

Table 3.4.2.2 : Morphological Matrix

Function	IDEA 1	IDEA 2	IDEA 3	IDEA 4
Type	Safety Helmet (ABS)	Safety Helmet (Polycarbonate)	Carbon Fiber Helmet	Safety Helmet High-Density Polyethylene (Hdpe)
Software	Arduino Ide	Arduino Ide	Platformio (Vs Code Extension)	Mobile Software (Everbridge)

Hardware	Arduino Esp32	Arduino (Esp32)	Esp32-S3 Devkitc	Arduino (Esp32-S3)
	Noise Detector (Max4466 Sound Sensor)	Arduino Sound Sensor (Db Meter)	Ky-038 Sound Sensor	Adafruit I2s Mems Microphone (Sph0645lm4h)
	Ldr (Light Dependent Resistor) / Tsl2561 Digital Light Sensor	Light Sensor (Ldr / Tsl2561)	Bh1750 Digital Light Sensor	Ams Tsl2591 – High-Precision Light Sensor
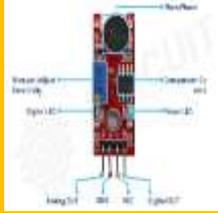
	Vibration Detector (Sw-420)	Vibration Sensor (Sw-420 / Adxl345 Accelerometer)	Bosch Bma400 Ultra-Low Power Accelerometer	Mpu-6050 – 6-Axis Gyroscope & Accelerometer (Best For Motion & Vibration)
Lighting System	Led Strip	Automatic Strip Led Light Waterproof	Automatic Led Light (2835 Smd Led)	Cob Headlamp Led Motion Sensor Head Torch Headlight Lamps Waterproof

Ear Protection	Ear Plug	Detachable Earmuff	Peltor X5a Ear Muffs	3m Peltor X4 Ear Defender With Headband, 32db
Programming Language	C++	C++	C++	Python
Power Supply	Lithium Polymer (Li-Po)	Rechargeable Lithium-Ion Battery	Solar-Powered Li-Po Rechargeable Battery	Turnigy Nano-Tech 1000mah 3.7v 1s Lipo Battery

3.4.2.3 : Concept 1 Generation Of 7 Basic Instruments On The Aeroguard Helmet: (THARSHAM MENAN A/L BALAKRISHAN)

Table 3.4.2.3 : Concept1 Generation Of 7 Basic Instruments On The Aeroguard Helmet

FUNCTION	CONCEPT 1	JUSTIFICATION
TYPE	Safety Helmet (ABS)	Made of Acrylonitrile Butadiene Styrene (ABS) material, lightweight but very strong. Lightweight and strong, meets safety standards, and provides room for sensors. Other than that, Cheap and easy to obtain.
SOFTWARE	ARDUINO IDE	Allows programming of microcontrollers like Arduino for interfacing with sensors.
HARDWARE	1. Arduino Circuit board	Able to connect with various sensors, offering excellent processing capacity and connectivity with other sensors.
	2. LDR (Light Dependent Resistor) / TSL2561 Digital Light Sensor	– Detects low-light conditions to activate the automatic lighting on the helmet. – TSL2561 provides accurate ambient light readings.
	3. Noise Detector (Max4466 Sound Sensor)	The Max4466 Sound Sensor is highly sensitive, offers analog and digital output, has adjustable sensitivity allows you to fine-tune the sound detection, low power

		(3.3V–5V), and it easily integrate with Arduino and ESP32.
	4. Vibration Detector(Sw-420)	- SW-420 perceives intense vibrations such as fall impacts.
LIGHTING SYSTEM	Automatic LED strip light	Bright and ideal for use mounting around the helmet and low power consumption (functions well on Li-Po or Li-Ion batteries).
EAR PROTECTION	Built-in Earplugs	- Lightweight & disposable. Provides efficient noise attenuation (NRR 29-33 dB). - Inexpensive and simple to replace.
PROGRAMMING LANGUAGE	C++	C++ is the best programming language because its efficiency, speed, and support for microcontrollers like ESP32 and Arduino. It has direct access to sensors, LEDs, and other hardware devices without using much memory.
POWER SUPPLY	Lithium Polymer (Li-Po)	The Li-Po battery, weighing 25g, is lightweight and compact, making it ideal for the smart safety helmet. It provides sufficient power to run the sensors and LED lights efficiently. Additionally, it is rechargeable and can be safely charged using the TP4056 charging module.

3.4.2.4 : Concept 2 Generation Of 7 Basic Instruments On The Aeroguard Helmet: (MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

Table 3.4.2.4: Concept 2 Generation Of 7 Basic Instruments On The Aeroguard Helmet

FUNCTION	CONCEPT 2	JUSTIFICATION
TYPE	Safety Helmet (Polycarbonate)	Impact-resistant, tough, and light polycarbonate material is ideal for safety helmets.
SOFTWARE	Arduino IDE	Used to write, compile, and upload code to the microcontroller, ensuring smooth operation of sensors and alert systems.
HARDWARE	Microcontroller (Arduino/ESP32)	Cost-effectively manages sensors, lights, and alarm systems with minimal power consumption.
	Arduino Sound Sensor (dB Meter)	Records ambient noise and sends a warning when it hits dangerous levels.
	Light Sensor (LDR / TSL2561)	Automatically levels helmet lights in low-lighting conditions for greater visibility.
	Vibration Sensor (SW-420 / ADXL345 Accelerometer)	Senses sudden falls or impacts, sending out alerts or emergency calls.
LIGHTING SYSTEM	Automatic strip led light waterproof	Provides adaptive lighting based on ambient light to provide maximum visibility.

EAR PROTECTION	Detachable earmuff	Conserves hearing by preventing damaging sounds while allowing essential communication.
PROGRAMMING LANGUAGE	C++	C++ is used for microcontroller programming, while Python is utilized for data processing and app integration.
POWER SUPPLY	Rechargeable Lithium-ion Battery	Offers long-lasting power with rapid recharging for extended use throughout the workday.

3.4.2.5 : Concept 3 Generation Of 7 Basic Instruments On The Aeroguard Helmet: (NANTHAKUMARAN A/L VASU)

Table 3.4.2.5 : Concept 3 Generation Of 7 Basic Instruments On The Aeroguard Helmet

FUNCTION	CONCEPT 3	JUSTIFICATION
TYPE	Carbon fiber Helmet	Constructed from a material that is stronger-to-weight than fiberglass or plastic and is both lightweight and extremely durable.
SOFTWARE	Platformio (vs code extension)	Makes development for embedded systems, such as smart safety helmets, efficient and scalable by providing quick compilation, integrated debugging, and smooth library management.
HARDWARE	Esp32-s3 devkitc	Robust development board with integrated wi-fi 4, bluetooth 5 (le). It's ideal for embedded systems such as smart safety helmets because of its high-performance capabilities and low-power modes.
	BH1750 digital light sensor	Uses an i2c interface to measure ambient light in lux with high accuracy. It is perfect for smart lighting and internet of things applications due

		to its low power consumption and broad detection range (1–65535 lux).
	KY-038 sound sensor	Allows the helmet to monitor environmental noise and alerts the wearer when noise levels exceed safe thresholds, adding an extra layer of protection.
	Bosch BMA 400 ultra-low power accelerometer	It improves energy efficiency and real-time motion tracking in smart safety systems with integrated tilt detection, and step counting.
EAR PROTECTION	Peltor x5a ear muffs	They are perfect for noisy environments because they offer high noise reduction (nrr 31db). Long-term wearability and optimal hearing protection are guaranteed by their sophisticated sound insulation, sturdy headband, and cozy ear cushions.
PROGRAMMING LANGUAGE	C++	High-performance programming language that is frequently used in microcontrollers, embedded systems, and internet of things applications.

POWER SUPPLY	Solar-powered li-po rechargeable battery	Integrates solar charging capabilities with lightweight, high-energy density lithium-polymer cells to provide off-grid, sustainable power solutions. and other portable electronics because it has a long battery life, charges quickly, and performs dependably.

3.4.2.6 : Concept 4 Generation Of 7 Basic Instruments On The Aeroguard Helmet: (DEVESH A/L THIYAGARAJAN)

Table 3.4.2.6: Concept 4 Generation Of 7 Basic Instruments On The Aeroguard Helmet

FUNCTION	CONCEPT 4	JUSTIFICATION
TYPE	Safety helmet high-density polyethylene (hdpe)	High-Density Polyethylene (HDPE) is a commonly used material for safety helmets due to its excellent strength, durability, good impact resistance, and ability to withstand heat and chemicals, making it a popular choice for construction and industrial applications where head protection is crucial.
SOFTWARE	Mobile software (e.g, everbridge)	Crisis Management, capabilities enabling teams to manage a critical event completely on the mobile device with oversight on task lists, incidents, documents, notes, and event updates. Reports to surface details on notification delivery, safety events, and incident response Inbox to view real-time updates from contacts who trigger Safety Connection functionality such as SOS, Check-in, Safe Corridor, and more.
HARDWARE	ARDUINO (ESP32-S3)	The ESP32-S3 is considered an upgrade to the ESP32, offering

		significantly improved processing power, more memory, and enhanced capabilities like faster Wi-Fi speeds, Bluetooth LE support, and advanced features for machine learning applications, all while maintaining backwards compatibility with the ESP32 development environment (ESP-IDF), making it a more powerful and versatile option for IoT projects.
	ADAFRUIT I2S MEMS MICROPHONE (SPH0645LM4H)	Unlike analog microphones, it outputs digital audio signals directly, avoiding noise and distortion from ADC conversion. Can detect a broader range of sounds, making it ideal for decibel (dB) metering and real-time audio processing.
	AMS TSL2591 high-precision light sensor	High dynamic range (188 µlux – 88,000 lux) Works in both low-light and bright sunlight. Infrared (IR) and Visible Light Channels More accurate ambient light measurement. Automatic Gain Control (AGC) Adjusts sensitivity automatically for different lighting conditions.
	MPU6050 – 6-axis gyroscope and accelerometer	Detects sudden impacts, falls, or head movements. Can send vibration or Bluetooth alerts if a worker falls.

LIGHTING SYSTEM	COB headlamp led motion sensor head torch headlight lamps waterproof	Rechargeable induction LED head lamp has a high-quality motion sensor mode, you can easily turn the lights ON/OFF by waving your hand within the sensor function range about 10cm.
EAR PROTECTION	3m peltor x4 ear defender with headband, 32db	Excellent for loud environments and provides protection against high-frequency noise while allowing speech and warning signals to be heard.
PROGRAMMING LANGUAGE	PYTHON	Easy to Learn – Simple and readable syntax Powerful – Used for web development, AI, automation, and more Huge Community – Lots of tutorials and support
POWER SUPPLY	Turnigy Nano-Tech 1000mAh 3.7V 1S LiPo Battery	Less Voltage sag during high-rate discharge, giving more power under load. Greater thermal control, pack usually doesn't exceed 60degC. Higher capacity during heavy discharge. Longer Cycle Life, almost double that of standard lipoly technology. Through improving electronic conductivity and ion transmission, the impedance is reduced .

3.4.2.7 :Proposed Final Concept

Table 3.4.2.7 :Proposed Final Concept

FUNCTION	CONCEPT 5	JUSTIFICATION
TYPE	Safety helmet(ABS)	Made of Acrylonitrile Butadiene Styrene (ABS) material, lightweight but very strong. Lightweight and strong, meets safety standards, and provides room for sensors. Other than that, Cheap and easy to obtain.
SOFTWARE	ARDUINO IDE	Allows programming of microcontrollers like Arduino for interfacing with sensors.
HARDWARE	1. ARDUINO circuit board	- Able to connect with various sensors, offering excellent processing capacity and connectivity with other sensors.
	2. LDR module (light dependent resistor)	– Detects low-light conditions to activate the automatic lighting on the helmet.

	3.Noise detector (Max4466 Sound Sensor)	- The Max4466 Sound Sensor is highly sensitive, offers analog and digital output, has adjustable sensitivity allows you to fine-tune the sound detection, low power (3.3V–5V), and it easily integrate with Arduino and ESP32.
	4 .Vibration detector(SW-420)	- SW-420 perceives intense vibrations such as fall impacts.
LIGHTING SYSTEM	LED Light	Provides adaptive lighting based on ambient light to provide maximum visibility and also can be used during rainy day because it is made of waterproof material.
EAR PROTECTION	Detachable earmuff	Conserves hearing by preventing damaging sounds while allowing essential communication. It can be easily removed and attach back to the helmet.
PROGRAMMING LANGUAGE	C++	C++ is the best programming language because its efficiency, speed, and support for microcontrollers like ESP32 and Arduino. It has direct

	102	access to sensors, LEDs, and other hardware devices without using much memory.
POWER SUPPLY	Lithium Polymer (Li-Po)	The Li-Po battery, weighing 25g, is lightweight and compact, making it ideal for the smart safety helmet. It provides sufficient power to run the sensors and LED lights efficiently. Additionally, it is rechargeable and can be safely charged using the TP4056 charging module

3.4.3 EVALUATION & SELECTION OF CONCEPTIONAL DESIGN

3.4.3.1 PUGH Matrix

Table 3.4.3.1: PUGH MATRIX: CONCEPT 1 AS DATUM (THARSHAM MENAN A/L BALAKRISHNAN)

CRITERIA	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4	CONCEPT 5
TYPE	D	2	1	2	3
SOFTWARE	A	3	2	1	3
HARDWARE	T	2	2	1	3
LIGHTING SYSTEM	U	3	2	1	3
EAR PROTECTION	M	3	1	2	3
PROGRAMMING LANGUAGE	-	3	3	2	3
POWER SUPPLY	-	2	1	2	3
TOTAL SCORE	-	18	12	11	21
RANKING	-	2	3	4	1

Legend = 3(+),2(=),1(-)

Table 3.4.3.2 : PUGH MATRIX: CONCEPT 2 AS DATUM (MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

CRITERIA	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4	CONCEPT 5
TYPE	3	D	1	2	3
SOFTWARE	3	A	2	1	3
HARDWARE	3	T	1	1	3
LIGHTING SYSTEM	1	U	2	1	3
EAR PROTECTION	2	M	1	2	3
PROGRAMMING LANGUAGE	3	-	3	1	3
POWER SUPPLY	3	-	1	2	3
TOTAL SCORE	18	-	11	10	21
RANKING	2	-	3	4	1

Legend = 3(+),2(=),1(-)

Table 3.4.3.3 : PUGH MATRIX: CONCEPT 3 AS A DATUM
(NANTHAKUMARAN A/L VASU)

CRITERIA	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4	CONCEPT 5
TYPE	3	2	D	2	3
SOFTWARE	3	3	A	1	3
HARDWARE	3	2	T	1	3
LIGHTING SYSTEM	2	3	U	2	3
EAR PROTECTION	2	3	M	2	3
PROGRAMMING LANGUAGE	3	3	-	2	3
POWER SUPPLY	3	2	-	2	3
TOTAL SCORE	19	18	-	12	21
RANKING	2	3	-	4	1

Legend = 3(+),2(=),1(-)

Table 3.4.3.4 : PUGH MATRIX: CONCEPT 4 AS DATUM (DEVESH A/L THIYAGARAJAN)

CRITERIA	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4	CONCEPT 5
TYPE	3	2	1	D	3
SOFTWARE	3	3	2	A	3
HARDWARE	3	2	2	T	3
LIGHTING SYSTEM	2	3	2	U	3
EAR PROTECTION	2	3	2	M	3
PROGRAMMING LANGUAGE	3	3	3	-	3
POWER SUPPLY	3	2	1	-	3
TOTAL SCORE	19	18	13	-	21
RANKING	2	3	4	-	1

Legend = 3(+),2(=),1(-)

3.4.4 Conceptual Design of the Proposed Product

The conceptual design of the Aeroguard Helmet seeks to combine conventional headgear protection with advanced smart technologies to improve the security and vigilance of workers in aviation repair environments. The design incorporates ergonomic comfort, integrated safety features, and real-time monitoring to reduce major hazards such as high noise exposure, poor light conditions, and falling threats (OSHA, 2022; Texas Instruments, 2020;García et al., 2021).

The helmet has core components such as noise level sensing sensor, auto LED lighting, alarm system, smart earmuff interface, and fall detection unit. All the components are loaded decently into a protective, compact cover made up of high-impact resistant material. There is an internal power source (rechargeable battery) that makes continuous use possible, while wireless communication modules provide the ability to monitor safety information remotely through a dedicated mobile or desktop application (Arduino, 2023).

Aesthetically, the product is still recognizable as a regular safety helmet but with minimal sensor housings and minimalist controls. The goal is to provide user comfort while incorporating sophisticated functionality without disrupting the worker's routine. The Aeroguard Helmet not only protects the user physically but also acts as an intelligent aid that reacts to environmental conditions, offering a proactive solution to occupational safety.

