DEPARTMENT OF AIRCRAFT MAINTENANCE

FINAL PROJECT REPORT

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

SUPERVISOR:

MR. MOHAMAD FAIZAL BIN DAUD

REPORT ENDORSEMENT

This report is being submitted, reviewed and endorsed to fulfil the condition and the requirement of report writing as specified

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CERTIFICATION OF PROJECT ORIGINALITY & OWNERSHIP

REMOTE CONTROL AIRCRAFT TUG

SESSION 1: 2023/2024

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

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ABSTRACT

The Remote Control Aircraft Tug (RCAT) project seeks to create a dependable and effective system for moving and maneuvering aircraft inside airport and hangar environments. The project gives precise control over speed and direction by utilizing wireless control technology providing safe and efficient aircraft operation. The software and programming for the project is based on the Arduino microcontroller board and the BTS7960 motor driver. The Arduino Uno R3 acts as the control center for the system and the programming logic enables the tug to respond to the commands received from the remote control system and execute the desired movements accurately. The integration of the BTS7960 motor driver ensures efficient power delivery to the motors which resulting in smooth acceleration and deceleration.

The usage of the FlySky FS-i6X remote control system improves the reliability and range of wireless control, allowing operators to operate in a flexible and easy manner. The advanced characteristics of the system, such as several channels and programmable functions, enable customization and adaptability to more additional feature in the future.

The locking device's structure, which includes mild steel and a locking pin, ensures a strong and solid connection between the tug and the aircraft. This assures that the aircraft landing gear stays securely connected during towing and avoids the possibility of accidentally disconnection.

Overall, the RCAT project provides a reliable as well as efficient solution for aircraft handling at airports and hangars. The combination of wireless control technology, the FlySky FS-i6X remote control system, and Arduino-based hardware and programming gives a versatile and user-friendly mode of operation. This initiative has the potential to increase efficiency and safety in approved maintenance training organization part 147 and flying academy operations by streamlining aircraft handling processes.

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LIST OF SYMBOLS

SYMBOLS	MEANING
V	Volt
DC	Direct Current
RPM	Rotation per Minute
Nm	Newton Meter
W	Watt
Mhz	MegaHertz
A	Ampere
GHz	GigaHertz
“	inch
ft	feet

LIST OF ABBREVIATIONS

ABBREVIATION	MEANING
RCAT	Remote control aircraft tug
LED	Light emitting diode
USB	Universal serial bus
VFD	Variable frequency drives
AC	Alternating current

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

What exactly is aircraft towing? What exactly is a remote-control aircraft tug? Towing an aeroplane means driving it forward using the power of a specialize ground vehicle linked to or supporting the nose landing gear, usually with the engines shut off. It might happen to both operational and out-off-service aeroplanes. It also usually for pushback the aircraft back the taxiway. There are two type of towing vehicle generally use in aviation industry nowadays which either using towbar or towbarless aircraft tug. Figure 1.1 and figure 1.2 are the most common forms of aircraft towing equipment and method.

Figure 1.1: Conventional aircraft truck (SkyBrary, n.d)

Figure 1.2: Towbarless aircraft truck (Google, n.d.)

Conventional aircraft trucks commonly use a metal tow-bar connected to the the nose landing gear of the plane. To avoid the landing gear being overstressed when the aircraft is pushed back, the tow bar has a shear pin that will snap and disconnect it from the plane. Unlike the conventional aircraft truck, we mentioned above, towbarless method do not use a tow-bar as a link between nose landing gear to the aircraft tow truck. The hydraulics raise the nose landing gear wheels off the ground instead of attaching them to the nose gear. Doing this saves all the time involved in attaching the tow bar to the plane and the tractor. It also frees up the ramp by removing the complexity of where to store the tow bars.

Some aircraft towbars are universal, meaning aircraft ground handling personnel can use them for multiple aircraft, but the size is a factor. For example, when towing a large aircraft, you would not want to use a portable universal towbar meant for a smaller jet. The towbar wouldn't be strong enough to move the mass of the aircraft and could easily warp and break. For this reason, most airport terminals are arranged for specific aircraft to use certain tow-in gates.

"The conventional tug-and-tow bar configuration would not clear tight constraints inside of this building for turning and positioning aircraft" (Carl Motter Jr, 5 December 2021)

Based on the statement above, it has been clarified that towing aircraft using tow bar is not suitable inside the building. It may be dangerous to perform a tight turn and may cause an accident and damage to the aircraft and ground crew.

1.2 PROBLEM STATEMENT


Boeing 737 crushes tow truck driver to death as it is being pulled to a gate at Bangkok airport

By Jack Elsom For Mailonline
08:59 07 Feb 2020, updated 09:12 07 Feb 2020

Figure 1.3 News of aircraft towing accident at Bangkok Airport (New straits times, February 2020)

Despite aircraft towing incidents are uncommon, they can have serious consequences ranging from minor aircraft damage to catastrophic disasters. These mishaps can happen at any point throughout the towing operation, from attaching the tow bar to manoeuvring the aircraft to releasing the tow bar.

Figure 1.3 shows that On February 7, 2023, a Nok Air Boeing 737 being towed at Bangkok's Don Mueang International Airport crushed a tow truck, killing the driver. According to initial reports, the connecting bar may have been defective. The disaster serves as a reminder of the necessity of aviation safety protocols.

Vistara aircraft hit by tow truck during push back at Mumbai airport, all passengers safe

Manju V / TNN / Updated: Aug 2, 2023, 14:17 IST

A Vistara aircraft which was ready to depart from Mumbai to Kolkata was hit by a tow truck during push back on Tuesday evening.

A Vistara aircraft engine was hit by a tow truck during push back at Mumbai airport on Tuesday. (ANI Photo)

Figure 1.4: News of aircraft towing accident at Mumbai airport (The times of India, August 2023)

Figure 1.4 shows that On August 1, 2023, a Vistara aircraft was damaged by a tow vehicle at Mumbai airport, causing engine damage and grounding the flight. All passengers were evacuated safely, and a replacement plane was scheduled. The accident's cause is being investigated. According to initial reports, the tow truck driver may have lost control of the vehicle.

This event highlights the significance of following safety protocols during airport ground operations. Ground crew workers must be adequately educated and equipped, and they must be alert at all times regarding situational awareness.

These two articles have highlighted the accidents caused by towing aircraft using conventional tow trucks and their consequences to the operator and ground crews. Hence, this proves and shows that the number of accidents increases rapidly every year.

1.3 PROJECT OBJECTIVES

1.3.1 General Project Objectives

This project aims to:

- To research and design the reliable method of securing the nose landing gear to device while towing the aircraft.
- To develop an innovative control system that offers intuitive and responsive handling of tight turning and maneuvering.
- To design a environmental friendly device that will not release the greenhouse gasses.
- To develop and build a remote-controlled tug capable of manoeuvring aircraft on the ground safely and effectively. This includes the ability to start, stop, reverse, and regulate the tug's speed and direction.
- To minimize the likelihood of incidents, RCATs may assist in reducing the risk of accidents by removing the need for human operators to be close to aircraft. This could help to avoid injuries and fatalities.
- To increase efficiency and productivity. Manually relocating an aircraft may be time-consuming and labor-intensive. Using a remote control tug can free up personnel for additional duties and additionally contribute to reducing aircraft turnaround time

1.3.2 Specific Individual Project Objectives

1.3.2.1 Product Structure

RCAT is aimed:

- To design structure as main body, it needs to be strong and solid to accommodate forward load of light aircraft.
- To research various of material that suitable and strong enough to deal with high load.
- To develop an compact, accessible and strong structure that fit all the electrical system, moving and locking mechanism.
- To design a compact design that easy to store.

1.3.2.2 Product Mechanism

RCAT is aimed:

- To design aircraft personal safety and easy to move with a clear view of towing process.
- To demonstrate the function of mechanical locking device which help to lock the tyre while towing an aircraft.
- To develop a mechanism of remote-control aircraft tug, which enables the operator to move and manipulate the tug in order to tow the aircraft from one location to another.
- To develop Remote control aircraft tug with sufficient power, torque, and traction capabilities to handle load of lightweight aircraft.

1.3.2.3 Software / Programming

RCAT is aimed:

- To research various of electronic component to fit in and control Remote Control Aircraft Tug remotely such as motor driver, microcontroller board and transceiver.
- To design a circuit diagram of specific electronic component to control dual motor movement from a distance using wireless control method.
- To develop a programming of Arduino Uno to control initial and maximum motor rpm based on range of joystick movement without any error occur.
- To assemble and demonstrate the wiring connection into main structure Remote Control Aircraft Tug.

1.3.2.4 Accessories & Finishing

RCAT is aimed:

- To design RCAT with aesthetic looks and finishing without affecting the functionality of the product.
- To develop RCAT with plenty of functional accessories to provide features like more visibility and safety advantages.
- To design the Remote control aircraft tug as an attractive and visually appealing product considering the overall aesthetic of the RCAT and its finishing aspect.
- To finish RCAT with coatings that prevent paint from peeling, flaking, or cracking while also protecting the underlying material from corrosion and other damage.

1.4 PURPOSE OF PRODUCT

This innovation's goal is to improve a current product specifically for lightweight aircraft through the application of an improved material and product. Essentially, our project serves three purposes. To begin with, we are developing this project to safeguard the safety of employees in the towing sector in general, since there have been countless examples or events of workers being engaged in accidents that occur while towing, and we wish to minimize worker exposure to aircraft towing mishaps.

In addition, we are developing this project to boost operational effectiveness and lower costs. An aircraft tow truck is often more expensive to operate and less efficient in operating lightweight aircraft, however, we are developing a technology that will primarily be employed in lightweight aircraft.

1.5 SCOPE OF PROJECT

1.5.1 General Project Scope

First and foremost, RCAT is applicable for lightweight aircraft or general aircraft which commonly use education institution like flying school academy, Approved Maintenance Training Organization (Past 147). Most of this institution may have a small hangar which not suitable to use to conventional huge tow truck.

RCAT which have a compact dimension make it easy to store and level up the maneuvering and tow the aircraft compare to conventional tow truck.

The locking device of RCAT only suitable and fit for general aircraft’s nose landing gear compare to commercial aircraft or jet which have a bigger nose landing gear. RCAT nose landing gear platform and locking device can fit tire that have 36 cm maximum diameter. For example, Cessna 172.

1.5.2 Specific Individual Scope

1.5.2.1 Product Structure

The Remote-Control Aircraft Tug is the new method of the towing aircraft, while adhering to various aviation organizations or manufacturers was release statements and documents acknowledging the implementation of remote-controlled tugs as a new generation of aircraft towing. Checking press releases or official publications from entities like the International Air Transport Association (IATA), International Civil Aviation Organization (ICAO), aircraft manufacturers (Boeing, Airbus), or ground handling service providers might yield such statements or acknowledgments regarding the innovation of remote-controlled aircraft towing.

Our structural product scope is more focusing to able to tow a general aircraft which have less weight compare to commercial aircraft.
This structural also focusing on the functionality. So the best shape of structure of RCAT is cuboid shape with simple design and easy to maintain other component inside it.

1.5.2.2 Product Mechanism

Foremost, this product can only be used for test light weight aircraft of specific load. Remote Control Aircraft Tug is a prototype that only allows small aircraft to medium as the weight of the aircraft is not exceed the limit. The locking device and the size of the tire are subjected to certain size of aircraft tire to be tested.
Furthermore, this product is designed in such way that it can be portable in order to allow personal to conduct which everyone can use without having any problem to understand this product mechanism.

1.5.2.3 Software / Programming

This product will keep a safety distance for ground personnel from the RCAT during the towing the aircraft from one point to the other point up to 20 meters using a wireless remote control. It will keep the crew safe if any unwanted event happened while performing to tow the aircraft.