3.5 PRODUCT SKETCHES

3.5.1: General Product Sketching
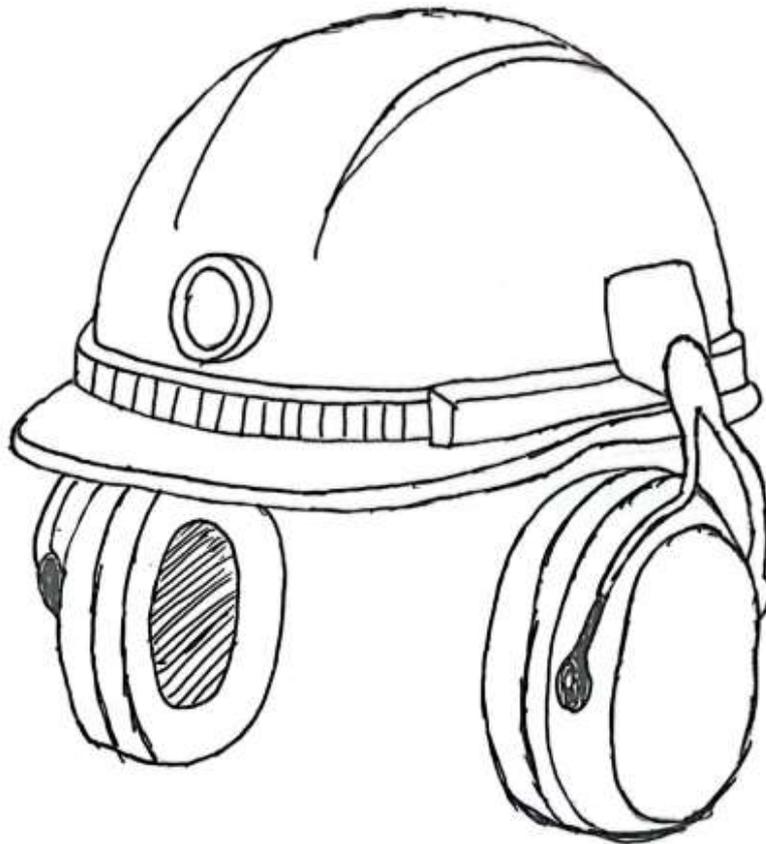
Figure 31: General Product Sketching

3.5.2 Specific Part Drawing / Diagram

3.5.2.1 Product Structure
(NANTHAKUMARAN A/L VASU)
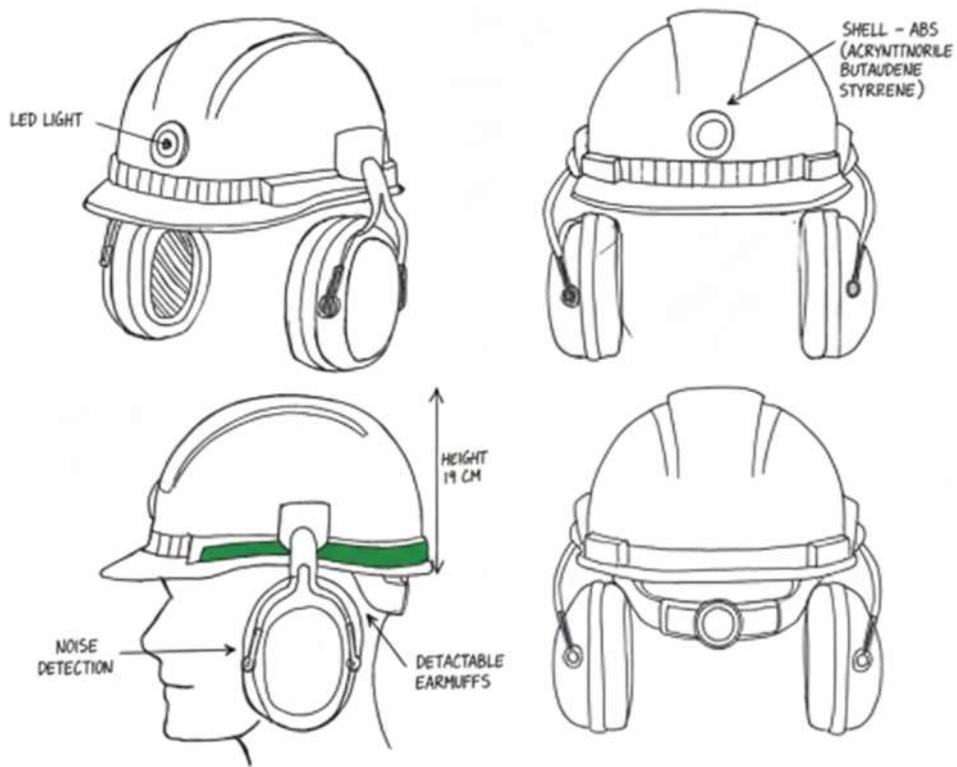
Figure 32: Top/Side/Front View

3.5.2.2 Product Mechanisms
(MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)
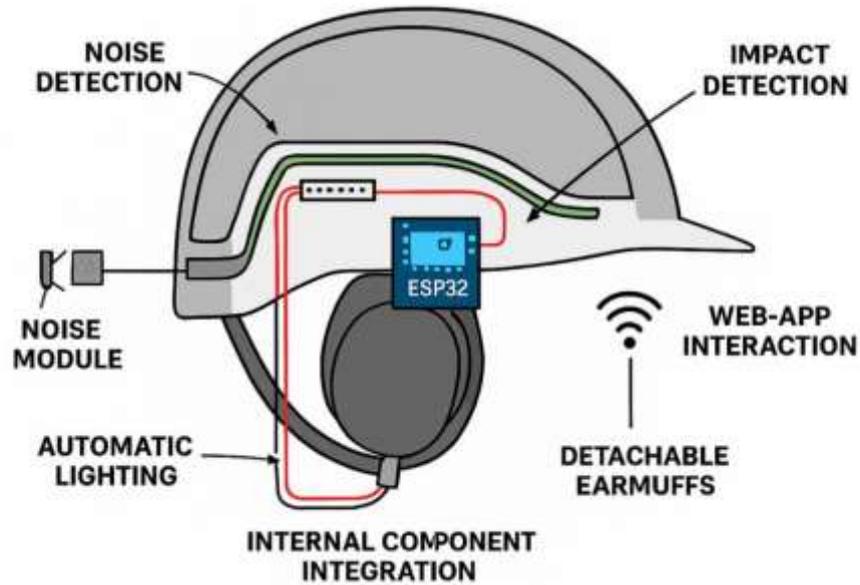
Figure 33: design of smart safety helmet

3.5.2.3 Software / Programming
(THARSHAM MENAN A/L BALAKRISHNAN)
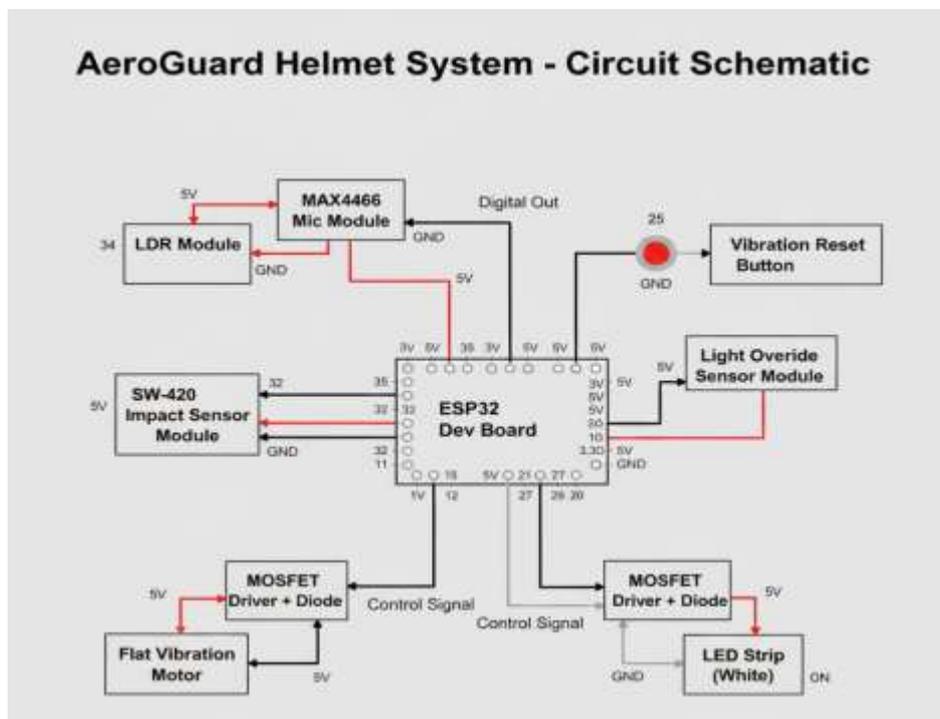
Figure 34: Circuit schematic of aeroguard helmet

Think of this circuit as a small, smart guardian built around the ESP32, which is its brain. This brain is always connected to the internet, letting you check on it from anywhere.

The system uses three main senses to watch the world:

1. **Eyes (LDR Module on GPIO 34):** This little sensor checks how bright it is outside. If it gets too dark, the ESP32 automatically flips the switch for the **LED Strip (GPIO 27)**, making sure the user can see and be seen.

2. **Ears (MAX4466 Microphone on GPIO 35):** This listens for loud, dangerous noise. If the sound level goes too high, the system immediately triggers the **Flat Vibration Motor (GPIO 12)** to give a silent, tactile alert to the wearer.

3. **Instinct (SW-420 Impact Sensor on GPIO 32):** This sensor is watching for sudden jolts or falls. If a serious impact occurs, the ESP32 logs the incident right away, recording it for safety review.

The wearer has simple controls:

- A **Light Button (GPIO 25)** lets them manually turn the light on or off, overriding the automatic LDR control.

- A **Reset Button (GPIO 33)** lets them easily silence or stop the vibration warning once they've acknowledged the noise hazard.

Because the lights and motors need more power than the ESP32 can safely provide, the system uses two little power-boosters, called **transistor drivers**, as electronic switches for the outputs. This setup ensures the components work reliably without burning out the central chip. Ultimately, this entire closed-loop circuit keeps watch over the user and the environment, sending all its status updates straight to the web via the ESP32's built-in connectivity.

3.5.2.4 Accessories & Finishing
(DEVESH A/L THIYAGARAJAN)
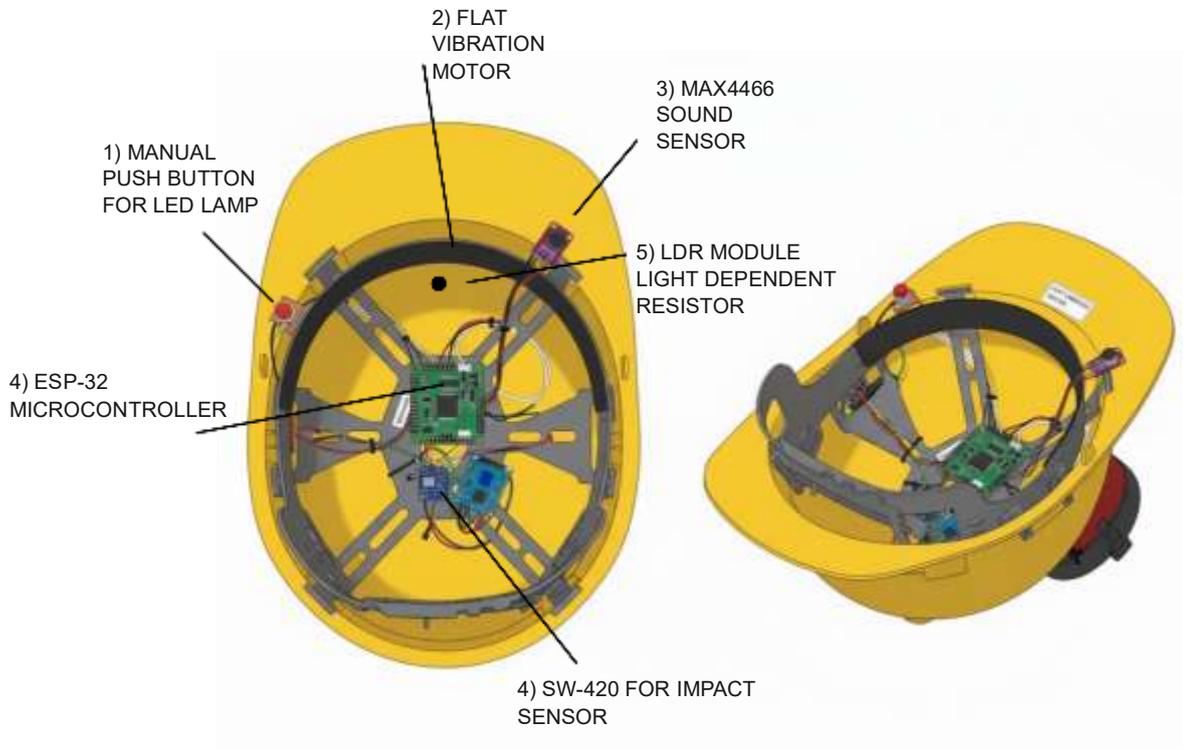
Figure 35: Outlook of the aeroguard helmet

3.6 PROTOTYPE / PRODUCT MODELLING

3.6.1 Prototype / Product Modelling
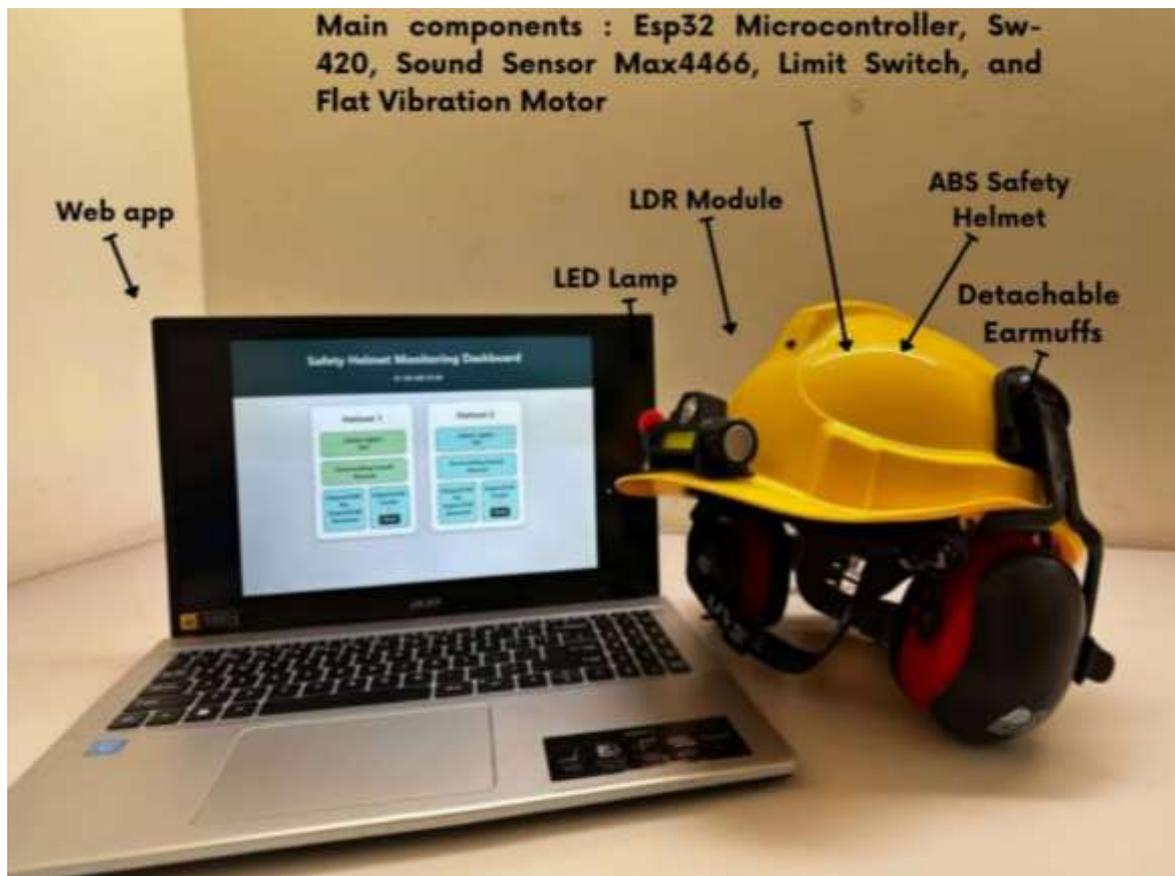
Figure 36: Look out of final product

AeroGuard Helmet prototype was created by incorporating physical safety structure of the helmet with the electronic system into one working unit. The last prototype is an ABS safety helmet with smart features which includes automatic system of lighting, noise level detection, impact detection, and wearable vibration alert system. These characteristics are arranged in a modular design that enables each part to be independent and to also get communication with the ESP32 microcontroller as the central controller.

The LDR module, MAX4466 sound sensor, SW-420 vibration sensor, LED lighting strip, flat vibration motors, and earmuff-mounted limit switch are the components of the physical prototype. All these modules are fitted to fit very easily within or around the internal structure of the helmet so that it is comfortable, the balance of weight and is ergonomically usable. It has detachable earmuff system, which contributes to the overall weight that can be

removed according to the user preference to provide better comfort in terms of using it over a long period.

At the software level, the prototype is also equipped with an operating web based monitoring dashboard with live readings being sent wirelessly by the helmet. The dashboard shows live images of the state of light, alerts of noise, detection of impacts, and counter of impact. This interface enables the supervisors to track workers offsite and act promptly in case of hazardous situations.

On the whole, the prototype is a full-scale working version of the AeroGuard Helmet, which is capable of bringing together hardware, sensors, wireless connectivity, and a visual monitoring system into a unified smart Personal Protective Equipment (PPE) system. This block diagram illustration depicts the relationship among every module and how the sensor inputs are used by the ESP32 to generate outputs, which in this case includes the activation of the LED, vibration alerts and dashboard notifications.

3.6.2 Prototype Development
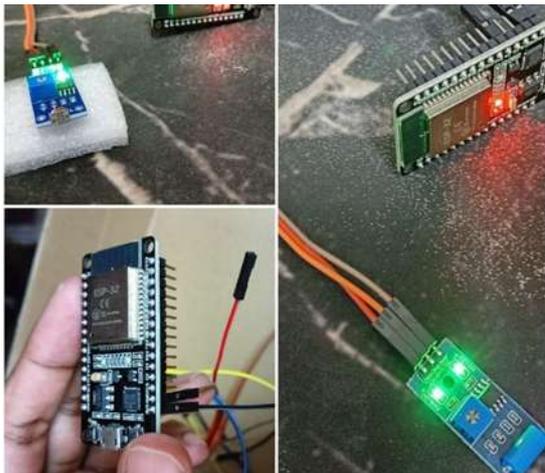
Figure 37: Testing sensors
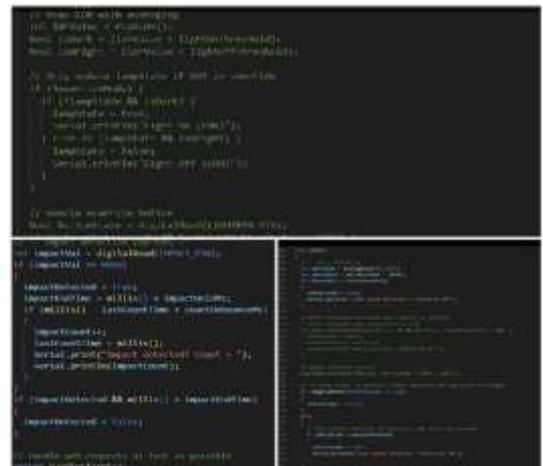
Figure 38: Coding all the sensors
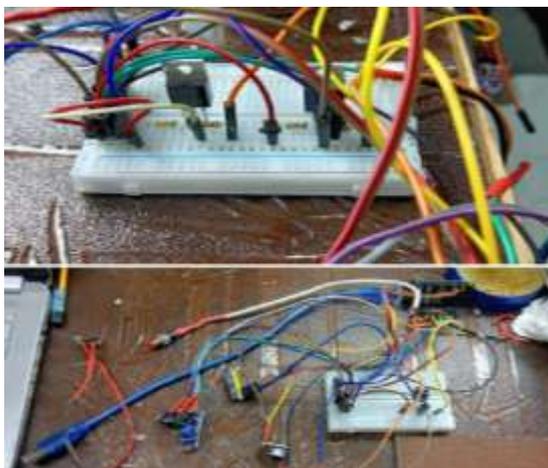
Figure 39: Connecting jumper wires board to pcb board

Figure 40 : Tranfering from bread
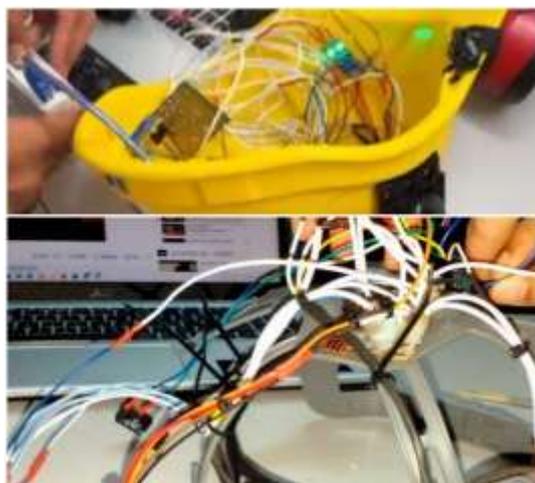
Figure 41 : Shortening wires

Figure 42 : Fixing into the helmet

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During the development phase, all sensors were first tested separately to ensure proper functioning. Each sensor was connected to the ESP32, uploaded with the respective test code, and monitored through the Serial Monitor for stable readings. When each component the LDR, MAX4466, SW-420, push button, limit switch, LED strip, vibration motor had been verified to work properly, the codes were combined into one integrated program. The team then checked that all sensors were working simultaneously with no conflicts and that data could be transferred properly to the web dashboard.

Once the software logic was validated, the complete circuit was assembled on a breadboard for initial integration testing. The jumper wires were arranged and connected through to create the complete wiring layout. When this breadboard prototype proved stable, the temporary wiring system was transferred onto a PCB board by soldering, thus creating a more permanent and durable circuit.

During the final assembly, the wiring harness was optimized for fitment inside the helmet. The wires were initially very long and created congestion, so they were shortened, reorganized, and secured neatly within the interior of the helmet. This allowed the components to be in the correct position, granting better access and enabling the AeroGuard Helmet to support all internal electronics safely while sustaining structural balance.

3.7 DEVELOPMENT OF PRODUCT

3.7.1 Material Acquisition

Table 3.7.1 : Material Acquisition

NO	Material	Component	Purpose / Usage
1	ABS Safety Helmet Shell	1 UNIT	Base structure on which all the components are mounted
2	ESP32 Microcontroller	1 UNIT	Laptop processing and communication unit
3	LDR Module	1 UNIT	unit Automatic lighting detector
4	MAX4466 Microphone Sensor	1 UNIT	Noise level detecting
5	SW-420 Vibration Sensor	1 UNIT	Impact and shock detection
6	LED Strip/ LED Lamp	1 UNIT	Helmet light
7	Flat Vibration Motor	2 UNITS	User alert system
8	Limit Switch	1 UNITS	Earmuff detection
9	Push Button switch	1 UNTIS	Light activation is by hand
10	Earmuff Attachment (Removable)	1 PAIR	Protects ear from high noise level
11	1120W Power Bank	1 UNIT	Power supply of helmet
12	Jumper Wires Multiple Electrical connections Multiple Double-sided Tape / Epoxy	As Mounting and attaching parts needed	Electrical connections
13	Double-sided Tape / Epoxy	As needed	Mounting and securing components
14	Cable Ties	As needed	Internal cable management

3.7.2 Machines and Tools Required

Table 3.7.2 : Machines and Tools Required

NO	Machine / Tool	Purpose
1	Soldering Iron	Permanent component and wiring soldering
2	Hot Glue Gun	Component attaching and attaching
3	Multimeter	Voltage and continuity testing
4	Wire Stripper Cable	Cable preparation
5	Laptop	PC ESP32 programming
6	Heat Gun Heat	shrink insulation
7	Drill Set drilling	Drilling internal mounting holes
8	Shaping internal components	Cutting Tools.
9	Measuring Tools (Vernier/Scale)	Component location accuracy

3.7.3 Specific Project Fabrication
3.7.3.1 Phase 1 – Base Structure (NANTHAKUMARAN A/L VASU)

Table 3.7.3.1 : Phase 1

Step	Description	Outcome
1	Check the safety and space of the helmet shell	Helmet ready to be internally modified
2	Mark mounting points	Correct coordinate of components
3	Bore or cut holes to the wiring	Clean cable routes
4	Fit internal support mounts	Stable internal structure

3.7.3.2 Phase 2 – Accessories & Mechanisms
(MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

Table 3.7.3.2 : Phase 2

Step	Description	Outcome
1	Attach ear system detachable ear system	Adjustable noise-protection system
2	Mount LED housing	Proper illumination angle
3	Fit limit switch in ear muff position	Appropriate detection of ear muff usage
4	Vibration motor mounting plate installation	Stable haptic feedback mechanism.

3.7.3.3 Phase 3 – Programming & Electrical Circuit
(THARSHAM MENAN A/L BALAKRISHNAN)

Table 3.7.3.3 : Phase 3

Step	Description	Outcome
1	Esprit sensorial wire (LDR, MAX4466, SW-420, Limit Switch, LED, Vibration Motor) to ESP32	All hardware connected
2	Install first test code into ESP32	Basic sensor test
3	Complete full firmware (LDR logic, Noise logic, Impact logic, Dashboard data flow)	Complete program structure
4	Web server (JSON webbox, HTML dashboard) implementation	Live monitoring system
5	Problems with debug (false triggers, Wi-Fi drops, slow refresh)	Optimized, stable system
6	Final firmware upload & calibration	100% operational helmet system

3.7.3.4 Phase 4 – Finishing
(DEVESH A/L THIYAGARAJAN)

Table 3.7.3.4 : Phase 4

Step	Description	Outcome
1	Wire with surface insulation and cable ties	Clean inside structure
2	Add safety casing	Secure and resilient hardware dealings
3	Surface finishing & labelling	Professional appearance
4	Final operational testing	system is presentable

3.8 PRODUCT TESTING / FUNCTIONALITY TEST

Table 3.8: Product testing

Step	Test Category	Procedure / Action	Expected Result	Pass/Fail Criteria
1	Power-On Test	Connect the 20W power bank to the helmet and switch on the ESP32.	System powers up and boots normally.	ESP32 must start without freezing or restarting.
2	Wi-Fi Connection	Allow the ESP32 to connect to the assigned hotspot.	"Wi-Fi Connected" appears on serial monitor.	Must connect within 10 seconds.

3	Dashboard Accessibility	Key in the IP address in a browser.	Web dashboard loads successfully.	Must display live sensor data.
4	Low-Light Lighting Test	Cover the LDR to simulate darkness.	LED strip turns on automatically.	LED activates immediately.
5	Bright-Light Lighting Test	Shine light on the LDR.	LED strip switches off.	LED must turn off smoothly.
6	Manual Override Test	Press the push button to toggle light.	Light switches based on button input.	Manual override must override auto mode.
7	Noise Detection Test	Produce noise above threshold.	Vibration motor activates; dashboard shows "Loud".	Vibration only activates when threshold exceeded.
8	Earmuff Switch Test	Press the limit switch (simulate wearing earmuff).	Noise alert stops; vibration deactivates.	System must cancel alert instantly.
9	Impact Detection Test	Tap the helmet to trigger SW-420.	Impact icon appears; counter increases by 1.	No false or double counting.
10	False Trigger Prevention	Shake helmet lightly.	No impact detected.	Minor vibration must not increase counter.
11	Impact Count Reset	Click "Reset Impact" on dashboard.	Count returns to 0.	Counter must refresh in real time.
12	Vibration Motor Function	Trigger noise or impact.	Motor vibrates smoothly.	No excessive shaking or noise from motor.
13	Data Transmission Test	Monitor dashboard updates.	Dashboard refreshes every 500 ms.	No data freeze or lag >1 second.
14	Full System Stress Test	Run all sensors together for 10 minutes.	System stays responsive.	No ESP32 crashes or resets.
15	Final Validation	Supervisor observes full run.	All features perform correctly.	System passes all checks.

3.9 LIST OF MATERIALS & EXPECTED EXPENDITURES

Table 3.9 :List of expenditure

No	Items	Unit	Price/Unit (RM)	Total (RM)
Product Structure				
1	Helmet	1	RM30.62	RM30.62
2	Detachable earmuff	1	RM38.00	RM38.00
Electrical components				
No	Items	Unit	Price/Unit (RM)	Total (RM)
1	Arduino Board	1	RM 35.60	RM35.60
5	LDR Light Sensor	1	RM5.00	RM5.00
6	Max4466 Microphone Sensor	1	RM3.41	RM3.41
7	Vibration Detector (SW-420)	1	RM14.20	RM14.20
8	LED Light	1	RM12.00	RM12.00
9	Flat Motor Vibrator	1	RM2.00	RM2.00
10	Total			RM140.83

CHAPTER 4

(RESULT & DISCUSSION)

4.1 PRODUCT DESCRIPTION

4.1.1 General Product Features & Functionalities

The AeroGuard Helmet is a smart safety helmet that is specifically created to enhance protection, situational awareness, and communication to aviation maintenance workers. It is an advanced system that incorporates intelligent electronics and ergonomics to form a very functional and comfortable headgear to be used in harsh maintenance conditions. The helmet integrates a number of prominent systems an automatic lighting system, sound detection system, impact and vibration detection system, fit-in detachable earmuffs, and a web based monitoring platform. Those features are controlled by a microcontroller of the ESP32 type, which is fed by a 20W powerbank to provide a responsive and reliable safety solution.
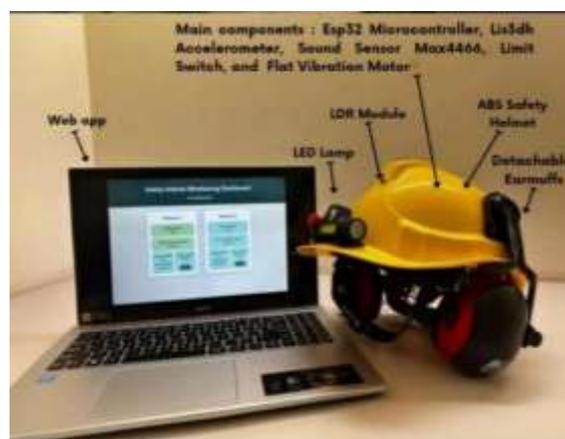
Figure 43: The Aeroguard Helmet and Web App

The ABS material is used to construct the helmet itself which has a toughness, impact resistance and lightweight characteristics. The design is structural and has been created to accommodate all the electronic components without affecting comfort and mobility. The combination of intelligent applications in a sustainable ABS shell leads to a helmet that gives a protective element as well as a technological assistance to safer maintenance activities.

Figure 44: ABS Safety Helmet

ESP32 microcontroller is used as the main control unit that connects all sensor inputs and outputs. It is able to process real-time information on sensors, turn lights on and off, vibration, as well as sound alarms, and send the information wirelessly to the web-based monitoring system. The web application enables supervisors to get the data on the helmets remotely such as the light levels, exposure to noise, incidences of impact and the status of the systems. This long-distance monitoring positively influences safety management and provides quick response to the incidents.
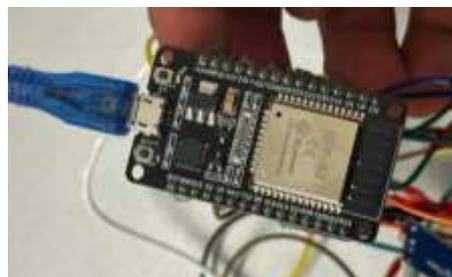
Figure 45: ESP-32 Microcrontroller

A Light-Dependent Resistor (LDR) module is the automatic lighting system and this unit can identify the amount of light in the surrounding environment. In the event that the ambient light drops below a predetermined threshold, the

ESP32 microcontroller will automatically trigger the LED lamp so as to have adequate light in the dark or closed spaces. This makes sure that maintenance work could be done without the danger of straining the eyes and enhances visibility. There is also an addition of a mini push button switch which can be used as a manual switch to trigger the emergency light in situations where the automatic system fails or when the user needs the immediate light when he or she is in an emergency.
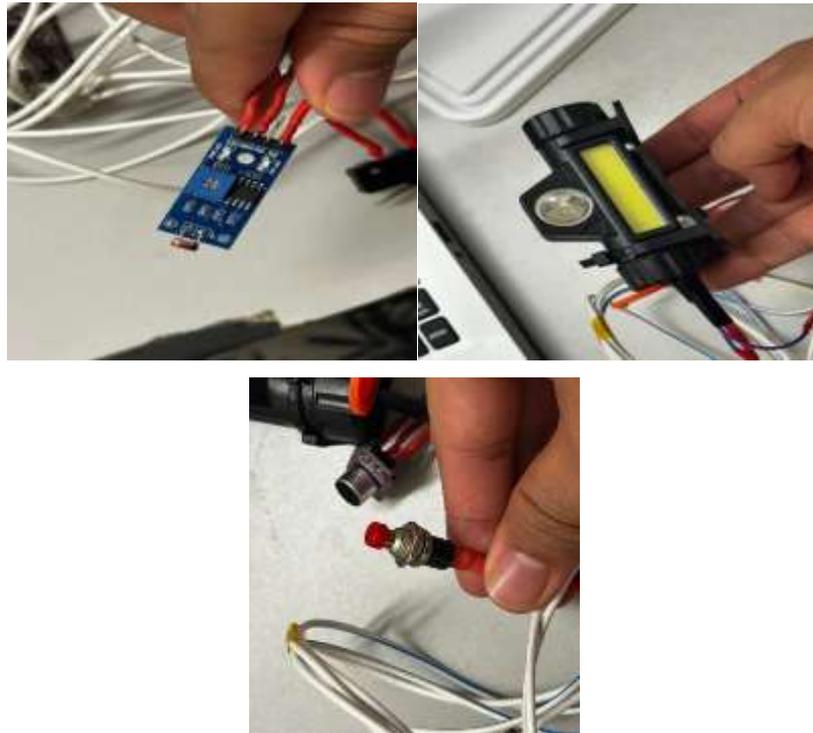
Figure 46 : LDR Module, LED Lamp and Mini Push Button

The sound detection system will consist of a sound sensor, the MAX4466, which monitors the level of noise in the working environment at all times. The helmet has an physical and visual warning when the noise level goes above the occupational safety threshold of 85 dB to draw the attention of the user. The property allows to minimize the chances of permanent hearing impairment and encourage adherence to safety standards in the workplace. The removable earmuffs are effective in noise isolation and comfort, thus the user can adjust the fit and ensure consistent hearing protection.
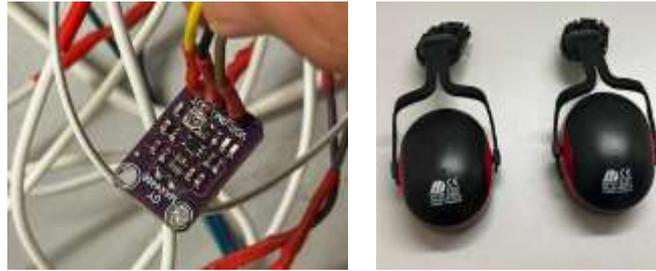
Figure 47 : Sound Sensor MAX4466 and Earmuff Detachable.