Next, RCAT also a user friendly where it uses only two channels signal to control the movement of RCAT. Move the joystick up and down will make the RCAT’s wheel move forward and backward simultaneously. However, if we move the joystick to the right, it will make the RCAT to the right as well which the left wheel move forward and the right wheel will move backward. This also happen to turn the RCAT to the left as well where the right wheel will move forward and left wheel will move backward. Even though, this project using only 2 channels of controlling signal, it is upgradable up to 10 channels to control the light and other mechanisms in future. So, the illumination system and locking mechanisms of RCAT all is manual by pushing the button to turn on the beacon light and LED light and securing the locking device using manual safety pin.

Then, RCAT build using Arduino programming to control both 24V DC motor that produce 250 W and 2750 rpm and 1.0 Nm torque. This project also fit with two BTS7960 as the motor driver which can handle high voltage up to 25V and 43A. This rating range of voltage suitable with the battery of the RCAT which is 12V DC that connected in series. As result the total voltage of RCAT as power source is 24V DC.

1.5.2.4 Accessories & Finishing

First and foremost, because this product is designed and developed for lightweight aircraft in accordance with lightweight aircraft specifications, RCAT is designed and developed to be able to provide the same safety features as conventional tow trucks.

Furthermore, for an attractive look of the product, we apply the base color to the aircraft locking device and body. In addition, we apply the coating and clear it since it is critical to protect the base color. The coating acts as a barrier against UV rays, abrasion, and environmental conditions.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL LITERATURE REVIEW

Aircraft towing is an important part of aviation operations since it aids in the movement of aircraft on the ground. It entails the regulated and safe movement of aircraft when they are not in flight, either inside airport grounds or between sites. Towing operations are carried out by specialized vehicles known as aircraft tugs or tractors, which were designed specifically to meet the specific demands of moving this massive and complicated equipment.

One of the most important functions of aircraft towing is to position aircraft within airport facilities such as hangars, repair areas, or boarding gates. This makes optimal use of limited parking space while also ensuring that aircraft are immediately available for maintenance, inspections, repairs, and other operational requirements. Furthermore, aircraft towing is essential during pre-flight preparations when aircraft are moved from parking stands to the runway for departure.

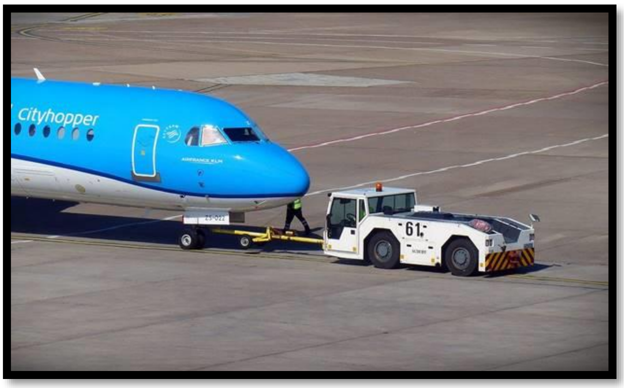


Figure 2.1: Aircraft towing during pre-flight preparations (google, n.d.)

Towing an aircraft necessitates meticulous planning, tight safety measures, and highly qualified people. Before beginning a tow, extensive inspections are performed to guarantee the structural integrity of the aircraft, landing gear, and other critical components. Weather conditions, weight and balance issues, and ground impediments are all variables in towing operations. To coordinate operations and guarantee the safety of the individuals and equipment involved, communication between the towing vehicle operator and the aircraft crew or ground control is critical.

Towing processes and equipment differ depending on the kind of aircraft. Smaller aircraft, such as single-engine propeller planes, may frequently be pulled manually by a team of ground crews using tow bars. Larger and heavier aircraft, particularly commercial jetliners, need the use of specialized tow trucks with tremendous pulling power. These tow vehicles use a variety of systems, such as tow bars, tow tractors, or towbarless tugs, to securely connect to the aircraft's nose or landing gear and generate the force required for controlled movement.

Figure 2.2: Larger aircraft towed using tow vehicle (google, n.d)

Figure 2.3: Smaller aircraft towed using tow bar (google, n.d.)

Technological improvements in recent years have improved aircraft towing operations. To enable greater accuracy and efficient motions, automated towing systems that use sensors, cameras, and precision control mechanisms have been developed. These systems assist tug operators by offering real-time data on aircraft location, clearance measures, and obstacle identification, therefore improving overall safety and minimizing error margins.

2.1.1 Type of Towing Devices in Aviation

Towbar and towbarless tugs are the two major types of aircraft tugs. Whatever category a tug comes under, there are a range of alternatives available, including both combustion and electric engines.

Towbar tugs feature a basic and adaptable design that allows them to be employed in a wide range of scenarios while potentially lowering repair and maintenance expenses. Because the tugs do not come into direct touch with the aircraft being moved, they can be utilized for any type of aviation. Furthermore, these tugs can be employed for non-aviation purposes. They can be fastened to any other heavy object that has to be transported from one location to another within an airport or hangar.

Figure 2.4: Towbar aircraft tug (google, n.d)

Towbarless tugs efficiently overcome the primary issues that towbar-equipped tugs face. They are smaller, quicker, and more agile. While towbarless tugs are more expensive up front, they quickly pay for themselves over time. Because of their speed, they can pull aircraft in less time, and because of their low profile and ergonomic design, they may be employed in confined locations where standard towbar tugs cannot. Furthermore, they only require a single qualified operator and, in certain situations may be operated remotely which will lowering operational expenses. Finally, depending on the sort of engine your tug has, these tugs utilise less energy, which implies cheaper fuel expenses or a longer battery life.

Figure 2.5: Towbarless aircraft tug (google, n.d.)

The relationship between aircraft and tug is often overlooked. When a towbar tug is in use, when this is the case, the aircraft is always being towed via the towbar, which means the tug is either pulling or pushing the plane (or other large objects).

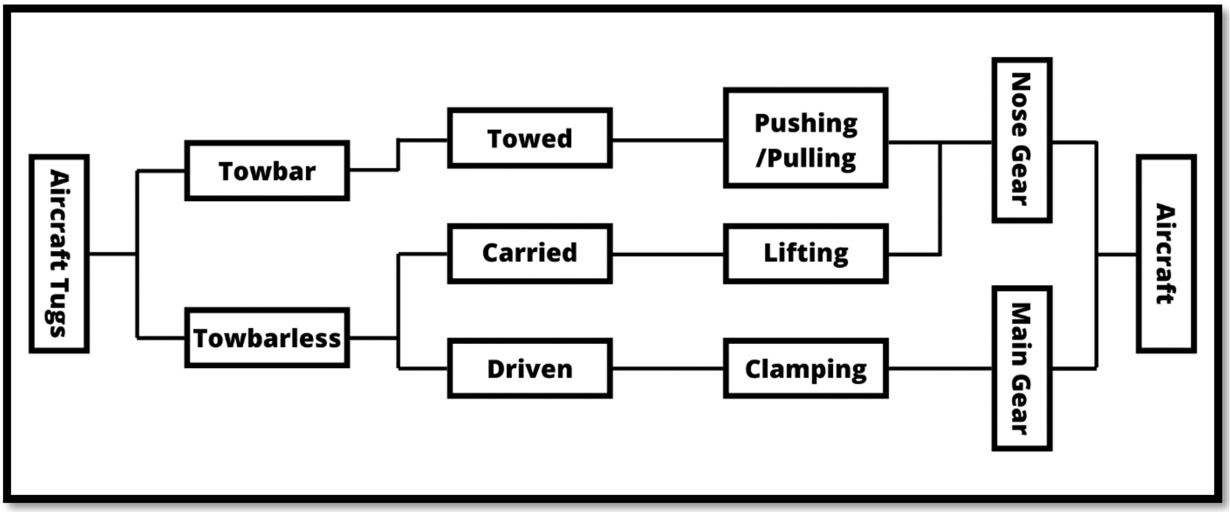


Figure 2.6: Difference between towbar and towbarless
(FLYTEK GSE, n.d.)

If a towbarless tug is in use, then the aircraft is not going to be towed. Instead, there are two other options. Either the aircraft is going to be carried or driven. When we say that an aircraft is carried, it does not mean that the entire aircraft is off the ground. It simply means that the tug lifts and carries the landing gear to which it is connected.

2.1.2 Remote control aircraft tug

Towbarless tugs, as we all know, include remote control aircraft tugs. A remote control aircraft tug, also known as a remote-controlled aircraft mover or a robotic tug, is a cutting-edge technical solution for aircraft towing. This specialized equipment uses remote control technology to safely and effectively handle and tow aircraft, providing various benefits over traditional manual or manned towing systems.

The remote-control aircraft tug can handle a variety of aircraft sizes, from small general aviation planes to huge commercial airliners. It is a small and adaptable device outfitted with strong motors, tough tyres, and innovative steering systems for precise and controlled movement. To maintain the greatest degree of safety during operations, the tug's design integrates safety measures such as anti-collision sensors, emergency stop functions, and real-time monitoring systems.

Figure 2.7: RC aircraft tug on lightweight aircraft (google, n.d.)

Figure 2.8: RC aircraft tug on large aircraft (MOTOTOK, n.d.)

One of the most important advantages of a remote-control aircraft tug is its manoeuvrability. The tug's small size and responsive agility allow it to easily handle tight areas, busy aprons, and complex airport layouts. This adaptability minimizes the likelihood of unintentional accidents and damage to aircraft or infrastructure, as well as improving access to aircraft parked in congested places.

The tug's remote-control capabilities let an operator to direct the aircraft's movement from a safe distance. This eliminates the requirement for a crew member to be physically present within the tug or to walk alongside the aircraft while it is being towed. As a result, the likelihood of personnel injuries or accidents is greatly minimized. The remote-control interface gives real-time data on the tug's location, speed, and other critical information to the operator, improving operational control and situational awareness.

Furthermore, remote control aircraft tugs offer increased operational efficiency. The precise control and manoeuvring capabilities of the tug enable faster aircraft turnaround times, minimizing ground delays and optimizing airport operations. The ability to remotely operate the tug also eliminates the time-consuming process of manually connecting and disconnecting the tow bar or other towing mechanisms, allowing for quicker and more efficient transitions between aircraft.

Figure 2.9: shows the flexibility to turnaround the aircraft using remote control aircraft tug (google, n.d.)

The implementation of remote-control aircraft tugs contributes to environmental sustainability. By eliminating the need for conventional fuel-powered tugs or vehicles that require constant idling or movement on the apron, remote control tugs reduce carbon emissions, noise pollution, and overall energy consumption. This aligns with the aviation industry's ongoing efforts to minimize its environmental footprint and adopt greener practices.

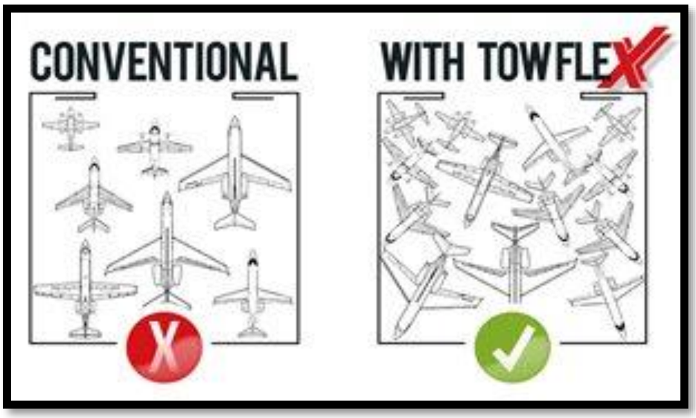


Figure 2.10: shows the efficiency of using RC aircraft tug on arrangements (Towflexx, n.d.)

2.2 SPECIFIC LITERATURE REVIEW

2.2.1 Product Structure

Official specifications for remote control aircraft tugs may vary depending on the specific regulations and guidelines set by different organizations and governing bodies. However, this some general specifications that are commonly observed for remote control aircraft tugs. Please note that these specifications may not cover all possible requirements, and it's important to refer to the specific regulations or guidelines applicable in your region or for your particular use case.