The impact and vibration system of detection involves the use of an SW-420 vibration sensor which detects sudden shocks, collisions, or constant vibrations. Upon sensing an impact or excessive vibration, an ESP32 activates a flat vibration motor to provide haptic feedback to the wearer, warning them immediately of potential danger. This aspect increases situational awareness, especially in situations where visual or auditory cues are inadequate. The system also has a built-in limit switch mechanism that automatically turns off the vibration motor when not in use or when the helmet has not been correctly fitted, in order to avoid false alerts and save power.

Figure 48: SW-420 Vibration sensor.

A 20W powerbank powers the whole system wherein there is a consistent and portable power supply given to all the electronic modules. It is more efficient than fixed battery systems in that this configuration is convenient, has a long battery life, and can be recharged easily by using regular USB connections.

Figure 49: Powerbank 20w

Then, web app monitoring system links the helmet to a web dashboard to track the real-time data. By this platform, supervisors are able to remotely monitor the noise and light levels as well as impact events. It is a useful tool in attaining safety management in the workplace because the system captures sensor data, gives pst analysis, and produces safety reports (Tan & Lee, 2024).

Figure 50: Web-App

To sum up, the AeroGuard Helmet is a safety device that integrates several smart subsystems and has a 20W powerbank and ESP32 microcontroller to provide a higher level of safety, efficiency, and real-time control. The integration of automatic lighting, sound sensing, impact detecting, vibration sensing, wireless data transmission makes it to become more modern and connected when compared to the traditional protective equipment in aviation maintenance work.

4.1.2 Specific Part Features

4.1.2.1 Product Structure (NANTHAKUMARAN A/L VASU)

The AeroGuard Helmet system, with its smart electronics and real-time monitoring functions, will reduce aviation maintenance injuries and fatalities. This prototype integrates robust helmet construction with embedded sensing and communication modules, therefore yielding a protective device that is robust, ergonomic, and technologically advanced for industrial safety applications.

The commercially sourced helmet shell was manufactured from Acrylonitrile Butadiene Styrene, a material noted for its resistance to impact and structural rigidity while being lightweight (Arduino,2023). The ABS will ensure that under all conditions, the helmet would provide a very stable and secure platform for intelligent electronic systems integrated into it without affecting user comfort or mobility during daily maintenance operations.

Inside, the electronics are placed at strategic positions and fixed properly to ensure reliability during operation. The four major modules that make up this system include the ESP32 microcontroller, which will be the central processing and communication unit 8; the LDR module for automatic ambient light detection (Digi-Key, 2023); the MAX4466 microphone module for real-time noise monitoring (Arduino Project Hub, 2023); and the SW-420 vibration sensor for impact and vibration detection (Arduino, 2023). These will be fixed firmly inside the inner cavity of the helmet and positioned in such a way as to achieve balance, stability of operation, and resistance to unplanned movement or vibration.

An LED illumination unit has been fitted to the front part of the helmet to provide the user with maximum visibility in dark or enclosed aircraft maintenance areas (Digi-Key, 2023). All wiring and electrical connections have been properly routed and secured along the inner structural framework to ensure good cable management and to avoid any accidental snagging, exposure, or internal interference. Detachable earmuffs are fitted on the helmet to provide varied hearing protection with noise isolation when higher decibel

levels are observed by the system in the active area of maintenance (Arduino Project Hub, 2023).

Overall, it is the integrated design and structured assembly that make the AeroGuard Helmet prototype successful in housing necessary electronic and protective systems while maintaining ergonomic comfort and durability for real-world aviation maintenance use.
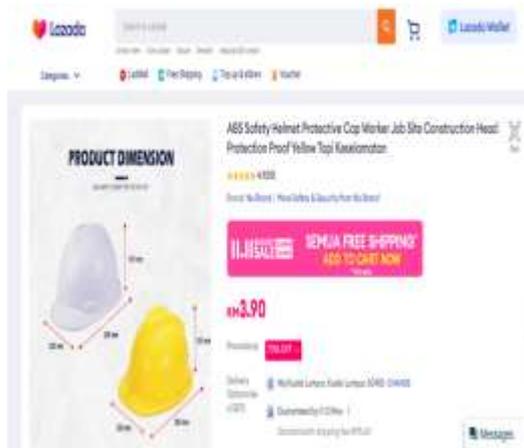
Figure 51: ABS Safety Helmet Selection

Figure 52: Fixing LED Light on Helmet

4.1.2.2 Product Mechanisms (MOHAMAD HAIKAL HAKMI BIN MOHD RAFAEEN)

The AeroGuard Helmet combines several sensors and modules to improve the user safety by offering real-time monitoring and alerting functionality and feedback. An ESP32 microcontroller is used to control the system and is the central processing unit that organizes the sensor inputs and responds to outputs. The core blocks that will be integrated are LDR module, MAX4466 microphone sensor, SW-420 vibration sensor and a web-based monitoring application. All them play a role in the particular protective characteristics as follows.

1) The module LDR (Light-Dependent Resistor):

Figure 53: LDR Sensor Module

LDR module is developed to sense the intensity of ambient light. When the helmet is used in the dark or low-light environment, it happens that the LDR detects the change in brightness and thus automatically switches on the LED light that has been mounted to the helmet. This makes the wearer visible enough in dark workplaces, enhancing the awareness of the situation, and minimizing the risk of accidents (Arduino, 2023).

2) MAX4466 Microphone Sensor:

Figure 54 : MAX4466 Mic Sensor

The MAX4466 is used to detect the level of noise in the air to detect the presence of high noise environments, which may be a hazard to the safety of hearing. The system is programmed to sound warnings, in case noise level is more than 85 dB, which is hazardous as per the occupational safety norms (Arduino, 2023). But to demonstrate, the sensitivity of the sensors was changed to react to lesser sound levels to replicate the same functionality somewhat.The ESP32 uses a signal as soon as the noise level has reached the threshold, which sends an alarm signal to the monitoring web application and triggers two flat vibration motors located in the helmet. This type of haptic feedback will alert the user that he or she is in a noisy working situation. Moreover, the ear-muff has a limit switch that is pressed when it is mounted. This will switch off the vibration motors and prevent transmission of noise alert to the monitoring app showing that the user has made the relevant hearing protection action (Arduino, 2023).

3) SW-420 Vibration/Impact Sensor:
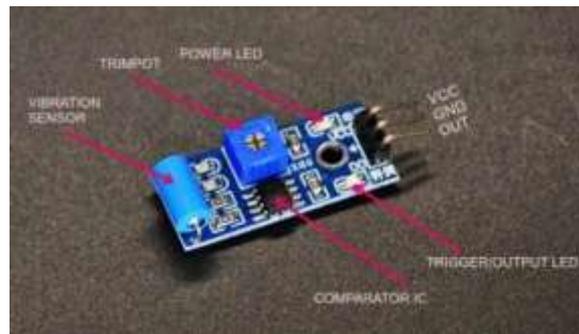
Figure 55: SW-420 Sensor

SW-420 module helps in identifying physical shocks, impacts or sustained vibrations. Upon a major impact being observed, an alert notification about the ESP32 is instantly provided to the monitoring application. The system further records the number of times the wearer has been hit enabling supervisors to measure the possibility of safety mishaps or frequent contact dangers in the workplace (Open Source Initiative, 2023).

4) ESP32 Microcontroller and Web Application:

Figure 56: ESP-32 Microcrontroller and Web-App

The ESP32 serves as the brain behind the AeroGuard Helmet, interpreting the data of all the sensors and controlling output agents like LED lights, vibration alerts and communication with the monitoring platform. Using the web application, safety supervisors are able to track real-time alerts, such as noise exposure alerts, light condition alerts and impact alerts. This functionality can improve the safety management of workplaces and respond promptly to an emergency (Arduino, 2023).To conclude, the mechanism of the AeroGuard

Helmet comprises a set of various sensors in one active system, which actively controls the situation in the environment and the safety of the workers. The LDR, MAX4466, SW-420, and limit switch interacting under the control of the ESP32 are an intelligent, responsive safety system that is appropriate in the industrial setting (Components101, 2023).

4.1.2.3 Software / Programming (THARSHAM MENAN A/L BALAKRISHNAN)

The software component of the AeroGuard Helmet serves as the central intelligence of the system, integrating multiple sensor inputs, executing control logic, and enabling real-time data monitoring through a web-based interface. The programming was developed using C++ within the Arduino IDE environment and implemented on the ESP32 microcontroller, chosen for its built-in Wi-Fi capability and efficient processing performance. The main objective of the software design was to ensure smooth coordination between the hardware components LDR module, MAX4466 microphone, SW-420 vibration sensor, and limit switch while maintaining reliable communication with the AeroGuard web application.

The LDR (Light Dependent Resistor) module was coded to monitor surrounding light intensity and control the helmet's LED illumination automatically. Using analog readings processed through an averaging algorithm, the ESP32 determines whether the ambient environment is dark or bright. When darkness is detected, the system activates the LED strip to enhance visibility, and the light turns off automatically when sufficient light is restored. The threshold values were optimized in the program to ensure stability, preventing flickering or false triggers due to rapid lighting changes.

The MAX4466 microphone sensor was programmed to detect excessive noise levels within the working environment. The system identifies loud noise based on deviation from a reference analog value which is 2048, representing approximately 85 dB. However, due to the difficulty of producing 85 dB in a normal demonstration setting, the sensitivity of the microphone input was intentionally adjusted to respond to lower noise levels for testing purposes. When high noise is detected, the software triggers dual vibration motors

mounted inside the helmet, alerting the wearer to a potentially hazardous sound environment. At the same time, the ESP32 transmits a real-time noise alert to the monitoring web application, notifying supervisors of the condition.

The limit switch installed near the earmuff mount acts as a feedback control mechanism. When the wearer closes the earmuff, the switch is pressed, signaling to the ESP32 that hearing protection is active. The software immediately deactivates the vibration motors and halts further noise alerts to the web application. This logic simulates real-life safety behavior ensuring that once proper protection is engaged, unnecessary alerts are suppressed.

Another important feature is the SW-420 vibration sensor, used to detect physical impacts on the helmet. The ESP32 reads the digital output from this sensor and records each detected impact as an event. Each occurrence is counted and displayed on the monitoring dashboard. To prevent false readings caused by minor vibrations, a debounce delay and impact hold time were implemented in the program. This ensures that only valid impact events are recorded, resulting in accurate data collection.

The web application represents the final component of the software system. Developed directly within the ESP32 firmware using HTML, CSS, and JavaScript, the web dashboard provides a live monitoring interface that displays helmet status, light activation, sound level alerts, and impact count. The system communicates through AJAX-based JSON data exchange, allowing real-time updates every half second without reloading the page. The server, hosted on the ESP32 via its built-in Wi-Fi module, makes the AeroGuard Helmet a fully self-contained IoT device that can be accessed using any smartphone or computer connected to the same network.

Overall, the software successfully integrates sensing, actuation, and web communication into a unified, reliable embedded control system. The combination of these programming features allows the AeroGuard Helmet to operate intelligently, providing proactive protection for maintenance personnel in noisy or hazardous environments.

4.1.2.4 Accessories & Finishing (DEVESH A/L THIYAGARAJAN)

The accessories and finishing stage played a major role in completing the AeroGuard Helmet into a functional, ergonomic, and visually refined prototype (Arduino, 2023). This phase focused on achieving a balance between structural strength, user comfort, and component integration to ensure the product not only worked effectively but also met aviation maintenance safety standards in both form and function (NIOSH, 2022).

The design process began with a conceptual hand sketch that visualized the overall layout of the helmet and the placement of all smart modules (R.E.Lyon, 2008). This early sketch served as a foundation to generate 3-view and perspective 3D models, which were later color-rendered to simulate the final prototype's appearance (OSHA, n.d). These design visuals helped the team validate sensor positions, LED placement, and wiring paths before any physical work began (ANSI/ISEA, 2014). The process also made it easier to plan component spacing for weight distribution and ergonomics.

In the accessories stage, clear mounting points were designed for the LED strip, sound sensor, vibration sensor, ESP32 board, detachable earmuffs & power bank as power supply. (Ergodyne, 2019). The LED strip was installed along the front brim to capture maximum illumination in dark areas, while the power bank was positioned at the rear as a counterweight (MSA Safety, n.d.). The sensor positioning was planned through group discussions, ensuring each component could function without interference. The sound and light sensors were mounted slightly apart to avoid signal disturbance, while the vibration sensors were positioned on the front section of the helmet (forehead part), where mechanical impacts are most likely to occur (NIOSH, 2021).

Figure 57: 3D Model of Helmet Structure and Sensor Mounting

The finishing stage involved ensuring that every component was properly aligned, secured, and accessible for future maintenance (HSE UK, 2023). The wiring layout was refined to minimize excess wire length and potential tangling inside the helmet (3M Safety Division, 2020). To achieve a professional-grade appearance, the outer shell was sanded and coated to remove uneven surfaces, followed by a matte finish for durability and scratch resistance (Lin & Huang, 2020). The internal section was inspected to confirm adequate ventilation, smooth padding contact, and no protruding edges that might cause discomfort.

In short, the accessories and finishing phase translated design concepts into a polished prototype ready for real-world testing. The result was a well-balanced, lightweight, and ergonomically sound smart helmet that combined technical precision with industrial-level finishing quality suitable for aviation environments.

4.1.3 General Operation of the Product

When the AeroGuard Helmet (AGH) is powered on, the ESP32 Microcontroller Unit (MCU) initializes all sensors, modules, and communication channels, preparing the entire system for operation. The MCU functions as the central processing unit that receives input signals from multiple sensors and generates corresponding outputs, including vibration alerts, lighting control, and wireless data transmission (Rahman et al., 2022). After initialization, the helmet begins continuous real-time monitoring of both the user's physical condition and surrounding environment.

The automatic lighting system consists of an LED lamp and an LDR (Light Dependent Resistor) module which detects changes in ambient brightness. When the illumination level drops below a predefined threshold—such as during nighttime maintenance or when working inside confined aircraft structures—the LDR sends a signal to the MCU, prompting it to automatically activate the LED lamp. This ensures that the user maintains sufficient visibility in low-light areas, reducing eye strain and improving safety (Kumar & Singh, 2021; Lim et al., 2023). Once the surrounding environment becomes bright again, the system switches the LED off to conserve power.

The sound detection system incorporates the MAX4466 microphone module to detect environmental noise levels in decibels (dB). When the noise exceeds the 85 dB limit recommended by OSHA safety guidelines , the MCU activates a flat vibration motor to alert the wearer through tactile feedback, indicating that the environment may be hazardous to hearing. Additionally, the detected noise level and a alert will be transmitted to the web-based monitoring dashboard, allowing supervisors to review and respond to high-noise conditions in real time (Ali et al., 2023).

The impact detection system utilizes the SW-420 vibration sensor, which detects sudden shocks and mechanical disturbances that may occur during slips, collisions, or falls. The MCU compares the sensor signal against preset sensitivity thresholds, and when an impact is detected, the system triggers a vibration alert for the wearer and sends an immediate notification to the web monitoring dashboard. This enables rapid supervisor awareness and

intervention during hazardous situations (Rahman et al., 2022; Zhang et al., 2021).

The helmet also incorporates a removable earmuff system designed for comfort and effective noise isolation. A limit switch is installed to detect whether the earmuffs are properly positioned. When engaged, the switch signals the MCU to deactivate noise-related vibration alerts, ensuring that warnings are only given when the user is actually exposed to harmful noise (Ali et al., 2023).

The ESP32 controls all the sensors, limit switch, and auxiliary push-button and maintains wireless communication with the web dashboard. Through the online monitoring interface, supervisors are able to observe current environmental readings such as illumination level, sound intensity, and recorded impacts, as well as past alert histories for trend analysis (Tan & Lee, 2024; Chen et al., 2022). A 20W portable power bank powers the system, offering sufficient operating duration during extended maintenance operations. The device also features intelligent power management that transitions into a low-power mode when inactive.

In summary, the AeroGuard Helmet functions as a fully automated, sensor-integrated safety system that enhances situational awareness and reduces human error through tactile alerts and remote monitoring. The incorporation of sensor fusion, embedded control, and wireless communication makes the AeroGuard Helmet a significant advancement in smart Personal Protective Equipment (PPE) for the aviation maintenance industry (Lim et al., 2023).

4.1.4 Operation of the Specific Part of the Product

4.1.4.1 Product Structure (NANTHAKUMARAN A/L VASU)

The product structure of the AeroGuard Smart Safety Helmet integrates both physical hardware components and digital monitoring systems to deliver enhanced protection and intelligent safety support for aviation maintenance personnel. It includes hardware such as an ABS-based industrial safety helmet, an ESP32 microcontroller, multiple environmental and motion sensors, detachable earmuffs, an LED lighting system, a vibration alert mechanism, and a portable power supply. These components are selected to ensure durability, reliability, and user comfort during prolonged operations in demanding maintenance environments (Arduino, 2023; MIT App Inventor, 2023).

The helmet shell is made of Acrylonitrile Butadiene Styrene, a lightweight material with high resistance to impact and mechanical stress (Arduino, 2023). In this study, an LDR light sensor, MAX4466 sound sensor, and SW-420 vibration sensor were installed within the helmet, placed in optimal positions to capture accurate real-time readings from the environment and physiological parameters of the wearer (Digi-Key, 2023; Arduino Project Hub, 2023; Arduino, 2023).

On the digital side, the AeroGuard system includes a web-based monitoring platform that allows for remote supervision and data visualization. It shows in real time the sensor reading of noise exposure, illumination, and impact/vibration events (Electronics Hub, 2023). This interface allows supervisors to monitor worker conditions, review incident logs, and ensure safety standards are met according to (Arduino, 2023) and (Arduino, 2023). This digital system is in place for seamless communications with the helmet using radio transmission to transmit the information in real-time to enhance decision-making and safety management, according to (MIT App Inventor, 2023) and (Espressif, 2023).

Together, these hardware and software components form a unified, intelligent safety solution that provides both physical protection and smart situational awareness. The combination of durable construction, advanced sensor

technology, and real-time data connectivity ensures that the AeroGuard Helmet functions as an innovative tool for workplace safety in the aviation maintenance sector.
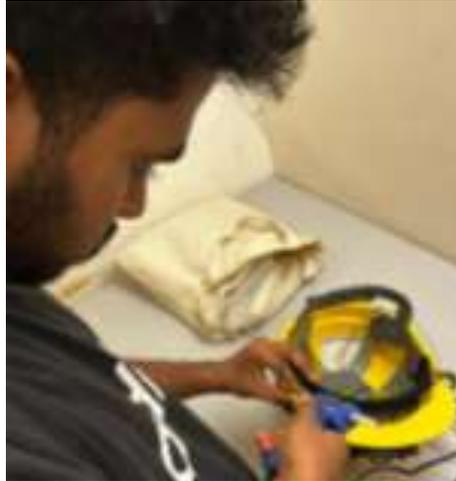
Figure 58: Attaching all the sensors on the Helmet

4.1.4.2 Product Mechanisms (MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

The AeroGuard Helmet is an operational system that is built around the combination of numerous sensors that operate under the supervision of the ESP32 microcontroller. The system automates and optimizes the system of environmental sense, activation of feedback, and transmission of real-time alerts to provide uninterrupted user safety. The components are programmed to have certain functions that react to different working conditions which include low light, high noise or physical impacts.

LDR module is always monitoring the amount of ambient light. When the light level in the surrounding becomes lower than some threshold, the resistance of the sensor rises, and the signal to the ESP32 microcontroller is transmitted. The microcontroller subsequently causes the activation of the light of the LED fitted on the helmet to enable visibility and safety during a dark or a poorly lit night (Components101, 2023). This is an automatic lighting system that will enable the workers not to have to manually adjust the lighting to ensure visibility, particularly in the dark or when there is an emergency.

Figure 59: Automatic Lighting Function

The sensor that detects a high level of noise is the MAX4466 microphone sensor. At the point where the environmental sound surpasses around 85 dB the MAX4466 converts audio signals into electrical signals and the ESP32 subsequently handles them. After the preset trigger, the system activates two vibration motors in the form of flats mounted in the helmet and transmits a notification of noise to the web-based monitoring platform (Arduino Tutorials, 2023). This alarm informs the user and the supervisor that the surrounding is

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too loud and it may cause damage. To be able to demonstrate, the sensitivity of the sensor was deliberately set higher to enable the system to respond at lower levels of decibel, which would be easier to demonstrate in controlled conditions.
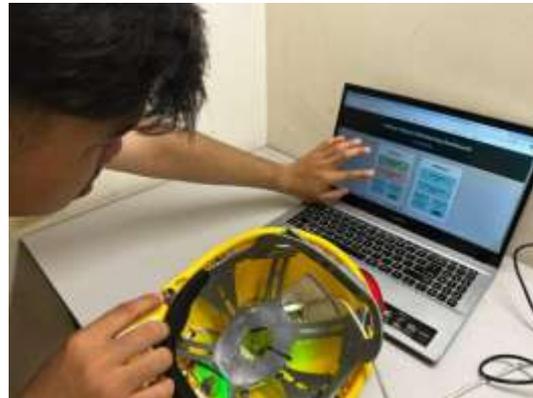
Figure 60: Noise Detection Alert

Lowering of the earmuff causes a limit switch to be pressed at the earmuff mount. This gesture will ensure that the ESP32 turns off the vibration motors and the noise alert is not sent to the monitoring application; this will ensure that the user has used the hearing protection feature (MIT App Inventor, 2023).

Figure 61: Impact Sensor Function

SW-420 vibration sensor is used to identify the shocks or impact on the helmet. The sensor will provide a digital signal on excitation by vibration or collision. ESP32 uses this input and sends an alert message immediately to the monitoring platform, which means that the wearer has been hit. The number of the impacts detected by the system is also logged and can be checked in the web application to perform additional safety evaluation [Digi-Key, 2023]. This

will enable the supervisors to track down the possible hazards or repetitive effects that might interfere with the security of the wearer.

The AeroGuard Helmet has the ESP32 microcontroller as its brain. It processes sensor data and handles wireless communication with the web monitoring interface as well as performs control commands. The ESP32 transmits real-time statistics of light status, noise levels, and number of impacts to the web dashboard using the built-in Wi-Fi capability (Arduino Project Hub,2023). The interface provides updated and past data, enabling supervisors to make correct choices regarding safety and take timely precautionary actions (Arduino, 2023). To conclude, the work of the AeroGuard Helmet shows that the interaction between the sensors and the microcontroller is well-organized. A combination of the LDR module, MAX4466, SW-420, limit switch, and ESP32 microcontroller enables the system to be dynamically responsive to the environment and provide user protection and situational awareness in the industrial environment (Electronics Hub, 2023).

4.1.4.3 Software / Programming (THARSHAM MENAN)

The operation of the software system begins as soon as the ESP32 microcontroller is powered on. During initialization, all sensor pins and output devices are configured, Wi-Fi connectivity is established, and the embedded web server is launched. Once connected to the designated network, the ESP32 continuously reads sensor data, processes input conditions, and updates the monitoring dashboard in real time.

The light control routine works via the LDR module, which continuously reads the ambient brightness by using the function *readLDR()*. This function does multiple analog samples and then averages them. The system compares the LDR reading to two threshold values called *lightOnThreshold* and *lightOffThreshold.* When the ambient light drops below the threshold programmed, the ESP32 switches on the strip LED automatically via *digitalWrite(LIGHTS_PIN, HIGH)* to light up the light for the user. In turn, if the environment gets bright enough, the lights will turn off. There is also a provision for a manual override via a push button connected to *LIGHTBTN_PIN*. It toggles *overrideMode* and *overrideState,* enabling the user to keep the LED on even if ambient light changes. In such a case, this assures the proper functionality of both automatic lighting and user override according to the situation.

The noise detection system uses the MAX4466 microphone sensor to monitor surrounding sound levels. ESP32 monitors the analog input from the sensor via *analogRead(MIC_PIN)* and compares it against a normal background noise value of 2048. Whenever the sound is greater than the defined 2048 analog value, ESP32 passes power via the digital pin to activate the vibration motor , thus always alerting the wearer of a very loud environment. At this point, an alert message will also be delivered on the web dashboard by way of the *handleData()* function for supervisor monitoring. In order for the system to stop vibrating and to discard the alert, when an earmuff is fit, the limit switch closes the circuit and send (digitalRead(RESETBTN_PIN)) signal to the esp32 to stop the vibration clear the alert from Web app.

The impact detection system works with the SW-420 vibration sensor that detects sudden shocks or strong vibrations. The ESP32 monitors the output of

the sensor via *digitalRead(IMPACT_PIN)* line continuously. When impact detected, the program sets *impactDetected = true*, increases *impactCount* by one, and directly forwards this data to the web dashboard, which shows up under "Impact/Fall Count". To avoid having the system count small movements or repeated signals, a timing control feature has been added with *millis()* and *countDebounceMs = 300*. This ensures that only genuine impact events are counted. The count is also reset through the function *resetImpact(),* which relays to the ESP32 via the */resetImpact* line, enabling supervisors to clear the count and begin a new session when needed.

The AeroGuard web dashboard is designed as the main monitoring platform for supervisors. Automatically refreshing every 500 milliseconds using the command *setInterval(fetchData, 500);* in JavaScript, it constantly requests fresh sensor data from the ESP32 via the */data* endpoint. In real time, the web interface displays key information: light status, sound levels, and aggregate impact counts. Such synchronized operation of the ESP32 firmware and the web dashboard means that an intelligent safety monitoring system allows both the workers and the supervisors to remain constantly aware of the workplace conditions.

Figure 62: Coding of LDR module

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```
void loop()
{
  // -- Mic + Vibration --
  int micValue = analogRead(MIC_PIN);
  int deviation = abs(micValue - 2048);
  if (deviation > noiseThreshold)
  {
    vibrationOn = true;
    Serial.println("Loud sound detected + Vibration ON");
  }

  // Reset vibration only when RESET button is pressed
  /*static unsigned long lastResetPress = 0;
  if (digitalRead(RESETBTN_PIN) == LOW && millis() - lastResetPress > 500) {
    vibrationOn = false;
    lastResetPress = millis();
    Serial.println("Switch pressed + Vibration OFF");
  }

  // Apply vibration control
  digitalWrite(VIBRATION_PIN, vibrationOn ? HIGH : LOW);*/

  // If reset button is pressed + force vibration off and block re-trigger
  if (digitalRead(RESETBTN_PIN) == LOW)
  {
    vibrationOn = false;
  }
  else
  {
    // Only enable vibration if loud noise AND reset not pressed
    if (deviation > noiseThreshold)
    {
      vibrationOn = true;
      Serial.println("Loud sound detected + Vibration ON");
    }
  }
```

Figure 63: coding of sound sensor

```
// -- Impact Detection (SW-420) --
int impactVal = digitalRead(IMPACT_PIN);
if (impactVal == HIGH)
{
  impactDetected = true;
  impactEndTime = millis() + impactHoldMs;
  if (millis() - lastCountTime > countDebounceMs)
  {
    impactCount++;
    lastCountTime = millis();
    Serial.print("Impact detected! Count = ");
    Serial.println(impactCount);
  }
}
if (impactDetected && millis() > impactEndTime)
{
  impactDetected = false;
}