- The aircraft tug should have dimensions suitable for maneuvering and towing aircraft of various sizes.
- Remote control aircraft tugs are designed to tow aircraft, so their towing capacity depends on the intended use and the size of the aircraft they are designed to handle. The specifications for towing capacity can vary significantly, ranging from a few hundred kilograms to several tons.
- Depending on the intended use and regulations, remote control aircraft tugs may incorporate various safety features. These can include emergency stop buttons, warning lights or sirens, and fail-safe mechanisms to prevent accidents or mishaps.

These specifications provide a general overview of what you might expect in a remote-control aircraft tug. However, it's important to note that specific requirements can vary depending on the purpose, location, and regulations in your area. It is recommended to consult with the relevant authorities or industry experts to ensure compliance with the specific guidelines applicable to your situation.

2.2.2 Product Mechanism

Mechanism of this project consist of two main aspect which are movement mechanism and locking mechanism. Each of wheel are driven by dual high torque motor to allow them turn independently with gearing system to increase torque strength to pull and pushback the aircraft. Locking mechanism also to secure the nose landing gear on a platform which attach at the back of the remote-control aircraft tug. It to ensure no accident happened during the towing procedure such as the nose landing gear slipped off from the platform and the landing gear get stuck on the platform. Locking mechanism must have guarantee the nose landing gear can lock at the platform during performing tow procedure and release the landing gear when it done.

2.2.2.1 TYPE OF ELECTRICAL MOTOR

1. Induction Motor

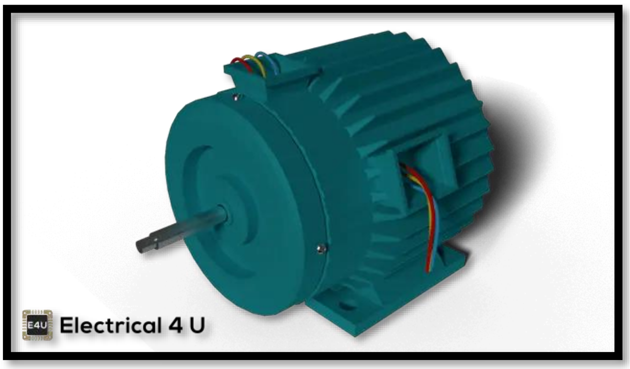


Figure 2.11: Example of induction motor (google, n.d.)

An induction motor, also known as an asynchronous motor, is an alternating current (AC) electric motor in which the electric current used for generating torque in the rotor is generated by electromagnetic induction from the magnetic field of the stator winding. As a result, an induction motor may be built without any electrical connections to the rotor. The rotor of an induction motor might be wound or squirrel-cage.

Three-phase squirrel-cage induction motors are commonly employed as industrial drives because they are self-starting, dependable, and cost-effective. Single-phase induction motors are often utilised for lesser loads such as garbage disposals and stationary power equipment. Although previously solely used for one-speed service, single- and three-phase induction motors are increasingly being employed in variable-speed applications using variable-frequency drives (VFD). VFDs provide particularly significant energy savings prospects for present and prospective induction motors in variable load applications such as fans, pumps, and compressors.

2.Synchronous Motor

Figure 2.12: Synchronous Motor (google, n.d.)

A synchronous electric motor is an alternating current (AC) motor in which the rotation of the shaft is synchronised with the frequency of the supply current in steady state; the rotation period is exactly equal to an integral number of AC cycles. Electromagnets are used as the stator of synchronous motors, creating a magnetic field that spins in time with the oscillations of the current. The rotor with permanent magnets or electromagnets rotates at the same rate as the stator field, resulting in the second synchronised rotating magnet field. A doubly fed synchronous motor is one that is powered by independently stimulated multiphase AC electromagnets on both the rotor and stator.

3. Rotator Motor

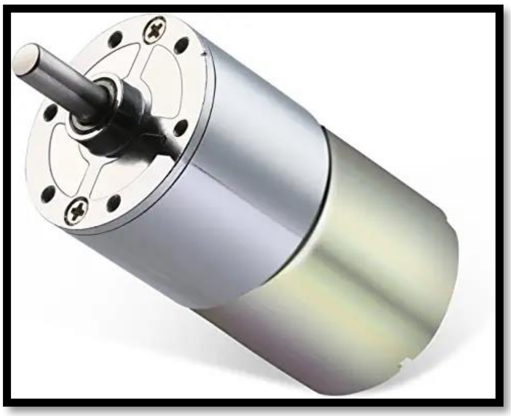


Figure 2.13: Rotator Motor (google, n.d.)

It is a moving part of an electromagnetic system that includes a motor, generator, and alternator. It's also known as a flywheel, a revolving magnetic core, or an alternator. An alternator has permanent magnets that move in close proximity to the iron plates of the stator to generate AC (Alternating Current). It functions by using existing motion. The interplay between magnetic fields and windings, which create torque in the vicinity of the axis, can cause this to rotate.

4. Stepper Motor

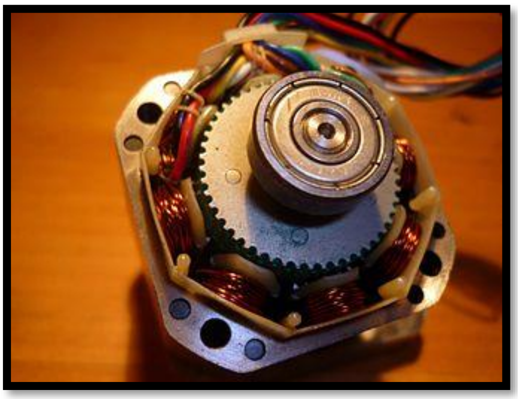


Figure 2.14: Stepper Motor (google, n.d.)

A stepper motor is a brushless DC electric motor that splits a whole revolution into a number of equal steps. As long as the motor is suitably scaled for the application in terms of torque and speed, the motor's position can be directed to move and hold at one of these stages without the need of a position sensor for feedback (an open-loop controller). Switched reluctance motors are large stepping motors with a reduced amount poles that are often closed-loop commutated.

2.2.2.2 TYPE OF HINGE

1. Rail Bracket Hinge

Figure 2.15: Picture of rail bracket hinge (google, n.d.)

A rail bracket hinge is a mechanical device that used for gates or door within the railing system. In such case, similar hinge principles as those used in doors could be applied. The gates within railings, fences or other enclosures often use hinges to allow for movement. The hinge may be attached to the gate or steel surface and supporting post or structure.

2. Door Hinge

Figure 2.16: Picture of door hinge (google, n.d.)

A door hinge is mechanical device that connects two solid object, typically a door and its frame, allowing the door to wing open and closed on a fixed axis. A door hinge are essential components in the construction and operation of door. They provide support between two surface. When the door is released, the hinge returns it to the closed position due to gravity or additional mechanisms like springs.

2.2.3 Software / Programming

2.2.3.1 Arduino Programming

On the aspect of software and programming, most of the equipment are related to electronic and electrical part. We also will contribute on circuit designing that suitable due this project neither at the controller and at the main body. Software and programming aspect also play an important role to control movement of this project and other mechanism and electrical system of this project such as locking mechanism and lighting system. This can be realized by using several type of Arduino board and others electronic components.

Figure 2.17: Arduino symbol (Arduino.com, n.d.)

Arduino is an open-source platform that may be used to create electronic creations. Arduino is made up of two parts: a physical programmable circuit board also known as a microcontroller board and software called an IDE application that can be downloaded into our computer which used to create and upload specific code to the physical board to control others electronic component.

The Arduino Software (IDE) comprises a code editor, a message area, a text terminal, a toolbar with basic operation buttons, and a series of menus. It links to Arduino hardware using USB cable in order to upload and interact with programmes.

Figure 2.18: Interface of Arduino IDE application (Docs.Arduino, n.d.)

2.2.3.2 Type of electronic (microcontroller)

In general, a microcontroller is a little computer or brain that performs and control the operations that we programme into it using Arduini IDE. They are also designed to be modular, having the ability to link to many sorts of inputs like as sensors, cameras, and microphones, as well as outputs such as LED lights, buzzer, digital screen and so on.

1. **Arduino Uno R3**

The Arduino Uno R3 is a microcontroller board containing the ATmega328P processor, 14 digital input/output pins, 6 analogue inputs, and a clock speed of 16 MHz. It is a versatile platform for creating interactive electronics projects, with ease of use, compatibility with various sensors and components, and programmability through the Arduino IDE using a simplified C/C++ language, making it popular among both beginners and experienced makers for prototyping and experimenting in the realms of embedded systems and robotics. It also able to control more than one electronic component in the same time make it main and popular microcontroller for most of the project.

Figure 2.19: Top view of Arduino Uno R3 (Google, n.d.)

2. **Arduino Nano**

The Arduino nano is a microcontroller/circuit board that is capable of doing simple programming and is breadboard friendly same as Arduino Uno R3 but different in size and dimension. Arduino Nano is smaller and more compact compare to Arduino Uno but but it is still capable of receiving input and executing code and output it to other devices just amount of component of can it control make the differences. Next, Both of Arduino Uno and Nano is cannot connected using wifi. So only can be controlled by using add-on receiver.

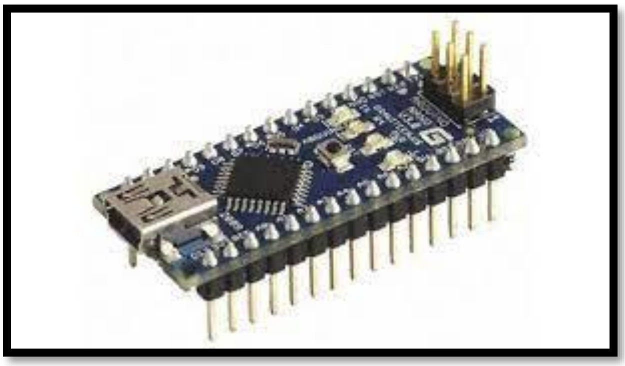


Figure 2.20: Arduino Nano (RS Component, n.d.)

2.2.3.3 Type of motor driver

The main purpose of motor driver actually used to regulate and control the motion of the motor by applying specific current and voltage rate. Because of output of the motor driver is in digital, it employs PWM pin (Pulse Width Modulation) to regulate the speed of a motor. Motor drivers are essentially current amplifiers with input signals.

1. L298N

This L298N Motor Driver Module is a high-power motor driver module that can power both DC and stepper motors which more than one motor in one time. The L298N Module is capable of controlling up to four DC motors with directional and speed control in the same time. However, it only capable to hold at low power rating 5 V to 35 V and peak current only 2A.

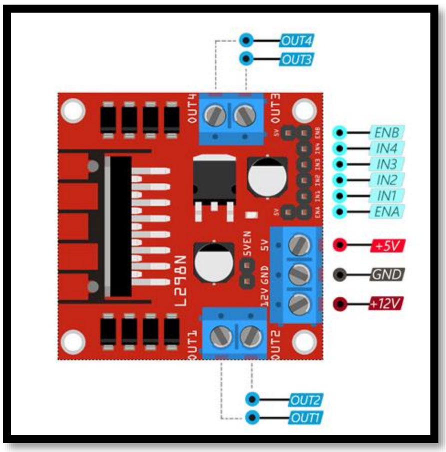


Figure 2.21: Layout of L298N motor driver (HiBit, n.d.)

2. BTS7860

The BTS7960 is a high current H bridge module with complete integration for motor driving applications. It only capable to control one DC motor at the same time. This type motor driver commonly used for project with high voltage requirement. This because it capable to hold power input up to 27V and peak current up to 43A. Just because it only capable to control direction and speed of only one motor, more wiring connection and more space required.