// Handle web requests as fast as possible
server.handleClient();
```

Figure 64 : coding of impacts sensor

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4.1.4.4 Accessories & Finishing (DEVESH A/L THIYAGARAJAN)

Once all components were assembled, the accessories and finishing section played a crucial role in ensuring smooth operation, safety, and ease of use (36). The LED lighting, power management, and external fittings worked in harmony with the internal electronics to provide reliable real-time safety feedback during testing (CDC,NIOSH, 2022).

The LED strip at the front automatically activated when the LDR detected reduced light intensity (NIOSH,2022). During operation, it consistently provided wide-angle illumination in dark or confined spaces such as under aircraft structures (R.E.Lyon, 2008). The earmuffs, mounted with side brackets, were tested for comfort and proper sealing during prolonged wear (HSE UK, 2023). Their detachable feature allowed flexibility for users who preferred lighter configurations during low-noise maintenance tasks (ANSI/ISEA Z89, 2014).

The power bank, positioned at the rear compartment, not only supplied steady current to the system but also acted as a balancing weight, improving the helmet's overall stability (3M Safety Division, 2020). During live tests, the team observed that this rear placement significantly reduced neck fatigue during long wear periods (Lin & Huang, 2020). Cable management channels inside the helmet ensured tidy and safe wiring paths, minimizing interference between the ESP32, sensors, and power supply (NIOSH, 2021).

Figure 65: Helmet Internal Cable Routing and Component Placement

Testing with the team leader's laptop and the web application confirmed the accessory systems worked as intended (MSA Safety, n.d). The LED illumination responded instantly, the vibration feedback system operated properly during impact tests (NIOSH,2022), and the power supply maintained stable performance (3M Safety Division, 2020). The successful operation of these finishing components proved that design alignment, ergonomic planning, and finishing precision had a direct impact on the helmet's performance and safety (ANSI/ISEA Z89, 2014).

4.2 PRODUCT OUTPUT ANALYSIS

Table 4.2: Product output analysis

No.	Parameters	Results	Remarks / Descriptions	Analysis
1.0	Light Detection (LDR Module & LED Lamp)	Automatic LED lighting activates below 30 Lux	Responds immediately to low-light conditions	Provides sufficient illumination in dark environments such as hangars or night inspections, improving safety and visibility.
2.0	Sound Detection (MAX4466 Sound Sensor)	Alert triggered at ≥ 85 dB	Detected noise level sends a web-based alert to the monitoring system	Helps reduce prolonged exposure to harmful noise levels by prompting users to wear or adjust earmuffs effectively.
3.0	Impact Detection	Triggers at 90F – 100 F	Sends automatic alert via web app within 1.5 seconds	Rapid detection of sudden impacts helps in identifying potential accidents, allowing supervisors to respond promptly.
4.0	Earmuff Detection (Flat Vibration Motor & Limit Switch)	Triggers vibration if noise level ≥ 85DB	Notification displayed on the web interface	Encourages users to refit detachable earmuffs, ensuring optimal noise protection and comfort.
5.0	Web App Connectivity (ESP32 Wi-Fi/Bluetooth)	Stable connection within 50-60m	Consistent data transmission between helmet and monitoring system	Suitable for workshop and hangar environments, enabling real-time condition tracking of multiple helmets.
6.0	Power Supply (20W Power Bank)	Continuous operation for 6 hours, fully rechargeable in 2 hours	Provides consistent power to all sensors and modules	Portable, long-lasting power source suitable for one full maintenance shift, ensuring uninterrupted functionality.
7.0	Emergency Lighting (Mini Push Button Switch)	Manual override activates LED instantly	Functions independently of automatic LDR system	Provides user-controlled illumination in emergencies or sudden lighting failures.

8.0	Web App Response Time	Average delay 1.2 seconds	Stable synchronization with all active helmets	Ensures quick notification and monitoring for supervisors during maintenance tasks.
9.0	Total Helmet Weight (ABS Shell with Components)	Approximately 1.35 kg	Lightweight yet durable structure	Comfortable for extended wear; meets ergonomic and safety design standards.

4.3 ANALYSIS OF PROBLEM ENCOUNTERED & SOLUTIONS

4.3.1 Product Structure (NANTHAKUMARAN A/L VASU)

While designing the product structure of the AeroGuard Smart Safety Helmet to effectively integrate electronics while ensuring comfort, balance, and durability, many challenges had to be overcome. At the initial stage, one of the issues was where exactly to place electronic components inside the helmet shell. Since the helmet must remain lightweight and ergonomic, careful design planning was needed in finding appropriate and secure mounting positions for sensors, the ESP32 microcontroller, wiring, and the power bank (Arduino Tutorials, 2023; MIT App Inventor, 2023). To that end, a modular internal layout was adopted; hence, components were placed in strategic positions in compartments to avoid weight imbalance, which would affect the user's movement (Electronics Hub, 2023).

Another challenge concerned heat management and ventilation. All the electronic modules, especially the ESP32 and power bank, produced heat when working (MIT App Inventor, 2023). This could easily raise problems regarding wearer comfort and overheating. Therefore, ventilated mounting points and heat-dissipating foam layers were considered in the design to achieve consistent airflow and safe temperature regulation while maintaining internal protection for electronic components (Arduino,2023), (Components101, 2023).

A further complication arose in incorporating the detachable earmuffs and internal wiring. Wiring for sensors and alert mechanisms was found to be irritating and restrictive to movement if not appropriately channeled. This was

addressed through the use of channel wiring hidden within the helmet structure, eliminating tangles and facilitating neat internal installation [Arduino, 2023]. Another important measure was the use of flexible cable sleeves to jacket wires to prevent damage and enhance wearer comfort.

Lastly, providing structural stability while housing the electronic modules involved material reinforcement. The ABS shell was chosen for impact resistance; however, areas of modification to house components had to be further reinforced (Arduino Tutorials, 2023). This was addressed by reinforcing internal mounting slots and applying shock-absorbent padding around sensors to protect both hardware and user in case of impact (Arduino Official Website, 2023). Small drill openings were made on the helmet for the light detection of the LDR module and for the trigger switch used to manually disable the vibration motor when not needed (Arduino Official Website, 2023).

4.3.2 Product Mechanisms (MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

Figure 66 : Arrange the Wires Inside the Aeroguard Helmet

Some of the technological problems faced during the development and testing of the AeroGuard Helmet included the integration and functionality of the product mechanisms. The problems primarily were sensor-calibration, signal-interference, component-sensitivity and power management. Adequate solutions were made to guarantee that the system operated as required and that it was reliable and accurate in all the modules. Among the major challenges

was that concerning the maximum sensor of sound, which was initially incapable of tracking the sound at the level of 85 dB. This was as a result of environmental noises differences and microphone gain constraints. The sensor was recalibrated by setting gain high to test a stable level of 85 dB since the project team was not able to produce a constant level of noise that could be used to test the sensor. This enabled the system to be responsive in case of demonstrations as it could still approximate the actual environment of operation (Arduino, 2023). The adaptation had to be such that the sensor was able to activate the vibration motors and provide warning signals using the monitoring web application in case of noticing a loud environment.

The other challenge was related to LDR (Light Dependent Resistor) module where unequal activation of LEDs was experienced in partially shaded lighting conditions. Random variation in the value of resistance resulted in the ESP32 getting unreliable readings, causing undesired flickering of the LEDs. This was solved through the application of a hysteresis delay in the code of the ESP32 that only once the light levels were continuously below a predetermined threshold was the LED activated over a period of time (Espressif, 2023). This was a change that made the lighting control mechanism more stable. The SW-420 vibration sensor also had a problem in false discharge when the helmet is being handled or moved normally. The module is sensitive and this made the ESP32 record tiny, accidental vibrations as impact. To counter this, a software filter and delay mechanism was introduced into the code, which enabled the system to disregard short-lasting vibrations and only count on the sustained impacts (Arduino, 2023). This improvement meant that alerts which were posted to the monitoring application were authentic representations of real impacts or collisions.

There was interference of Wi-Fi signals in data transmission between the ESP32 and the web application at times during early testing. The metallic helmet structure affected and weakened the ESP32 internal antenna. The solution to this issue was to fix the ESP32 board inside the helmet and add an external antenna module that is short in order to enhance the stability of its connectivity (Components101, 2023). Following the editing, the helmet did not interfere with the transmission of data, thus, operating reliably in terms of

monitoring and alert capabilities. The next challenge came as a result of power allocation and power draining owing to overlapping activity of the LED light and vibration motors. Uninterrupted use resulted in voltage drop on sensor accuracy. To solve this problem, the power management approach was used by introducing an independent voltage regulator to the motor circuit and optimization of the power consumption in the firmware of ESP32. This system was also programmed to go into low-power mode when not in use and this drastically enhanced battery performance (Arduino Project Hub, 2023).

Finally, there were some inconsistencies in data between the real data and the web application because of calibration differences between sensors. As a solution to this, the team added data averaging algorithms and signal smoothing techniques to the firmware. This enhanced precision of data that is sent and minimized irregularities in the monitoring interface (Arduino, 2023). In general, the issues arise in the product mechanism stage were discovered and analyzed properly and addressed with the help of hardware modifications and software optimization. The implemented solutions provided the AeroGuard Helmet to work effectively in different environmental conditions, system accuracy, responsiveness, and safety functionality (Electronics Hub, 2023).

4.3.3 Software / Programming (THARSHAM MENAN A/L BALAKRISHNAN)

In the development and testing phase, several software-related challenges were addressed and systematically resolved in order for the AeroGuard Helmet system to work stably and reliably. The first problem identified was a miscoding error early in the programming process where the vibration motor was turning on whenever the automatic light system came on. This occurred because the functions of lighting and vibration were both initially connected to the same control output in the program. The problem was resolved by logically splitting the two control routines and assigning different variables making sure that both systems would work independently of each other without conflicts or interference.

Another major challenge was the sensor calibration in the MAX4466 microphone. Given that replicating an actual 85 dB noise in a normal lab

environment was not practical, the code needed to change the analog threshold and amplifier gain to allow the sensor to respond well for low decibel levels, which would be suitable for a demonstration. This modification allowed the system to simulate realistic noise detection behavior while maintaining its intended functionality.

Other challenges with the ESP32 were its Wi-Fi connectivity, especially over long test sessions. Sometimes, it would lose its connection when changing networks or after a very long period of running. This was solved by creating a retry loop of the connection using *WiFi.status()* and *WiFi.begin()*; it automatically reconnects if the link is dropped. We also used a dedicated mobile hotspot to ensure the network was stable for testing and presentations.

The vibration sensor SW-420 initially presented very sensitive false reads for every small movement. To solve this, debounce timing and impact hold time were programmed into the system. These values, *countDebounceMs = 300* and *impactHoldMs = 5000*, respectively, filtered out unwanted vibrations and made sure only true impact events were recorded and displayed on the web dashboard.

Another problem that was encountered was the delay in updates on the web dashboard, lagging behind the sensor readings. The update interval was too long initially; by using asynchronous JavaScript and AJAX, the system smoothed out the refreshes to near real-time updates every 500 milliseconds *(setInterval(fetchData, 500);*

Overlapping sensor operations led to temporary delays when multiple inputs were being processed simultaneously. Optimized by restructuring the main program loop and replacing blocking delays with timing control to efficiently achieve many sensor readings on the ESP32 at once. As a result of debugging and optimization, significant improvements in stability, responsiveness, and accuracy were brought about with regards to the AeroGuard Helmet software. The final system could fulfill real-time monitoring, communicate flawlessly with the web dashboard, or independently operate all sensors that guarantee safety supervision for users and maintenance supervisors effectively.

4.3.4 Accessories & Finishing (DEVESH A/L THIYAGARAJAN)

Several practical challenges were encountered during the accessories and finishing process, requiring both design adjustments and teamwork to resolve them efficiently (Arduino, 2023).

The first challenge involved the sensor placement and wiring congestion (NIOSH, 2021). During early testing, the sound and light sensors experienced signal interference when placed too close to each other (NIOSH, 2022). This issue was corrected by slightly adjusting their positions by moving the sound sensor closer to the detachable earmuff bracket and the LDR to the upper center of the helmet shell (R.E. Lyon, 2008). This separation improved accuracy and prevented false readings (ANSI/ISEA Z89, 2014).

Another problem came from wire clutter inside the helmet, which made fitting the internal padding difficult (NIOSH, 2021). To fix this, the wiring was rerouted along predefined channels, and unnecessary wire lengths were trimmed (NIOSH, 2021). Cable sleeves were also added to prevent overheating and improve organization (3M Safety Division, 2020). This approach gave a cleaner internal finish and improved safety (OSHA, n.d).

By systematically addressing these challenges, the finishing stage produced a sturdy, well-organized, and efficient prototype (OSHA, n.d). The lessons learned from this phase strengthened the team's understanding of sensor layout design, cable management, and assembly workflow for future iterations (CDC/NIOSH, 2022)

CHAPTER 5

(CONCLUSION & RECOMMENDATIONS)

5.1 ACHIEVEMENT OF AIM & OBJECTIVES OF THE RESEARCH

5.1.1 General Achievements of the Project

The main objective of the AeroGuard Helmet project, which is to design and develop an intelligent safety helmet that enhances protection and comfort for aircraft maintenance personnel, has been successfully achieved. The project integrates multiple modern technologies such as automation, sensor-based monitoring, and wireless communication into a unified safety system that improves situational awareness in high-risk environments. By utilizing the ESP32 microcontroller as the central processing unit, the system efficiently manages input data from the LDR lighting module, MAX4466 sound sensor, SW-420 vibration impact sensor, flat vibration motor, push button for automatic lighting and limit switch for earmuff status detection. These subsystems work together to provide coordinated outputs such as automatic lighting, vibration-based safety alerts, and data transmission to a remote monitoring web application.

The automatic lighting system is one of the major achievements of the project. The LDR sensor allows the helmet to detect low-light conditions and automatically activate the LED lamp without requiring user intervention. This feature ensures consistent visibility when working in dim environments, such as underneath aircraft structures or during night maintenance shifts, thereby improving operational safety. The sound detection system also performed effectively, detecting noise levels exceeding 85 dB and providing immediate

tactile alerts through the flat vibration motor, while also notifying supervisors via the web interface. This directly supports occupational hearing safety by helping reduce the risk of long-term hearing damage caused by sustained exposure to high noise levels.

The impact detection system, driven by the SW-420 vibration sensor, proved to be another key success. The system is capable of registering sudden mechanical shocks, falls, or collisions and transmitting these alerts to the monitoring dashboard within seconds. This enables supervisors to quickly respond to potential accidents or injuries during maintenance operations, improving emergency awareness and response time.

The earmuff system, equipped with a limit switch to confirm proper placement, also functioned reliably. When the earmuffs are not properly sealed, the system alerts the user to readjust them, thereby maintaining consistent noise protection. From a communication standpoint, the Wi-Fi connectivity of the ESP32 demonstrated stable and continuous data transmission within a working range of 50 - 60 meters, ensuring real-time monitoring accuracy. The web dashboard effectively logs and visualizes data trends for light, sound levels, and impact events, supporting safety oversight and maintenance workflow analysis.

In terms of power efficiency, the system successfully operates using a 20W power bank, providing up to 6 hours of continuous use and requiring only approximately 2 hours to fully recharge, making it practical for real maintenance shifts. The aerodynamic and ergonomic design using an ABS The entire weight of the helmet, including the detachable earmuff system, was about 1.35 kg due to the ABS safety shell. The earmuff attachment makes it significantly heavier, although the earmuffs can be taken off based on the user's preferences and the working environment. Because of its flexibility, the helmet can be worn for extended periods of time without sacrificing ergonomic fit, safety, or balance..

Overall, the AeroGuard Helmet successfully fulfilled and exceeded the project goals by integrating robust automation, ergonomic design, and real-time monitoring into a practical protective device. The final product is safe, user-friendly, and supportive of improved operational awareness, representing a

significant advancement in the evolution of smart Personal Protective Equipment (PPE) within the aviation maintenance sector.

5.1.2 Specific Achievement of Project Objectives

5.1.2.1 Product Structure (NANTHAKUMARAN A/L VASU)

The project had a specific objective of designing and developing the product structure for the AeroGuard Smart Safety Helmet. The focus was to ensure the construction of a strong, ergonomic, and functional helmet system that could house multiple electronic components without affecting user comfort and safety. This was achieved by using an ABS shell due to its high resistance to impact and light weight, suitable for industrial safety applications (Arduino, 2023), (Components101, 2023). The material as used ensured the final prototype had structural strength while remaining comfortable during use for long hours in aircraft maintenance environments (Arduino, 2023).