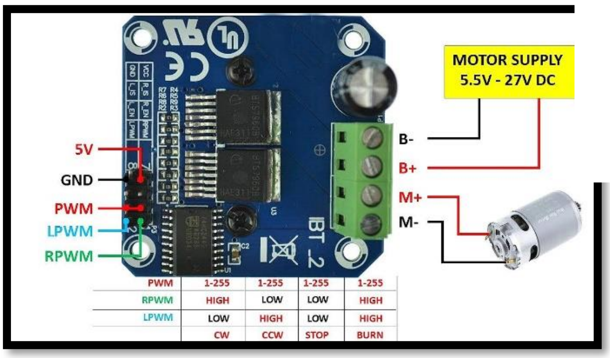


Figure 2.22: Layout connection of BTS7960 (MyBOTIC, n.d.)

2.2.3.4 FlySky FS-I6x

The Flysky FS-i6X is a popular 6-channel radio transmitter and receiver for remote-controlled (RC) vehicles and planes such as drones, aeroplanes, helicopters, automobiles, and boats. It works at 2.4GHz. It capable to control the device up to more than 30 meters away. It is suitable for Arduino connection and can be connected with breadboard.

Figure 2.23: Remote control and receiver of FlySky FS-I6X (Google, n.d.)

2.2.4 Accessories & Finishing

This literature review explores the various accessories and finishing techniques employed in RCAT products. The aim is to provide a comprehensive overview of the existing research and knowledge in this domain. The review covers a wide range of topics, including towing accessories and finishing products. The findings of this review will serve as a valuable resource for researchers, hobbyists, and enthusiasts interested in RCAT.

This product also is designed with plenty of accessories and finishing that can improve the safety of RCAT. The accessories and finishing features that are used by RCAT have a relation to safety and compliance whereby to improve the safety standard.

2.2.4.1 Typical Accessories on Remote Control Aircraft Tug

1. **Beacon light**

Because they influenced visibility, safety, and aesthetics, the use of beacon lights as accessories in remote control aircraft tug projects has gotten a lot of attention. Research indicates that beacon lights play a pivotal role in reducing the risk of accidents by enhancing visibility during both daytime and low-light conditions. These lights, often equipped with high-intensity LED sources, facilitate easy identification of the aircraft tug from a distance, enabling proactive navigation and collision avoidance.

The Integration of beacon lights remote control aircraft tugs aligns with industry standards and regulations. Guidelines set by organizations such as the International Civil Aviation Organization (ICAO) emphasize the importance of beacon lights in aviation operations, highlighting their role in ensuring safety and visibility.

Figure 2.24: Beacon light (Amazon.Com, 2022)

2. **LED tube light**

The use of LED tube lights as accessories in remote control aircraft tug projects has gotten a lot of attention because of the enormous influence they have on safety and operating efficiency in low-visibility circumstances. According to research, LED tube lights play a critical role in boosting visibility and minimizing accidents in foggy environments. LED tube lights have the advantage of being an energy-efficient, long-lasting, and ecologically responsible lighting option.

Compliance with industry regulations, such as those established by the International Civil Aviation Organisation (ICAO), emphasizes their significance in aviation operations. The incorporation of LED tube lighting improves the visual attractiveness of the project. In summary, LED tube lights improve visibility, decrease dangers, satisfy regulatory requirements, and add to the overall aesthetics of remote-control aircraft tug projects.

Figure 2.25: LED light (google, n.d.)

3. **Matte black spray paint**

The main frame structure and the locking device were originally silver in colour, therefore painting a light colour could affect this product would reduce the appealing look of this RCAT product. Matte paint black is a low sheen or gloss style of paint. It is frequently utilized for its aesthetic properties, since it may provide a sleek and modern appearance. However, matte paint black provides several practical advantages.

Figure 2.26: Samurai black spray (Lazada, 2022)

Matte black spray paint is used for Its low reflection, which causes most incident light to be absorbed, contributing to its black look. This optical feature extends to heat absorption, making matte black paint appropriate for applications RCAT to avoid the heat being absorbed by the sidewall panels. Besides that, It is used to reduce glare and reflections, improve pilot sight, and decrease distractions.

2.3 REVIEWS OF RECENT RESEARCH / RELATED PRODUCTS

2.3.1 Related Patented Products

2.3.1.1 Airplane Power Dolley

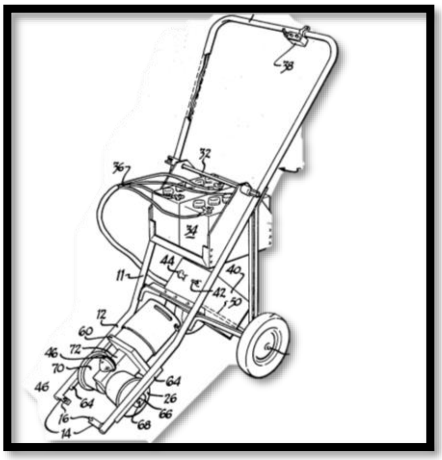


Figure 2.27: Airplane Power Dolley diagram (google scholar, 2018)

Summary of this pattern are:

1. Patent name : Airplane Power Dolley
2. Patent number : US3150734A
3. Published date : 29 / 9 / 1964
4. Patent office country : United State of America
5. Intentor : Jr Anderson Duggar
6. Abstract or discription :

   It is intended to be easily attached to a ground wheel of the plane and to move the plane by power derived from a source carried by the tow stick. In operation, the tow stick is wheeled to the plane and the drum is placed against the nose wheel as shown in figure below. he drum is then rotated slowly forward, or counter-clockwise and the nose wheel.

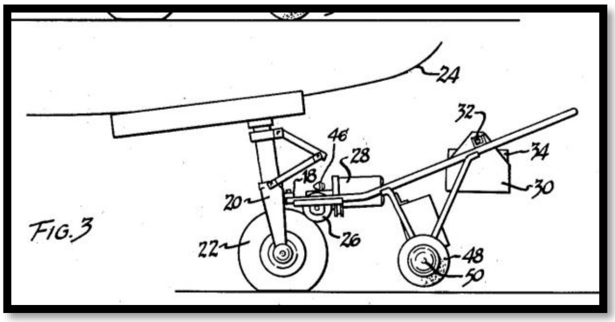


Figure 2.28: Operation Airplane Power Dolley (google scholar, 2018)

2.3.1.2 Towbarless airplane tug

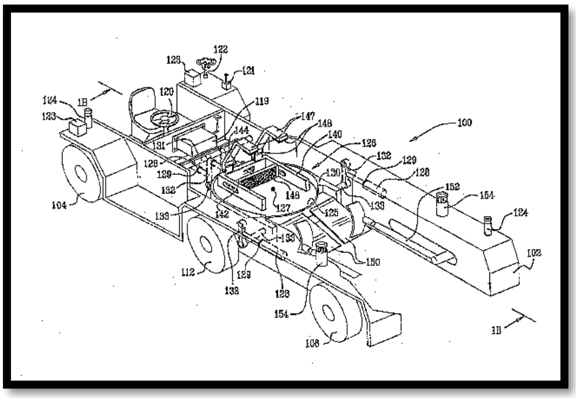


Figure 2.29: Patent towbarless airplane tug (google scholar, 2020)

Summary of this pattern are:

1. Patent Title: Towbarless airplane tug
2. Patent No.: US20110224845A1
3. Published Date: 2011-09-15
4. Patent Office Country: United States
5. Inventors: Arie Perry, Ran Braier
6. Abstract: The present invention relates generally to systems for airplane ground movement, and more particularly to control methods of ground vehicles of such systems. Airplane tugs are often provided for towing airplanes between ground locations at an airport, thus obviating the need for the airplane to move itself under its own power, saving jet fuel. The tugs may be provided with a towbar, which connects a landing gear with the tug, or towbarless, in which a towbar is not provided, in which, typically, the landing gear sits directly on the chassis of the tug.

2.3.1.3 Plane tractor

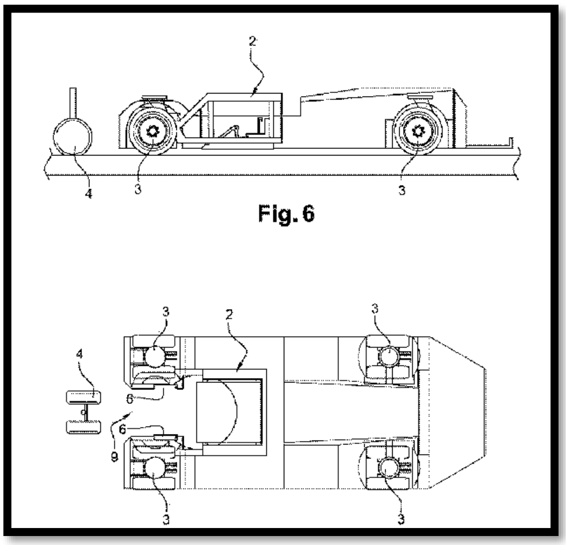


Figure 2.30: Patent Plane Tractor (google scholar, 2022)

Summary of this pattern are:

1. Patent Title: Plane tractor
2. Patent No.: US9085374B2
3. Published Date: 21 Jul 2015
4. Patent Office Country: United States
5. Inventors: Laurent Decoux
6. Abstract: The invention relates to a plane tractor that grips the nose gear of a plane, including a chassis; wheel modules connected to the chassis, each wheel module including at least one actuator for inducing a vertical movement of the module in relation to the chassis; a gripping platform for gripping the nose gear of a plane, the platform together with the chassis having freedom of movement substantially in circular translation; and damping and actuating means connecting the platform and the chassis

2.3.2 Recent Market Products

2.3.2.1 SMARTug Remote Control Aircraft Tug

Figure 2.31: SMARTug product (Smarttug.com, n.d.)

The summary or information of this product such as :

1. Product name: SMARTug Remote Control Aircraft Tug
2. Published date: 13 / 7 / 2020
3. Inventor: A division of SMARTech Industries
4. Product description:
5.

The design focus of SMARTug is to provide a platform that is truly easy to use, does not require physical strength to operate and allows the operator to move freely around the aircraft, untethered from the tug, to visually maintain safe distances with other aircraft or structures and controlled easily using radio remote control which we can control the tug movement form distance.

Figure 2.32: Operation of SMARTug on lightweight aircraft (Smarttug.com, n.d.)

2.3.2.2 TOWFLEXX – ELECTRIC TOWBARLESS AIRCRAFT TUGS

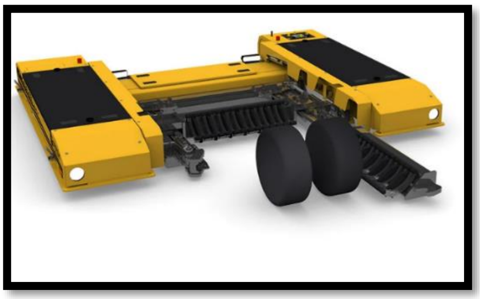
Table 2.1 Type of Towflexx aircraft Tug

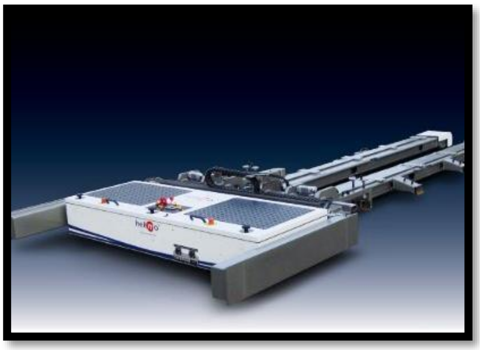
No	Marketed Product	Product Summary
1	 **Figure 2.33: Tow Flex 3 – TF3 (Towflex.com, n.d.)**	Product Name: Tow Flex 3 – TF3 Published year: 2022 Inventors: Tow FLEXX Inc. Description: The TF3 is the smallest remote controlled aircraft tug of Tow FLEXX. Within a few seconds the aircraft is picked up and can then be effortlessly manoeuvred to the desired location by remote control. The nose wheel is mounted on a specially designed turntable, which allows the operator to turn the tug 360° around the nose gear without twisting it.
2	 **Figure 2.34: Tow Flex 4 – TF4 (Towflex.com, n.d.)**	Product Name: Tow Flex 4 – TF4 Published year: 2022 Inventors: Tow FLEXX Inc. Description: The Tow flex TF4 is able to tow Aircraft and Helicopter up to 14.000kg / 30.000lbs. That is why the Tug is ideal for Twin Turboprops as well as for Small- and Midsize Jets. The Remote Control allows the Operator total Mobility during manoeuvring to move around the Aircraft freely, to observe the whole Repositioning the best possible Way.

3	 **Figure 2.35: Tow Flex 5 (Towflex.com, n.d.)**	Product name: Tow Flex 5 Publish year: 2022 Inventors: Tow FLEXX Inc. Description: With its towing capacity of up to 60,000kg / 132,000 pounds, the TowFLEXX TF5 is a true heavyweight and unique in its class. Perfect for Super-Midsize Jets, Military Jets and Helicopters with Single- and Twin-Tires. However, the adjustable nose wheel adapters allow small aircraft to be moved. This makes the TF5 an absolute all-rounder, which is why it is used by FBOs, MROs, corporate flight departments, private owners and military personnel all over the world

2.3.2.3 MOTOTOK

Table 2.2: Type of Mototok product in market

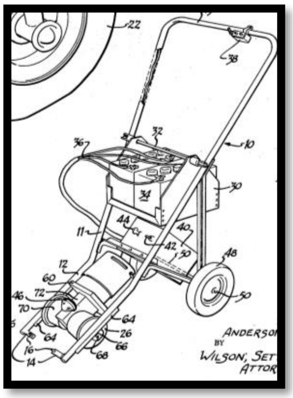
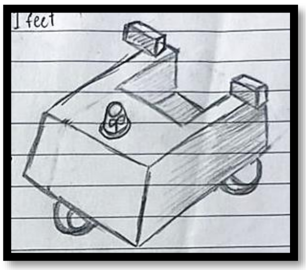
No	Marketed Product	Product Summary
1	 **Figure 2.36: M-528 (M series) (Mototok, n.d.)**	Product Name: M-528 (M series) Published year: 2020 Inventors:MOTOTOK INTERNATIONAL GMBH Description: Designed for business jets with a single or double nose wheel, sporting airplanes, and wheeled helicopters, M528 is the small powerpack for towing the Cessna Citation Excel, the Bombardier Learjet 40, the Hawker 800 or any other aircraft up to 28 tonnes (61,730 lbs).
2	 **Figure 2.37: Mototok Alligator 4000 (Mototok, n.d.)**	Product Name: Mototok Alligator 4000 Published year: 2020 Inventors:MOTOTOK INTERNATIONAL GMBH Description: The world's most compact electric aircraft tug has now become even more compact. Its patented clamp technology fixes the nose gear securely and smoothly. The overall height of the alligator is so low that even extensive attachments below the aircraft fuselage do not obstruct the nose gear clamping.

3	 **Figure 2.38: Helimo (Mototok, n.d.)**	Product name: Helimo Publish year: 2022 Inventors:MOTOTOK INTERNATIONAL GMBH Description: perfect tug for all skidded helicopters. Helimo can move every type of helicopter with skids regardless of obstacles such as cameras, radar, floats, winds, and -weapons mounted on the belly or skids of the helicopter. The helimo is universal and easily adjustable to meet the specifications of the helicopter.

2.4 COMPARISON BETWEEN RECENT RESEARCH AND CURRENT PROJECT

2.4.1 Airplane Power Dolley vs. SMARTug Remote Control Aircraft Tug vs. Remote Control Aircraft Tug

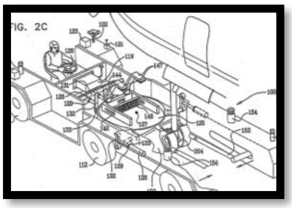
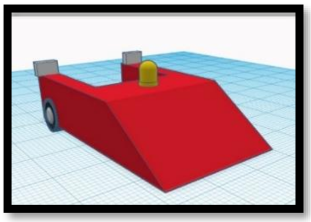
Table 2.3: Comparison Airplane Power Dolley vs. SMARTug Remote Control Aircraft Tug vs. Remote Control Aircraft Tug

PRODUCT	Airplane Power Dolley	SMARTug Remote Control Aircraft Tug	Remote Control Aircraft Tug
Design			
Purpose	To help ground personnel have supported aircraft pulling devices.	To allow the user feel free to move around the aircraft and easy storage	To move a lightweight aircraft safely in tight turn
Dimension (inch)	N/A	N/A	36” x 30” x 18”
Locking Device	driving drum which mounted as a unit on a sub-frame	Electric Hydraulic NLG Lifting System	Mechanically locking with automatic electrical servo motor locking
Movement mechanism	Supported by motor and control by person in charge. (dual wheel)	Dual wheel configuration with one pilot wheel	Dual integrated wheel configuration. One pilot wheel in front.
Configuration	friction contact with the wheel of the plane.	Towbarless	Towbarless
Accessories	N/A	LED Night Operation Loading Lights	1. Beacon light 2. Fog light

Control mechanism	A supported handle	Radio remote control	Radio remote control
Battery Capacity	N/A	24 VDC – 158 Ahr Deep Duty Cycle Batteries	DUAL 12 VDC IN SERIES – 150 Ahr

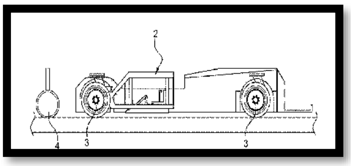
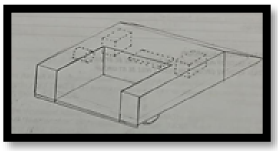
2.4.2 Towbarless airplane tug vs. TOWFLEXX – Electrical Towbarless Aircraft Tug vs. Remote Control Aircraft Tug

Table 2.4: Comparison Towbarless airplane tug vs. TOWFLEXX – Electrical Towbarless Aircraft Tug vs. Remote Control Aircraft Tug

PRODUCT	Plane Tractor	TOWFLEXX	Remote Control Aircraft Tug
Design			
Purpose	Receiving a landing gear of an airplane and towing it.	To move various aircraft or rotorcraft with 360 turn able wheel	To move a lightweight aircraft safely in tight turn
Dimension	N/A	1.200mm x 1.600mm x 450mm	36 inch x 30inch x 18inch
Locking Device	Fully Hydraulic secure door.	Hydraulic and mechanical locking	Mechanically locking with automatic electrical servo motor locking
Movement mechanism	Six tyre configurations controlled by steering	Tri-wheel with 360 turning	Dual integrated wheel configuration. One pilot wheel in front
Configuration	Towbarless	Towbarless	Towbarless
Accessories	Warning light Warning alarm	Front Light	1. Beacon light 2. Fog light
Control mechanism	Drive by person	Radio remote control	Radio remote control
Battery Capacity	Using engine	5km / 3,8mi	DUAL 12 VDC IN SERIES – 150 Ahr

2.4.3 Plant tractor vs. MOTOTOK vs. Remote Control Aircraft Tug

Table 2.5: Comparison between Plant tractor vs. MOTOTOK vs. Remote Control Aircraft Tug

Product	**Plane tractor (Patent Product)**	**Remote Control Aircraft Tug (Current Project)**	**M-528 (M series) (Market Product)**
Design			
Purpose	To move an airplane with an airplane tractor using the gripping method for gripping the nose gear of the airplane using such a tractor	To move a lightweight aircraft safely in a tight turn and at compact area	To move various aircraft with convenient and quick loading and releasing of the aircraft's nose gear.
Locking device	Hydraulic cylinder	Mechanically locking with electrical servo motor locking	Hydraulically
Configuration	Towbarless	Towbarless	Towbarless
Dimension	N/A	36 inch x 30 inch x 18 inch	75.35 inch x 72.99 inch x 12.99 inch
Battery capacity	Tractor engine	DUAL 12 VDC IN SERIES – 150 Ahr	4 x 115 Ah

Accessories	1. sensor measuring an angular displacement of the turret in relation to the gripping platform	1. Beacon light 2. Fog light	1. LED high-beam driving lights 2. Safety flashlights and beeper 3. Safety nose wheel paddles
Movement mechanism	Eight wheels are configurated with four-wheel modules.	Dual integrated wheel configuration. One pilot wheel in front	Dual integrated wheel configuration with different rotating speed
Control mechanism	Drive by individual	Radio remote control	Radio remote control

CHAPTER 3

RESEARCH METHODOLOGY

3.1 PROJECT BRIEFING & RISK ASSESSMENT

LAMPIRAN D

POLITEKNIK MALAYSIA BANTING

PERMOHONAN MENGGUNAKAN KEMUDAHAN MAKMAL/ BENGKEL

Makmal/Bengkel :...

BIL	NAMA PELAJAR	NO. PENDAFTARAN	TARIKH	MASA
1				
2				
3				
4				

SENARAI PERALATAN/BAHAN YANG DIPERLUKAN

BIL	ITEM	UNIT	T/TANGAN PENERIMA	T/TANGAN PEMULANG	CATATAN
1					
2					
3					
4					
5					
6					
7					
8					

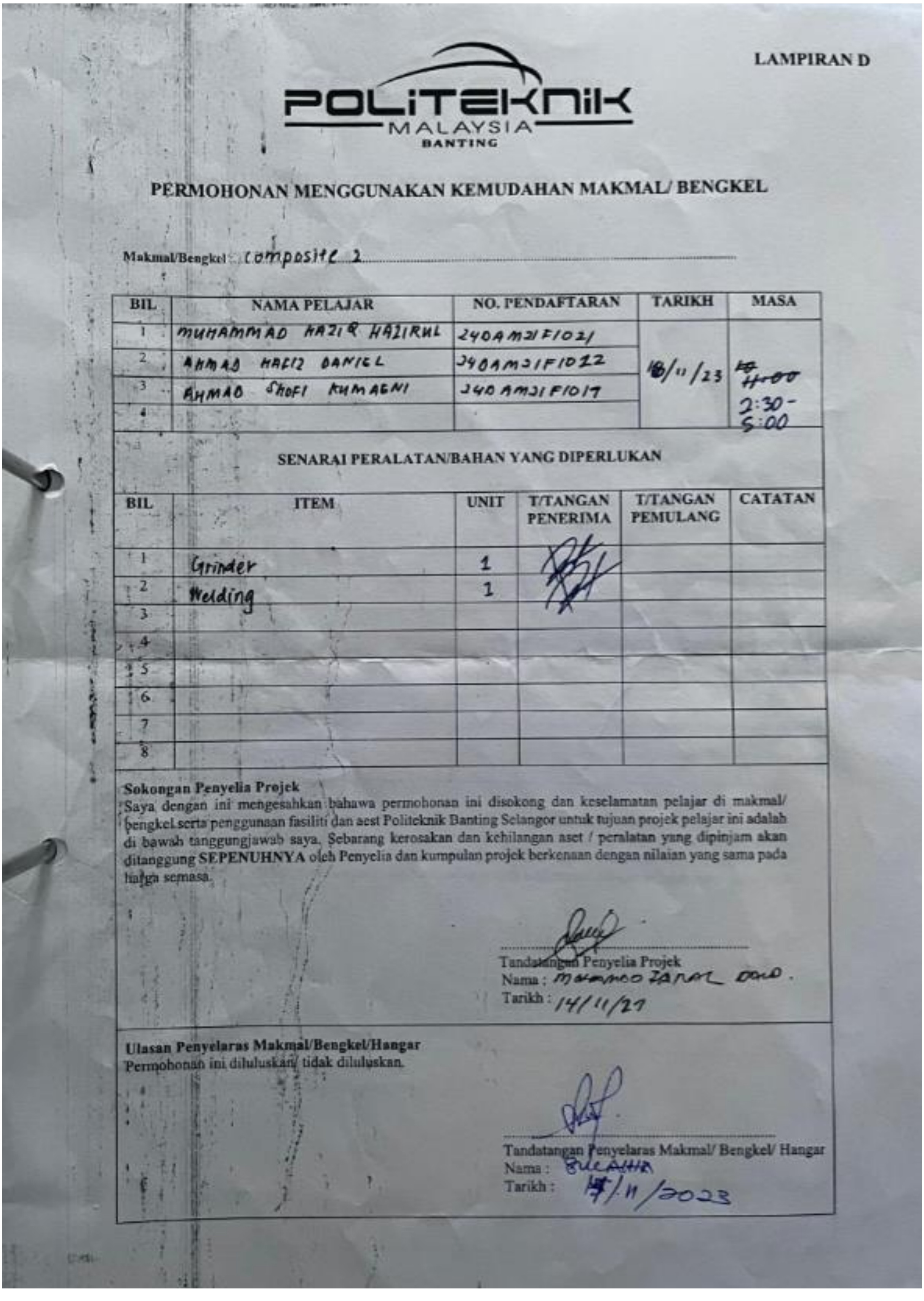
Sokongan Penyelia Projek
Saya dengan ini mengesahkan bahawa permohonan ini disokong dan keselamatan pelajar di makmal/ bengkel serta penggunaan fasiliti dan aest Politeknik Banting Selangor untuk tujuan projek pelajar ini adalah di bawah tanggungjawab saya. Sebarang kerosakan dan kehilangan aset / peralatan yang dipinjam akan ditanggung **SEPENUHNYA** oleh Penyelia dan kumpulan projek berkenaan dengan nilaian yang sama pada harga semasa.