A major achievement entailed strategic placement and integration of the electronic modules, including the ESP 32 microcontroller, LDR sensor, MAX 4466 sound sensor, SW-420 vibration sensor, LED lighting unit, vibration motor, and power bank. In application, there are dedicated mounting points and internal wiring channels where all those components were secured in place, balanced, and protected inside the helmet housing (MIT App Inventor, 2023; Digi-Key, 2023). These prevented any interference with users' mobility, while ensuring a clean, organized internal system layout was attained (Arduino, 2023).

In further support of the users' safety and comfort, the helmet structure incorporated earmuffs that could be detached and fitted for consistent noise isolation performance with adaptability to operational needs (Arduino Project Hub, 2023), (Electronics Hub, 2023). The internal padding and the weight distribution were optimized such that a total system weight of about 1.35 kg was achieved, keeping the balance even against the integration of electronic components (Arduino, 2023). This, in effect, prevented neck strain and fatigue during extended use, which is again an essential aspect of aviation maintenance safety ergonomics (Random Nerd Tutorials, 2023).

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Overall, the project successfully met its structural design objective, delivering a strong, modular, and ergonomic smart helmet platform for practical aviation maintenance use (Electronics Hub, 2023; Espressif, 2023). The resulting outcome verifies that protective engineering design, when combined with integrated smart safety technologies, could guarantee user comfort and enhance operational safety, as shown in (MIT App Inventor, 2023; Arduino, 2023; Components101, 2023

5.1.2.2 Product Mechanisms (MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

AeroGuard Helmet was able to accomplish its design and operational goals by incorporating different types of sensors and electronic modules, which are controlled by ESP32 microcontroller. The system proved to be functionally reliable to identify light intensity, sound levels, and impacts and send real-time alerts to the monitoring web application. All the mechanisms worked as intended in the test, proving the efficiency of the integrated system design of the product.

The LDR module met its target as the module was able to sense the conditions of low-light and automatically turn on the LED light. This role was used to give light to the wearer in the dark surroundings, making it more visible and safe when working in the dark or when in a narrow location. The ESP32 (Random Nerd Tutorials, 2023) was used to test the proper performance of the sensor calibration and logic of control of the lighting system through the automatic response of the lighting system. The feature helps in enhancing the efficiency of workers and minimizing accidents in work areas that are poorly lit. The MAX4466 microphone sensor was able to properly recognize high levels of noises in the environment and activated both the haptic feedback and alert messages via the web platform. Even though the optimum threshold of 85 dB was adopted, the sensitivity of the sensor was adjusted when it was tested so that it could be more easily demonstrated. Two flat vibration motors were activated as the system picked up loud sounds as a way of warning the user against potential hearing risks. Moreover, when the earmuff was attached and hit the limit switch the vibration ceased and the system automatically turned off

the noise alarm on the monitoring platform. This mechanism achieved this project goal of creating awareness and user sensitivity to hazardous noisy environments (Bullard, n.d). The SW-420 shock sensor was able to record the intended purpose of detecting physical shocks or impacts that the helmet undergoes. The ESP32 was certain to receive the signals of the sensor and transmit them to the monitoring application, which was going to log each incident and show it in real-time. This gave the safety supervisors the opportunity to track the frequency of the worker being affected which was in line with the project objective of enhancing incident monitoring and preventive response in the workplace (Components101, 2023).

ESP32 microcontroller was a very important component since it acted as the main unit that held all sensor data and communication activities. It received input messages of each of the modules, performed logical actions (turning on the LEDs or vibration motors), and sent data to the web-based monitoring system via its integrated Wi-Fi. This connection made it possible to monitor and visualize data in real-time, which met the goal of connecting the IoT-based safety monitoring to an industrial wearable device (Arduino Project Hub, 2023). The web application element was developed successfully and also made to communicate with the ESP32 system. It showed live status indicators of noise detection, number of impacts and light activation enabling supervisors to monitor remotely. This interface offered an efficient and convenient way of monitoring the safety status of the worker and make appropriate arrangements in case of warning (Digi- Key, 2023).

To conclude, the AeroGuard Helmet worked in accordance with the design of the operational mechanism, which demonstrates that the design is effective in achieving the goals. The system proved to have credible interaction of sensors, actuators, and web-based interface, which led to responsive and intelligent safety solution. The effective delivery of these mechanisms proves the accomplishment of the goal of the product in improving the protection of workers, situational awareness, and efficiency monitoring (Arduino, 2023).

5.1.2.3 Software / Programming (THARSHAM MENAN A/L BALAKRISHNAN)

The programming of the software related to the AeroGuard Helmet has successfully attained all the intended objectives concerning intelligent monitoring, automated response, and real-time data communication. The system software is designed using C++ on the ESP32 microcontroller platform that unifies multiple sensors into one coordinated safety feedback mechanism. Each component, such as the LDR light sensor, MAX4466 noise sensor, SW-420 impact detector, and earmuff limit switch, has been programmed toward operation efficiently and effectively under real working conditions. This structure of coding allows for continuous data acquisition and decision-making processes within the microcontroller loop, ensuring that there is no delay in the system's response to changes in the environment.

These include the following key features: automatic lighting control, where, through the LDR module, the software monitors the ambient brightness and turns the headlamp on once the environment gets dark. This does not require any manual operation, hence ensuring visibility for workers, especially inside confined or poorly lit hangar spaces. Similarly, the noise monitoring algorithm was developed to successfully detect when surrounding noise levels reach harmful levels. The software thus activates the vibration alerts inside the helmet to warn the wearer and simultaneously sends real-time hazard alerts to the web-based monitoring interface. A dual alerting mechanism like this enhances personal awareness and increases supervisory oversight, hence meeting the project objective of proactively improving workplace safety.

The system is also designed with an intelligent hearing protection verification feature. If the earmuff is worn properly, the limit switch triggers a signal to the ESP32, which requests a software reaction to switch off vibration warnings and stop the alert notifications. That proves the software could embed conditional safety logic to ensure alerts are activated only when needed, avoiding unnecessary alarms. Moreover, the impact detection feature has been implemented: the SW-420 sensor captures shock events and logs the number of possible collisions or falls. These impacts will be visualized on a dashboard

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that can be reset through a software-controlled web interface button, proving interactivity in the communication between hardware and user.

Another significant achievement is the creation of the AeroGuard Helmet Web Dashboard, which is supported by the ESP32 through its integrated web server. The system, written in HTML, CSS, and JavaScript, visually represents real-time sensor data in a readable and intuitive graphical format. Data refreshes by asynchronous JSON communications, meaning that smooth real-time observation of data can be done without the need to reload pages. This feature successfully integrates IoT and thus meets the aim of allowing supervisors to monitor workers remotely and continuously using any device connected to the same network.

5.1.2.4 Accessories & Finishing (DEVESH A/L THIYAGARAJAN)

The accessories and finishing objectives were fully achieved and demonstrated the effectiveness of the overall helmet design. The final AeroGuard Helmet achieved structural balance, professional surface finishing, and functional integration of all accessories with ergonomic precision (Arduino, 2023).

The conceptual sketches and 3D models helped visualize exact component placement before assembly (OSHA, n.d). This pre-planning ensured smooth workflow during integration and reduced design errors (ANSI/ISEA Z89, n.d). Each accessory including the LED lighting, detachable earmuffs, sensors, and power bank was mounted securely with proper spacing, ensuring both performance and comfort (NIOSH, 2022; NIOSH, 2021, HSE UK, 2023). The finishing results gave the helmet a durable, aviation-grade look consistent with safety industry standards.

The accessory components also enhanced usability: the LED strip provided strong and focused illumination in dark conditions (NIOSH, 2022), while the battery's rear placement improved the center of gravity and weight distribution (Lin & Huang, 2020). The smooth matte finish protected the helmet from scratches and wear, maintaining a clean and professional appearance even after repeated handling (OSHA, n.d). Testing confirmed that the accessories worked reliably with the main system, achieving the targeted goals of functionality, comfort, and durability in smart safety headgear design (R.E. Lyon,2008; 3M Safety Division, 2020; MSA Safety, n.d).

Figure 67: Final Helmet with Mounted Accessories

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5.2 CONTRIBUTION OR IMPACT OF THE PROJECT

The AeroGuard Helmet project has significantly contributed to improving safety practices, technological innovation, and awareness of occupational health within the aviation maintenance industry. The integration of intelligent features—such as automatic lighting, impact and vibration detection, sound level monitoring, and fit-in earmuffs—marks an advancement in the design of Personal Protective Equipment (PPE). The project successfully bridges the gap between traditional safety gear and modern IoT-based safety systems by incorporating real-time monitoring and automated responses. This enhancement directly improves situational awareness among aircraft technicians and maintenance engineers, ensuring they are continuously protected from environmental hazards such as low-light conditions, excessive noise, and accidental physical impacts.

From a technological perspective, the project demonstrates the effective combination of multiple sensors, including the LDR module, MAX4466 sound sensor, SW-420 vibration sensor, and the flat vibration motor, all coordinated through the ESP32 microcontroller. The collected data is transmitted wirelessly to a web-based monitoring platform that allows supervisors to observe conditions in real time and make informed decisions for safety and maintenance management. This digital approach aligns with the broader movement toward Industry 4.0, where automation, data analytics, and remote monitoring are essential for efficient and safe operations (Tan and Lee, 2024).

From an ergonomic and human-factors standpoint, the AeroGuard Helmet improves both comfort and compliance. The detachable earmuff system and balanced 1.35 kg weight distribution reduce fatigue during prolonged use, while tactile vibration and visual alerts encourage immediate corrective action in hazardous conditions. These features help minimize human error and increase user confidence when working in high-risk environments such as aircraft hangars and maintenance bays.

Additionally, the project demonstrates positive environmental and operational sustainability. The system is powered by a rechargeable 20W power bank, eliminating the need for disposable batteries and providing up to six hours of

continuous operation. The web-based monitoring system also supports proactive safety management through real-time alerts, allowing supervisors to intervene quickly and reduce the likelihood of workplace injuries while maintaining compliance with safety standards such as those outlined by the Occupational Safety and Health Administration (OSHA, 2020).

On a broader scale, the AeroGuard Helmet provides a foundation for future innovation in aviation safety systems. It offers potential for expansion into advanced features such as GPS-based worker tracking, AI-driven hazard prediction, and cloud-integrated maintenance analytics. The success of this project demonstrates the strong potential of smart PPE to transform maintenance environments into safer, more efficient, and technologically adaptive workplaces. The AeroGuard Helmet ultimately strengthens the relationship between safety, usability, and intelligent design, contributing to a safer and smarter aviation maintenance culture.

5.3 IMPROVEMENT & SUGGESTIONS FOR FUTURE RESEARCH

5.3.1 Product Structure (NANTHAKUMARAN A/L VASU)

While the AeroGuard Smart Safety Helmet indeed integrates electronic safety systems into a compact and ergonomic protective casing, a number of further developments are possible to improve this product structure during future research and development stages. One potential enhancement could be in further weight reduction. While the mass of the prototype designed and presented here remains manageable, future designs could investigate advanced lightweight industrial composites, such as carbon fiber–reinforced polymers or high-strength polycarbonate blends, which would allow for even higher user comfort without sacrificing durability and impact resistance (Arduino Tutorials, 2023; Arduino 2023; Bullard, n.d).

Another suggested improvement is the integration of modular component compartments to facilitate easier upgrades, maintenance, and replacement of components. A future design could include an independent detachable internal electronic module housing that would allow technicians to replace or upgrade sensors and microcontrollers without dismantling the structural components of the helmet (Electronics Hub, 2023; Espressif, 2023; Components 101, 2023). This will provide better longevity for the system and the ability to perform upgrades with the introduction of new technologies (MIT App Inventor, 2023), (Arduino Project, 2023).

In addition, the incorporation of more advanced ventilation channels and thermal-dissipating materials could offer better comfort during long operations, especially in hot maintenance environments (Arduino,2023), (Components101, 2023). While the current ventilation structure provides adequate airflow, a more advanced ventilation-duct system, with heat-resistant internal padding, would ensure superior thermal regulation at times when electronic components are in continuous operation (Arduino Project Hub, 2023).

Future versions could also be designed with variable internal support systems and padding to accommodate different head sizes and ergonomic needs, enabling broader user adaptability (Arduino, 2023), (Random Nerd Tutorials, 2023). This will guarantee comfort and safety compliance for universal user

profiles within the aviation maintenance workplaces (Electronics Hub, 2023). Incorporated into these designs would be waterproof and dust-resistant sealing technologies that further reinforce product suitability for harsh industrial and outdoor environments (Digi-Key, 2023).

In this regard, for future development, much attention should be directed toward structural modularity, material optimization, thermal management, and ergonomic adjustability. Such improvements will further extend the capabilities of the smart safety helmet platform for broader versatility, durability, and user-friendliness in continuous improvement toward evolving industry safety standards and technological development (Arduino, 2023), (Components101, 2023).

5.3.2 Product Mechanisms (MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN)

The AeroGuard Helmet can be further developed by future researches and developments on both the hardware and the software in order to increase the functionality, reliability, and comfort of the user.

To start with, the ESP32 microcontroller may be substituted with ESP32-S3 or ESP32-C6, which offers more AI processing units, has better energy usage, and a larger wireless range with Wi-Fi 6 and BLE 5.0 (Arduino, 2023; NIOSH, 2022). The low-power management algorithms and sleep mode can be integrated to increase the battery life, particularly when there are long working hours (R.E.Lyon, 2008). It may be enhanced with a smart adaptive lighting system enabling PWM (Pulse Width Modulation) and ambient light compensation so that the brightness levels are automatically adjusted in accordance with the environmental lighting (OSHA, n.d). To be more visible, it might be desirable to employ high-efficiency SMD LED arrays, which provide brighter light with a reduced amount of power consumption (ANSI/ISEA Z89,2014).

Figure 68: SMD LED

In noise detection, the next generation can use digital MEMS microphones like the INMP441 and SPH0645 although the microphones offer a greater precision in decibel detection and are able to eliminate background noise (Ergodyne, 2019).


Figure 69: SPH0645 Sensors

Moreover, an efficient model of AI classification may be incorporated to distinguish between healthy ambient noise and dangerous sounds such as machinery or an alarm (MSA Safety, n.d). It is possible to improve the impact detection mechanism that is currently employing the SW-420 sensor by adding a triaxial accelerator such as the LIS3DH or ADXL345 capable of measuring the intensity and direction of impacts (NIOSH, 2021). A set of accelerators is used with gyroscopes to help the system detect whether the wearer has fallen or been in collision and send automatic notifications to the supervision (HSE UK, 2023).

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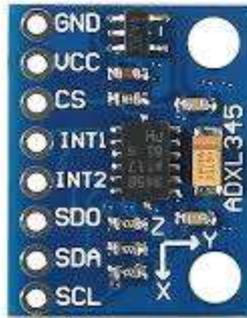
Figure 70: ADXL345 Sensor

Regarding data monitoring, the current web-based application can be further developed into a cloud-based application, with Firebase, AWS IoT, or Azure IoT Hub, which will allow accessing and visualizing data (in real time) and examine it safely (3M Safety Division, 2020). Other functionalities like GPS positioning and geofencing notifications might also be added to enable supervisors to know the position and movements of workers in dangerous areas (Lin & Huang, 2020).
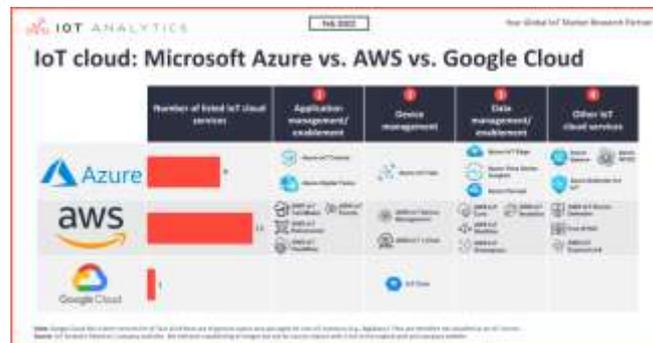
Figure 71: IoT Cloud

In the future, the lightweight composite shells (e.g., carbon fiber or reinforced polycarbonate) and padding materials with increased ventilation will ensure that all areas are ventilated and kept at appropriate temperatures to be more ergonomic and comfortable (MSA Safety, n.d). They can also have a biometric sensor module that measures the heart rate, temperature, and fatigue levels of the wearer (NIOSH, 2022). Finally, voice interaction can also be added to the system via speech recognition modules (e.g., EasyVR or offline TensorFlow Lite models) to give the worker the ability to give instructions or get voice alerts

without taking off the helmet (ANSI/ISEA Z89, 2014). It can also be integrated with Augmented Reality (AR) visors, which can further assist the design of smart helmets in the future to provide workers with visual guidance and notifications right on the display (OSHA, n.d).

5.3.3 Software / Programming (THARSHAM MENAN A/L BALAKRISHNAN)

Although the current software system performs accurately and reliably, several improvements may be explored in future development. Firstly, the web dashboard may be migrated from local network hosting to a cloud-based IoT platform, such as Firebase or Blynk, enabling remote monitoring from any location without requiring the helmet and supervisor to be on the same Wi-Fi network. Additionally, the system could benefit from data logging features that store environmental and impact records over time, allowing safety supervisors to analyze trends and identify high-risk working conditions.