....
Tandatangan Penyelia Projek
Nama :
Tarikh :

Ulasan Penyelaras Makmal/Bengkel/Hangar
Permohonan ini diluluskan/ tidak diluluskan.

....
Tandatangan Penyelaras Makmal/ Bengkel/ Hangar
Nama :
Tarikh :

Figure 3.1: Blank document of permission of usage lab (CIDOS, 2023)


LAMPIRAN D

POLITEKNIK MALAYSIA BANTING

PERMOHONAN MENGGUNAKAN KEMUDAHAN MAKMAL/ BENGKEL

Makmal/Bengkel: composite 2

BIL	NAMA PELAJAR	NO. PENDAFTARAN	TARIKH	MASA
1	MUHAMMAD HAZIQ HAZIRUL	24DAM21F1021	18/11/23	2:30-5:00
2	AHMAD HAFIZ DANIEL	24DAM21F1022		
3	AHMAD SHOFI KUMAENI	24DAM21F1017		
4				

SENARAI PERALATAN/BAHAN YANG DIPERLUKAN

BIL	ITEM	UNIT	T/TANGAN PENERIMA	T/TANGAN PEMULANG	CATATAN
1	Grinder	1	[signature]		
2	Welding	1			
3					
4					
5					
6					
7					
8					

Sokongan Penyelia Projek
Saya dengan ini mengesahkan bahawa permohonan ini disokong dan keselamatan pelajar di makmal/ bengkel serta penggunaan fasiliti dan aset Politeknik Banting Selangor untuk tujuan projek pelajar ini adalah di bawah tanggungjawab saya. Sebarang kerosakan dan kehilangan aset / peralatan yang dipinjam akan ditanggung SEPENUHNYA oleh Penyelia dan kumpulan projek berkenaan dengan nilaian yang sama pada harga semasa.

Tandatangan Penyelia Projek
Nama: MOHAMAD ZANAL DAUD.
Tarikh: 14/11/23

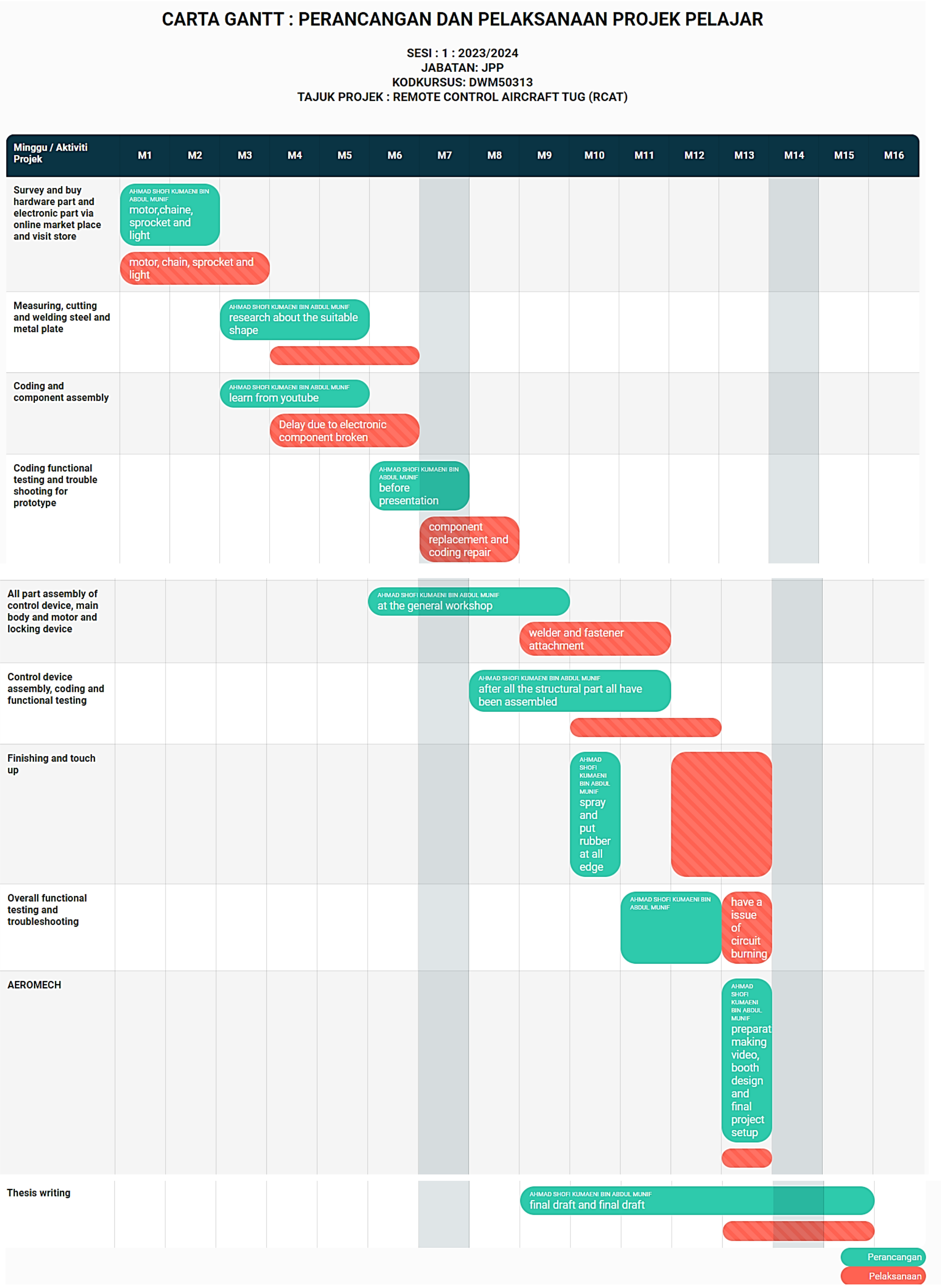
Ulasan Penyelaras Makmal/Bengkel/Hangar
Permohonan ini diluluskan/ tidak diluluskan.

Tandatangan Penyelaras Makmal/ Bengkel/ Hangar
Nama: BULAIHA
Tarikh: 17/11/2023

Figure 3.2: Filled document of permission usage lab

3.2 OVERALL PROJECT GANTT CHART

Table 3.1: Overall Gantt chart



3.3 PROJECT FLOW CHART

3.3.1 Overall Project Flow Chart

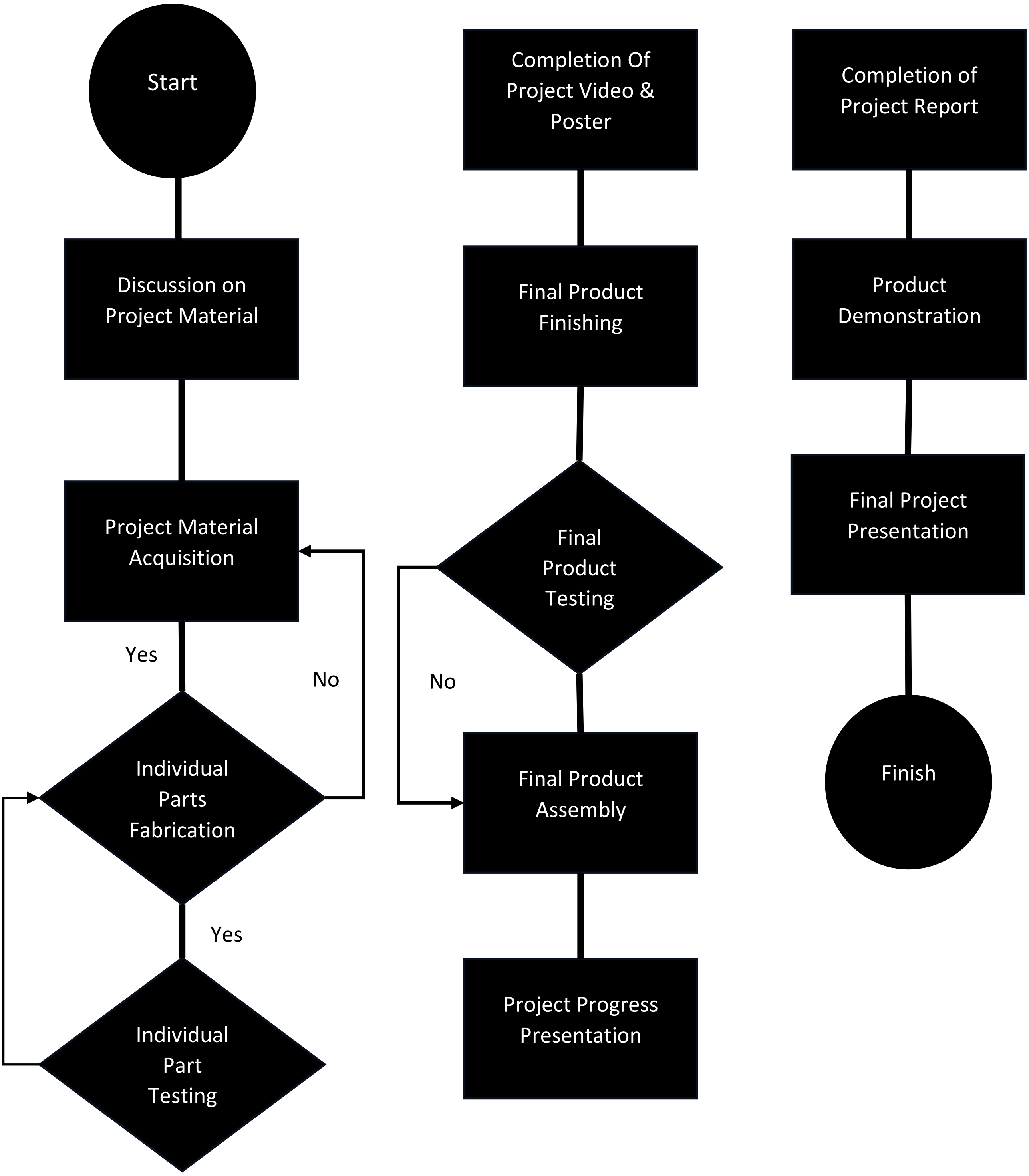


Figure 3.3: Overall flow chart

3.3.2 Specific Project Design Flow / Framework

3.3.2.1 Product Structure

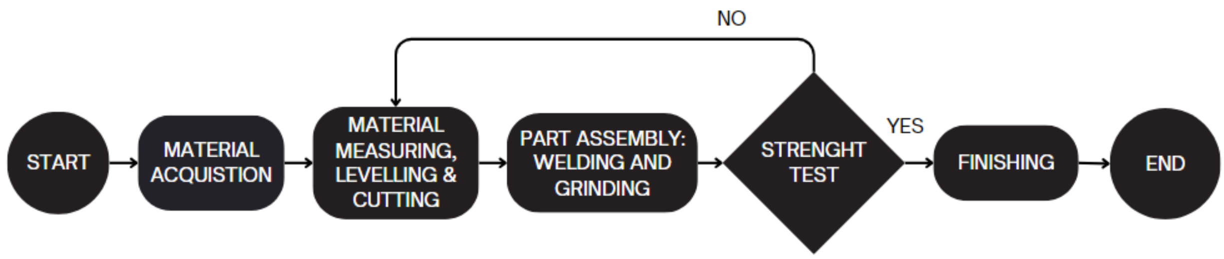


Figure 3.4: Structural flow chart

3.3.2.2 Product Mechanism

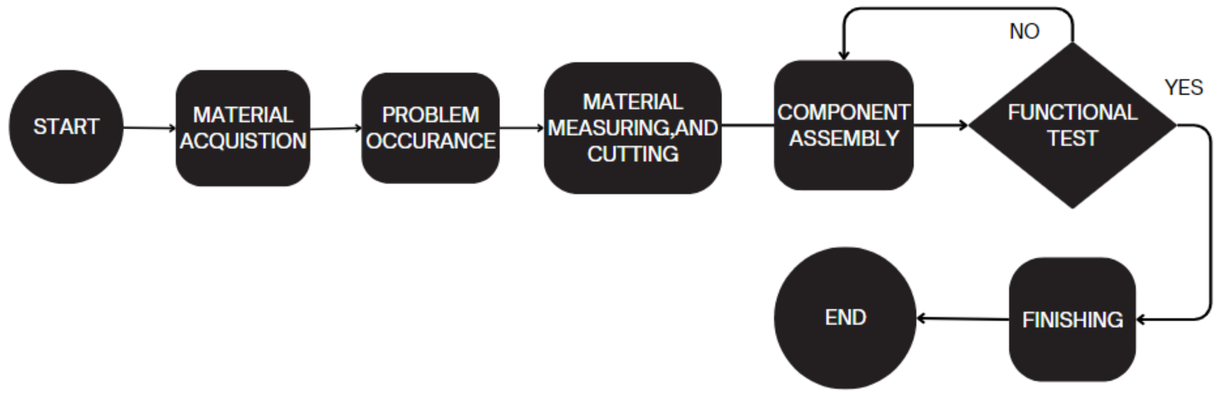


Figure 3.5: Mechanism flow chart

3.3.2.3 Software / Programming

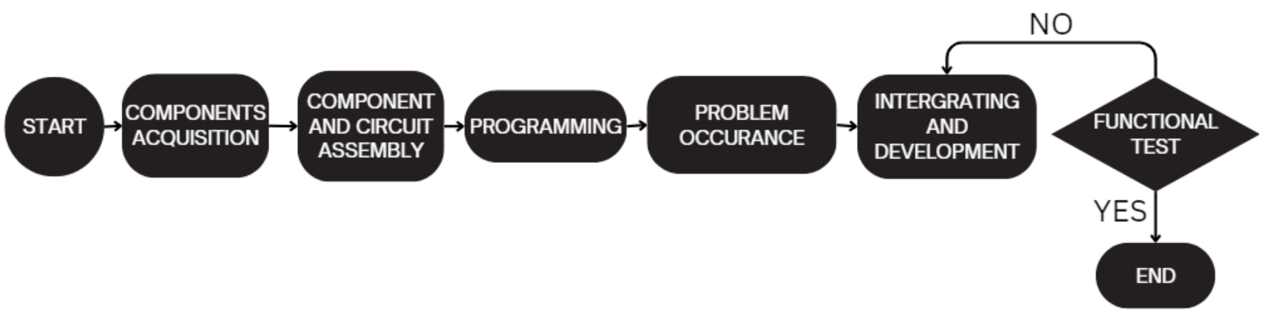


Figure 3.6: Software / Programming flow chart

3.3.2.4 Accessories & Finishing

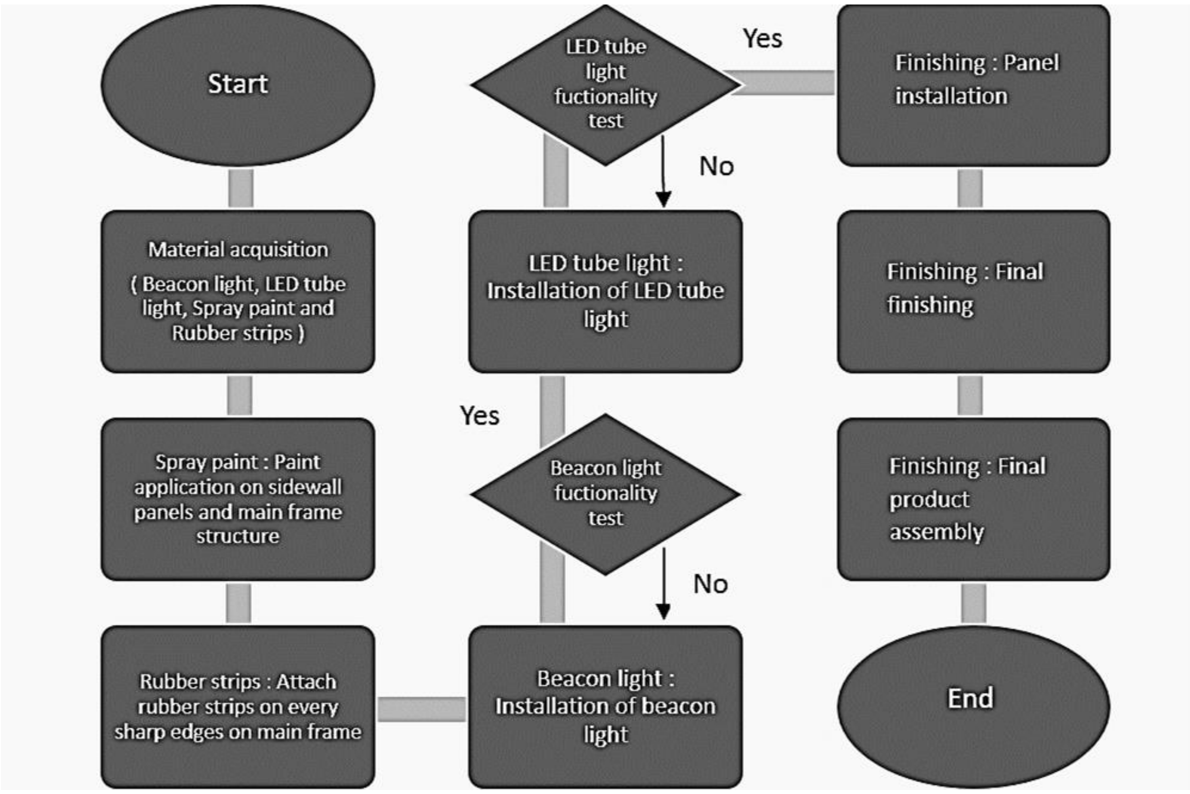


Figure 3.7: Accessories and finishing flow chart

3.4 DESIGN ENGINEERING TOOLS

3.4.1 Design Requirement Analysis

Our group had done a google form to survey and collect as much data from targeted responder such as Licence Aircraft Engineer (LAE), Licence Aircraft Technician (LAT), flight crew, lecturer and intern student. 49 responders in total were answer our questions related to aircraft towing and from this survey we also collected responder's suggestion to be added-on on our project. We also have found and studied few articles and research papers related to our project on Google Scholar and other website to have clear information and relevant past research data which useful in our project construction. Here are some of the question in our goggle form as the bench mark to this project.

3.4.1.1 Questionnaire Survey

1. The question as figure 3.8 were asked regarding the chances of reducing accidents during the towing process which already happened of American Airline. According to the pie chart, most of the respondents have chosen yes (98%) and a tiny portion of respondents answer No (2%).

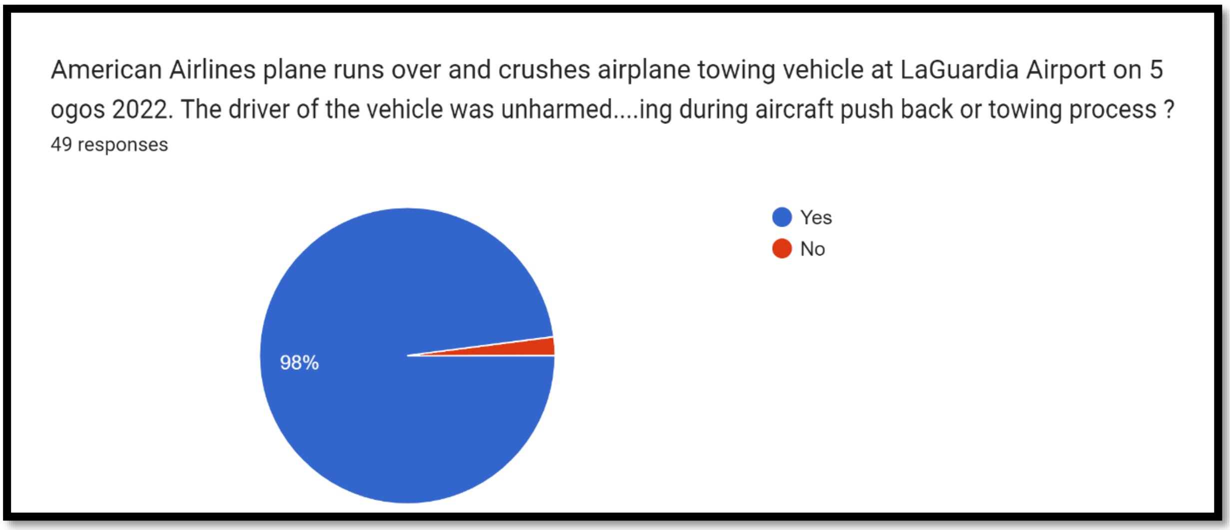


Figure 3.8: Questionnaire from google form survey

2.The pie chart on figure 3.9 displays that the respondents have agreed with the statement of presence of robotic has a positive impact, Yes (93.9%) and No (6.1%)

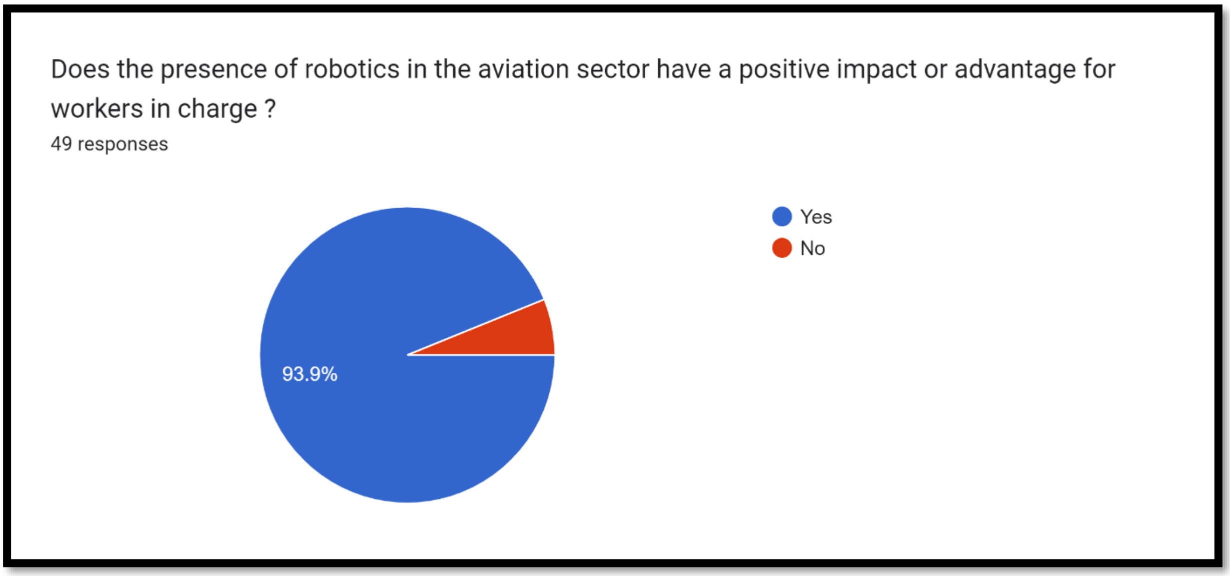


Figure 3.9: Questionnaire from google form survey

3. The last question on figure 3.10 were asked about which type of remote control tug is the best to utilised and around (85.7%) respondents have chosen remote control tug by tyre and a little proportion of respondents have also chose non wheel fairing (by chain) around (14.3%)