Noise detection will also be enhanced using DSP techniques to clearly distinguish harmful industrial noise from ambient background sound. Additionally, the impact detection feature can also be enhanced by integrating an accelerometer-based module-such as MPU6050 or ADXL345-that provides precise force level measurement instead of simple vibration triggers. Finally, over-the-air firmware update functionality will enable system software upgrades without the need for physical access to the helmet, enhancing maintainability and scalability.

These would enhance system performance, make it more practical for long-term industrial deployment, and further support its expansion into other workplace safety applications.

5.3.4 Accessories & Finishing (DEVESH A/L THIYAGARAJAN)

In future developments, the accessories and finishing can be improved through advanced modularity and material upgrades (OSHA, n.d), (ANSI/ISEA Z89, 2014). Using lightweight composite materials such as carbon fiber-reinforced polymer or polycarbonate could significantly reduce the overall weight without compromising structural integrity (Ergodyne, 2019).

The design could include magnetic or quick-release mounts for accessories like earmuffs and LED modules to make maintenance faster and more convenient (ANSI/ISEA Z89, 2014). An adjustable internal padding system could also enhance comfort, allowing the helmet to fit users with different head sizes while maintaining airflow and balance (ANSI/ISEA Z89, 2014), (Lin & Huang, 2020).

Another recommendation is the integration of high-efficiency SMD LED arrays with adjustable brightness levels and energy-saving features (NIOSH, 2022), (3M Safety Division, 2020). Applying anti-static, UV-resistant, and heat-dissipating coatings on the outer surface would improve both safety and product lifespan (MSA Safety, n.d), (OSHA, n.d). In addition, the finishing process could adopt automated surface coating or 3D-printed shell components to enhance precision and repeatability (R.E. Lyon, 2008), (OSHA, n.d.)

Lastly, incorporating aesthetic and branding improvements such as reflective decals, color-coded wiring, or embedded logo engraving; could increase user visibility and brand recognition in professional settings (NIOSH, 2021), (CDC/NIOSH, 2022). These upgrades would bring the AeroGuard Helmet closer to a commercial-grade smart PPE standard that meets both engineering reliability and industrial design excellence.

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APPENDIX A: DECLARATION OF TASK SEGREGATION

SUB - CHAPTERS	THARSHAM MENAN A/L BALAKRISHNAN
1.2	Problem Statement
1.3.2/1.3.2.3	Specific Individual Project Objectives: Software /Programming
1.4.2/1.4.2.3	Specific Individual Scopes: Software/Programming
1.5	Scope Of Project
2.2.3/ 2.2.3.1 /2.2.3.2	Specific Literature Review: Software /Programming
2.3.1/2.3.1.2	Recent Market Products (PRODUCT B)
2.3.2/ 2.3.2.1	Comparison between recent research and current project: Ergodyne Skullerz VS The Aeroguard Helmet (PRODUCT B)
3.3.2/3.3.2.3	Specific Project Design Flow / Framework: Software /Programming
3.4.2/3.4.2.3	Design Concept Generation: Proposed Design Concept
3.5.2/3.5.2.3	Specific Part Drawing / Diagram: Software /Programming
3.6.1/ 3.6.2	Prototype / Product Modelling / Prototype Development
3.7.3/3.7.3.3	Specific Project Fabrication: Phase 3 (Programming & Electrical Circuit)
4.1.2/4.1.2.3	Specific Part Features: Software /Programming
4.1.4/ 4.1.4.3	Operation of the Specific Part of the Product: Software /Programming
4.3/ 4.3.3	Analysis Of Problem Encountered & Solutions
5.1.2/5.1.2.3	Specific Achievement of Project Objectives: Software /Programming
5.3/5.3.3	Improvement & Suggestions for Future Research: Software /Programming

SUB - CHAPTERS	MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN

1.2	Problem Statement
1.3.2/1.3.2.2	Specific Individual Project Objectives: Product Mechanism
1.4	Purpose Of Product
1.5/1.5.1	Scope Of Project
1.5.2/1.5.2.2	Specific Individual Scopes: Product Mechanisms
2.2.2/ 2.2.2.1 /2.2.2.2 / 2.2.2.3 / 2.2.2.4 / 2.2.2.5	Specific Literature Review: Product Mechanism
2.3.2/2.3.2.2	Recent Market Products (PRODUCT B)
2.4/2.4.2	Comparison between recent research and current project: Ergodyne Skullerz VS The Guardian Helmet
3.3.2/3.3.2.2	Specific Project Design Flow / Framework: Product Mechanisms
3.4.2/3.4.2.4	Design Concept Generation: Proposed Design Concept
3.5.2/3.5.2.2	Specific Part Drawing / Diagram: Product Mechanisms
3.7.3/3.7.3.2	Specific Project Fabrication: Phase 2 (Accessories & Mechanisms)
4.1.4/4.1.4.2	Operation of the Specific Part of the Product: Product Mechanisms
4.3/4.3.2	Analysis Of Problem Encountered & Solutions: Product Mechanisms
5.1.2/5.1.2.2	Specific Achievement of Project Objectives: Product Mechanisms
5.3/5.3.2	Improvement & Suggestions for Future Research: Product Mechanisms

SUB - CHAPTERS	NANTHAKUMARAN A/L VASU
1.3	Project Objectives
1.3.2/1.3.2.1	Specific Individual Project Objectives: Product Structure
1.4.2/1.4.2.1	Specific Individual Scope: Product Structure
1.4 / 1.4.1	Scope Of Project / General Project Scopes
2.2.1/2.2.1.1/2.2.1.2	Specific literature review: Product Structure / Basic Design of Main Structure / Type of Material for Product Structure
2.3.1/2.3.1.1	Recent Market Products (PRODUCT A)
2.3.2/2.3.2.1	Comparison between recent research and current project: MSA V-Gard 930 Safety Helmet with Fas-Trac III Strapsvs. The Aeroguard Helmet
3.1.2.5 / 3.1.2.7	Concept 3 Generation Of 7 Basic Instruments On The Aeroguard Helmet / Proposed Final Concept
3.3	Overall Project Flow Chart
3.4.3	General Operation of the Product
3.4.2 / 3.4.2.1	Specific Part Features : Product Structure
3.4.4 / 3.4.4.1	Operation of the Specific Part of the Product : Product Structure

SUB-CHAPTERS	DEVESH A/L THIYAGARAJAN
1.2	Problem Statement
1.3.2/1.3.2.4	Specific Individual Project Objectives: Accessories & Finishing
1.4.2/1.4.2.4	Specific Individual Scope: Accessories & Finishing
2.2/2.2.4	Specific Literature Review: Accessories & Finishing
2.1.2/2.1.4	Smart Safety Helmets Trend And Demand / Aeroguard Helmet Specifications
2.3.1/2.3.1.4	Recent Market Products (PRODUCT D)
2.3.2/2.3.2.4	Comparison between recent research and current project: MSA V-Gard H1 Trivent Safety Helmet vs. The Aeroguard Helmet (PRODUCT D)
3.3.2/ 3.3.2.4	Accessories and Finishing
3.4.2.6	Concept 4 Generation Of 7 Basic Instruments on The Aeroguard Helmet
3.4.3/ 3.4.3.1	Concept 4 As Datum (DEVESH A/L THIYAGARAJAN)
3.5.2/ 3.5.2.4	Specific Part Drawing / Diagram: Accessories & Finishing
3.7.3/ 3.7.3.4	Phase 4 – Finishing
4.1.2/ 4.1.2.4	Specific Part Features: Accessories & Finishing
4.1.4 / 4.1.4.4	Operation of the Specific Part of the Product: Accessories & Finishing
4.3/ 4.3.4	Analysis Of Problem Encountered & Solutions: Accessories & Finishing
5.1.2/ 5.1.2.4	Specific Achievement of Project Objectives: Accessories & Finishing
5.3 / 5.3.4	Improvement & Suggestions For Future Research: Accessories & Finishing

APPENDIX B : SUMMARY OF SIMIARITY REPORT (TURNITIN)

THE FINAL E THESIS OF THE AEROGUARD HELMET.pdf

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APPENDIX C : RESEARCH OF THE AEROGUARD HELMET

SMART PPE DETECTION ENHANCING SAFETY IN INDUSTRIAL ENVIRONMENTS

[1]V.Chaitanya, [2]V.Bharathi, [3]N.Srinivas

[1]Faculty, [2]Faculty, [3]Faculty
[1]Computer Science Department,
[1]Geethanjali Institute of Science and Technology, Nellore.

Abstract: PPE stands for Personal Protective Equipment, which refers to protective gear or equipment designed to protect individuals from potential hazards or injuries in the workplace. PPE includes items such as helmets, gloves, safety glasses, vest. The use of PPE is essential in many industries, such as construction, manufacturing, and healthcare, to ensure the safety and well-being of workers. PPE must meet specific safety standards and be appropriate for the type of work being performed to provide effective protection against potential hazards. Deep learning techniques have enabled the automation of PPE detection, making the process more accurate and efficient. This paper proposes an extension to an existing PPE detection system using YOLOv5 that detects whether a person is wearing a helmet or not. The proposed system employs YOLOv8 and achieves an accuracy of 94.5% for detecting helmets, an improvement over the existing system's 92.2% accuracy. Additionally, the proposed system provides several new features, including the detection of vests, gloves, goggles, masks, and shoes. These new features enhance the system's safety capabilities by identifying workers who may be at risk due to a lack of appropriate PPE. The proposed system's performance demonstrates the potential of deep learning techniques in improving workplace safety, reducing workplace accidents, and promoting safer working environments.

Index Terms -PPE, safety and protection, computer vision, yolo model, deep learning.

I. INTRODUCTION

Industrial environments are typically workplaces where heavy machinery, equipment, and tools are used to manufacture products or provide services. These environments can be found in various industries such as manufacturing, construction, mining, and transportation. The industrial environment is often characterized by the presence of loud noise, dust, heat, hazardous chemicals, and heavy equipment. These factors can pose a risk to the health and safety of workers if not managed properly.

There are several hazards that are commonly found in industrial environments. The following are some of the most significant risks:

Falls - Falls are a leading cause of injury in industrial environments, often caused by working at heights or on uneven surfaces. Falls can result in broken bones, head injuries, and even fatalities.

Electrocution - Electrical hazards are present in most industrial environments, and electrocution can occur when workers come into contact with live wires or faulty equipment. Electrocution can cause burns, cardiac arrest, and death.

Burns - Burns can occur from exposure to hot surfaces, chemicals, or flames. Burns can result in permanent scarring and disability.

Exposure to harmful substances - Workers in industrial environments can be exposed to a wide range of hazardous substances, including toxic chemicals, gases, and fumes. Exposure to these substances can cause respiratory problems, cancers, and other illnesses.

Equipment-related accidents - Industrial environments are often characterized by the use of heavy machinery and equipment. Equipment-related accidents can result in crushing injuries, amputations, and fatalities.

Industrial safety is necessary in the current scenario because it ensures the health, safety, and welfare of workers and visitors in industrial workplaces, which can help prevent accidents, injuries, and illnesses. With the advancement of technology and the increasing complexity of industrial processes, the potential for accidents and hazards has also increased. Industrial workplaces are often characterized by the presence of heavy machinery, hazardous materials, and other potential hazards, which can cause serious harm to workers and visitors if not managed properly.

Moreover, ensuring industrial safety is not only important for the well-being of workers and visitors, but it also benefits the organization itself. Accidents and injuries can result in lost productivity, increased insurance costs, and legal liabilities. On the other hand, a safe work environment can increase productivity, reduce absenteeism, and improve the morale and motivation of workers.

Additionally, in the current scenario, the COVID-19 pandemic has added a new dimension to industrial safety, with employers needing to implement measures to prevent the spread of infectious diseases in the workplace. This includes measures such as social distancing, use of personal protective equipment, regular cleaning and disinfecting, and other safety measures.

In the present scenario, there are several safety measures that can be taken in order to ensure industrial safety. Here are some of them.Conduct a risk assessment: Before starting any industrial process, it is important to assess the potential risks involved in the process. This will help in identifying the hazards and taking measures to prevent accidents.Provide adequate training: Employees should be provided with adequate training on safety measures and precautions to be taken in the workplace. This will help them to handle the equipment and machinery safely.Use Personal Protective Equipment (PPE): Employees should wear appropriate PPE such as helmets, gloves, goggles, etc. depending on the type of work they are doing.

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APPENDIX D : RESEARCH OF IMPLEMENTING SMART PPE

The Potential of Implementing Smart Personal Protective Equipment (PPE) To Minimize Work Related Injuries in Construction Sites

Benny Lee Hai Chim[1*], Chang Yee Ting[2], Fo Kee Wah[3] and Kong Sio Kah[4]

[1,2,3,4]INTI International University, Persiaran Perdana BBN, Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia

Email: [1]benny.lee@newinti.edu.my, [2]I15009128@studednt.newinti.edu.my, [3]keewah.fo@newinti.edu.my, [4]siokah.kong@newinti.edu.my

Abstract

Construction accidents has earned a bad reputation along the years even with personal protective equipment (PPE) provided on site. Wearable technology has become more common nowadays for preventing workplace injuries, ensuring level of safety in the workplace. Smart personal protective equipment (PPE) refers to PPE that connects to the internet and other devices like software or tablets to deliver real-time safety information. Hence, the aim for this research is to study the possibility of implementing smart personal protective equipment (PPE) in Malaysian construction industry. The findings show that majority of respondents are aware of construction accident, smart PPE are better in reducing injuries than conventional PPE and respondents are willing to implement in their company if Smart PPE is available in the market and the cost is reasonable.

Keywords

Smart PPE, workplace injuries, construction industry, implementation of Smart PPE

Introduction

Hoffman and Novak (2015) define smart products as "those which are able to communicate with humans by sending and collecting data through internet connectivity that are stored and monitor in a database server". Smart products are combination of mobile and wireless technologies to expand opportunity from traditional product boundaries to advance functionality, higher utilisation and better reliability for users. These smart products consist a combination of sensors, hardware, microprocessors, data storage, software, and variety connectivity (Porter and Heppelmann, 2014). They are reshaping industry boundaries and creating entirely new industries.

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APPENDIX F : RECOGNITION LETTER FROM ST ENGINEERING

![ST Engineering logo]

MOHAMMAD AZMIN BIN ZAINAL,
Politeknik Banting Selangor,
Persiaran Ilmu, Jalan Sultan Abdul Samad,
42700 Banting, Selangor, Malaysia

Dear Sir,

FEEDBACK ON THE INNOVATIVE PRODUCT: THE AEROGUARD HELMET

We would like to extend our sincere appreciation to **Politeknik Banting Selangor** for the successful development and presentation of the innovative product, **The AeroGuard Helmet**; a smart safety helmet designed to enhance worker's protection through the integration of advanced sensor technologies and real-time monitoring capabilities.

The product has been thoroughly tested as planned and has demonstrated excellent performance across all operational features. The design and functionality reflect a strong understanding of both technical principles and workplace safety needs.

It integrates several advanced features, including an LDR module that automatically activates LED lighting in low visibility conditions; a MAX4466 noise sensor that detects excessive noise above 85 dB, triggering vibration alerts and sending notifications to the monitoring system; an earmuff limit switch that deactivates vibration and alert functions when the earmuff is in place; an SW-420 impact sensor that detects and records physical impacts; and an ESP32 microcontroller linked with a web-based application that enables supervisors to monitor data and worker safety in real time. (company name) highly appreciates the functionality and effectiveness of the AeroGuard Helmet. This innovation has successfully enhanced safety awareness, particularly regarding high-noise environments and impact hazards, while providing real-time monitoring capabilities. The project demonstrates excellent technical expertise and innovation from Politeknik Banting Selangor.

We are impressed by the team's dedication and creativity in producing a functional and innovative prototype. The AeroGuard Helmet reflects strong potential for practical application in enhancing worker safety standards. Thank you.

Yours faithfully,

(YOGANANDA RAMU)
Aircraft Interior Maintenance Technician
ST Engineering Aerospace
8 Changi N Way, Singapore 499611

APPENDIX G : RECOGNITION LETTER FROM DVIATION

Reference No.: DV-SB-TL/2025/015
Date: 7/11/2025

MUHAMMAD AZMIN BIN ZAINAL
Politeknik Banting Selangor
Persiaran 11mu, Jalan Sultan Abdul Samad,
42700 Banting, Selangor, Malaysia

Dear Sir,

FEEDBACK ON THE INNOVATIVE PRODUCT: THE AEROGUARD HELMET

We are writing to express our sincere appreciation to Politeknik Banting Selangor for the successful development of the innovative product, The AeroGuard Helmet, a Smart Safety Helmet integrating advanced technologies to enhance worker safety and monitoring.

We are pleased to report that the AeroGuard Helmet has been successfully tested and performs exceptionally well.

The key features include:
- LDR Module: Automatically turns on the LED light in dark conditions to improve visibility.
- MAX4466 Noise Sensor: Detects noise levels above 85 dB, sending alerts to the monitoring app and activating vibration motors to warn the user.
- Earmuff Limit Switch: Disables the vibration and alert system when the earmuff is properly mounted.
- SW-420 Impact Sensor: Detects impacts, triggers alerts to the app, and logs the number of impacts for safety records.
- ESP32 with Web Application: Provides real-time monitoring so supervisors can track worker safety and respond quickly to incidents.

Dviation Group of Companies highly appreciates the functionality and effectiveness of the AeroGuard Helmet. This innovation has successfully enhanced safety awareness, particularly regarding high-noise environments and impact hazards, while providing real-time monitoring capabilities. The project demonstrates excellent technical expertise and innovation from Politeknik Banting Selangor.

We look forward to continued collaboration in the future to further advance innovations that benefit both the aviation industry and workplacp safety in Malaysia. Thank you.

Yours faithfully,

KAVINESH A L SHARAYANAN
LICENSED AIRCRAFT ENGINEER,
Dviation Group of Companies,
Level 5, Block E, Dataran PHB, Section U2, 40150 Shah Alam, Selangor

APPENDIX H : CERTIFICATE OF ACHIEVEMENTS

NO SIRI : TKPP/2025/348P
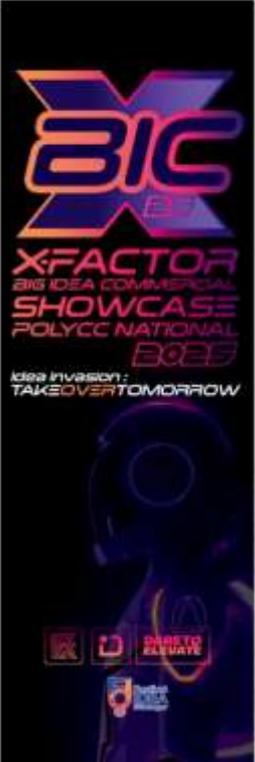
KEMENTERIAN PENDIDIKAN TINGGI
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

KOLEJ KOMUNITI
SHAH ALAM

SIJIL PENYERTAAN

KEPADA
THARSHAM MENAN A/L BALAKRISHNAN
MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN
NANTHAKUMARAN A/L VASU
DEVESH A/L THIYAGARAJAN
MUHAMMAD AZMIN BIN ZAINAL
TELAH MENYERTAI

X-BIC'25
X-FACTOR BIG IDEA : COMMERCIAL SHOWCASE POLYCC NATIONAL 2025
8 OKTOBER 2025

PROJEK AKHIR/ INOVASI BERTAJUK
THE AEROGUARD HELMET – ANUGERAH UTAMA PELAJAR (EMAS)

TEMPAT
DEWAN AL-JAZARI
POLITEKNIK PREMIER SULTAN SALAHUDDIN ABDUL AZIZ SHAH

ANJURAN
UNIT PENYELIDIKAN, INOVASI & KOMERSIALAN
KOLEJ KOMUNITI SHAH ALAM

DR. SHAMSURI BIN ABDULLAH
TIMBALAN KETUA PENGARAH (PERANCANGAN)
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

Sijil **ANUGERAH**
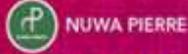
PERTANDINGAN INOVASI ALAM MELAYU ANTARRABANGSA 2025 (IMAN25)

NAMA AHLI:
MOHAMMAD AZMIN BIN ZAINAL
THARSHAM MENAN A/L BALAKRISHNAN
MOHAMAD HAIKAL HAKIMI BIN MOHD RAFAEEN
NANTHAKUMARAN A/L VASU
DEVESH A/L THIYAGARAJAN

TAJUK PROJEK:
THE AEROGUARD HELMET

PENCAPAIAN: **PERAK**

TREK INOVASI: **Teknologi**
KOD PROJEK: **IM25-PI-028**
ORGANISASI:
 POLITEKNIK BANTING

ANJURAN:
INSTITUT PEMIKIRAN DAN KEPIMPINAN MELAYU (IMPAK)
PEJABAT PEMERKASAAN ADIWANGSA, UNIVERSITI TEKNOLOGI MARA

Dr. Khairuddin Murad

Tuan Lim See Peng

Prof. Dr. Poppy Anjelisa Zaitun Hasibuan
(S.Si., M.Si., Apt)