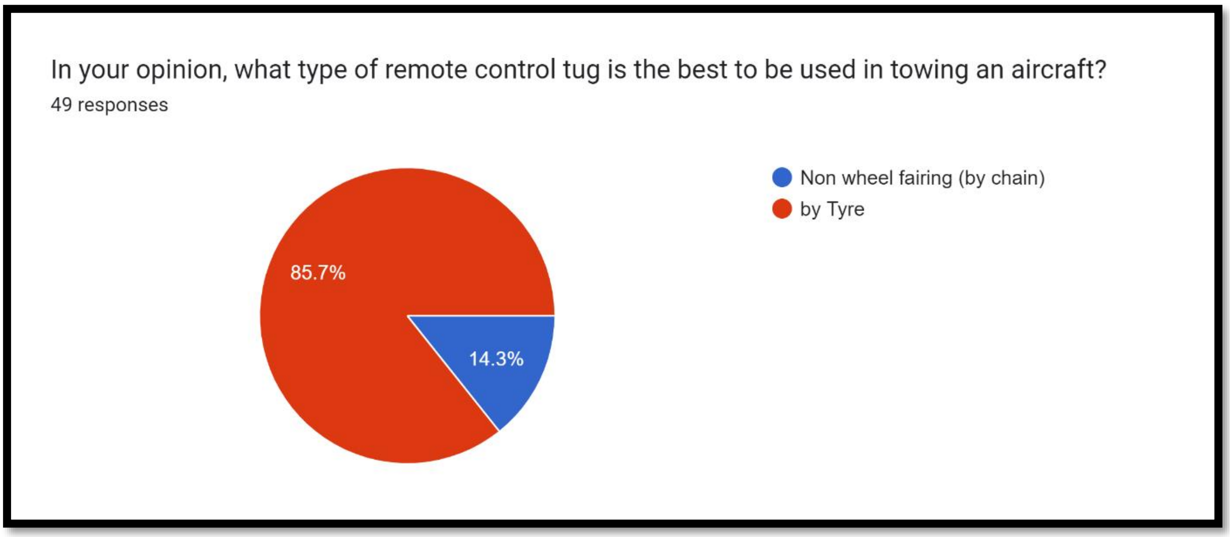


Figure 3.10: Questionnaire from google form survey

4.The pie chart of figure 3.11 displays that the respondents have 100% agree upon this innovation is easier to store than a standard tow truck.

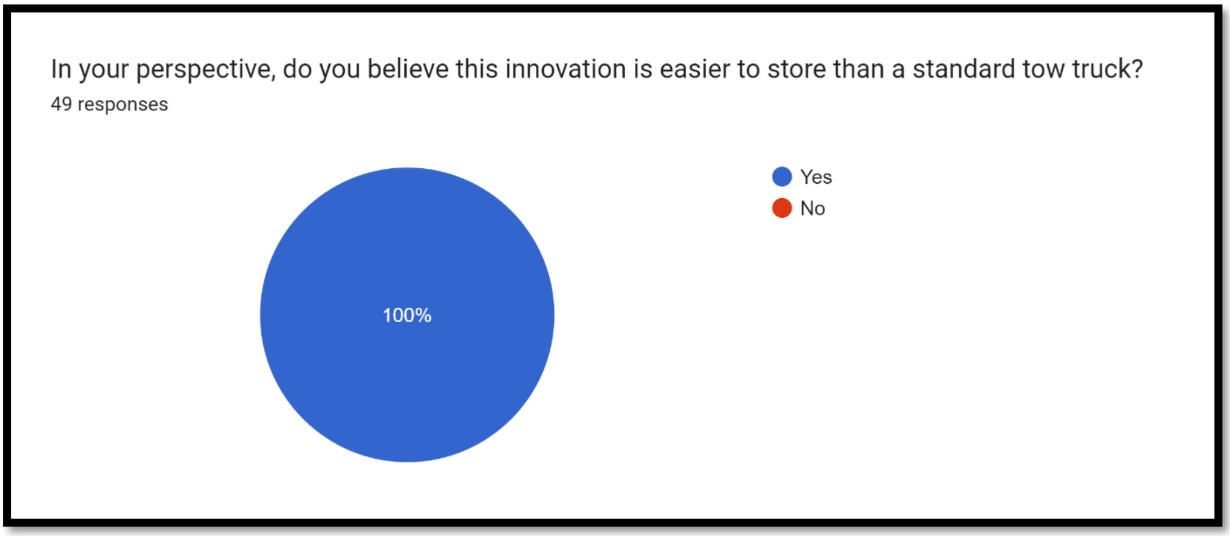


Figure 3.11: Questionnaire from google form survey

5. The highest percentage obtain for this question of figure 3.12 regarding can usage of robotic can lower the number of workers getting injured was Yes (93.9%) and follow by No (6.1%)

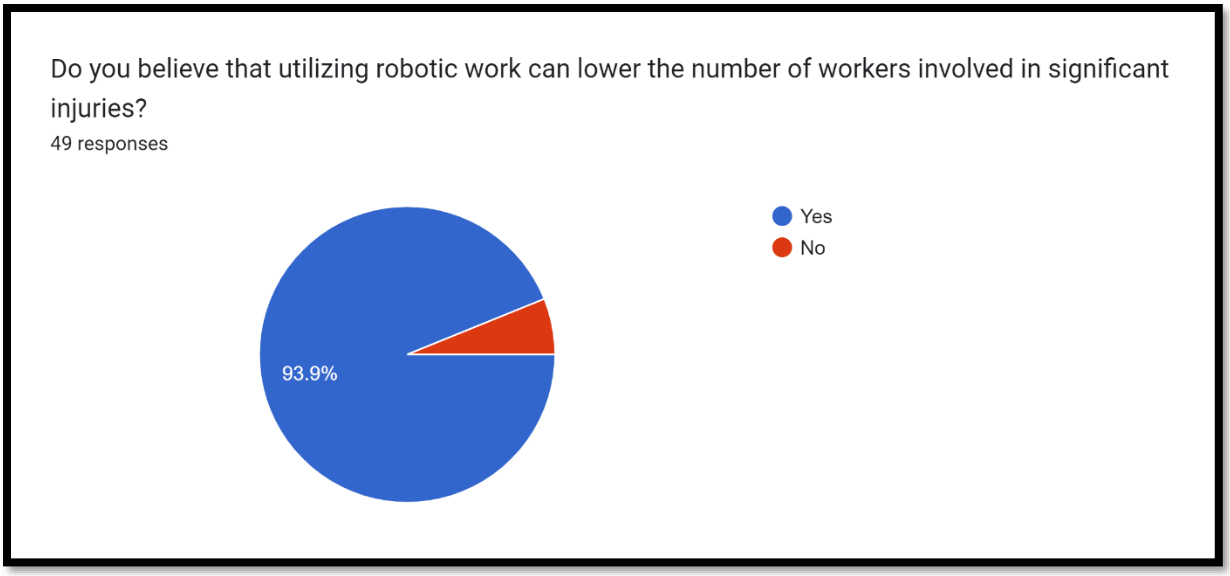
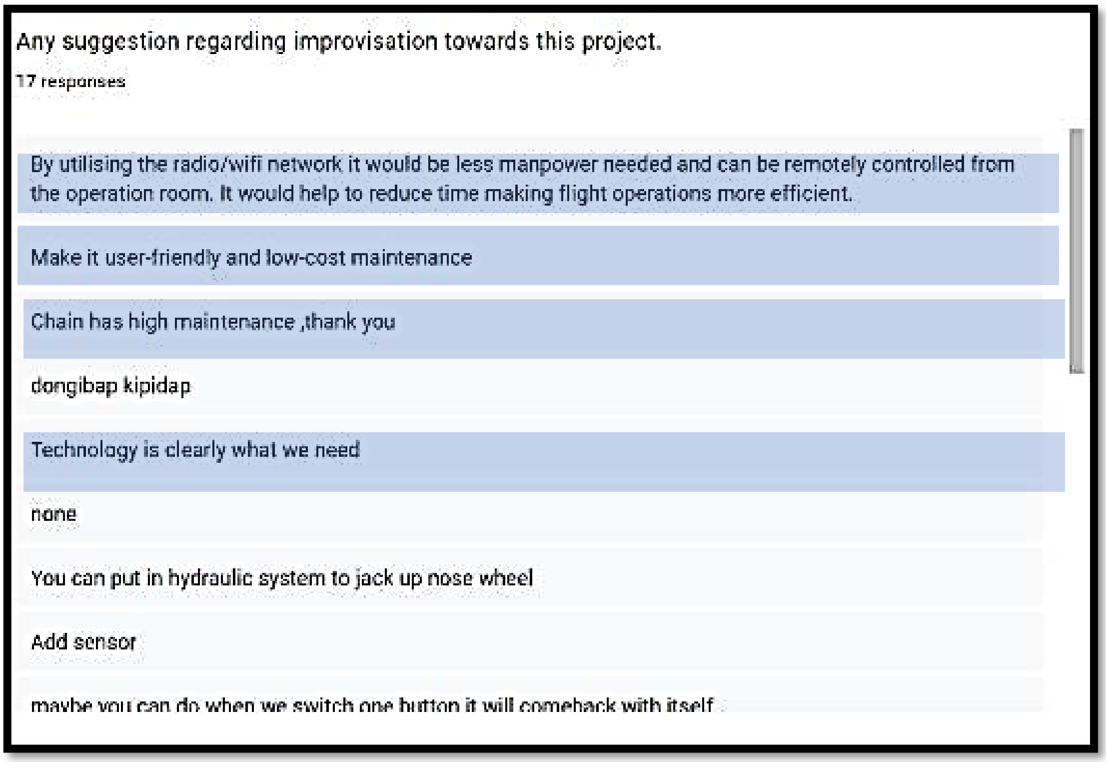


Figure 3.12: Questionnaire from google form survey

6. We also asked about suggestion as figure 3.13 until figure 3.15 that can be apply on our project based on responder's recommendation. There is highlighted suggestion that may be realized or able to apply on this project. Some of the recommendation such as adding camera, beacon light, user friendly control system and it must be test before it considers as success project.



Any suggestion regarding improvisation towards this project.

17 responses

By utilising the radio/wifi network it would be less manpower needed and can be remotely controlled from the operation room. It would help to reduce time making flight operations more efficient.

Make it user-friendly and low-cost maintenance

Chain has high maintenance ,thank you

dongibap kipidap

Technology is clearly what we need

none

You can put in hydraulic system to jack up nose wheel

Add sensor

maybe you can do when we switch one button it will comeback with itself

Figure 3.13: Questionnaire from google form survey

Any suggestion regarding improvisation towards this project.

17 responses

Referring to the images attached, I would like to suggest the tug to be equipped with beacon light.

no

Maybe you Can add a sensor which can detect the distance to avoid collisions

nothing

Will there be cameras on this project? If none, include all possible and needed angles with camera to allow better control and safer towing. Include a wider lens upon installing, so a bigger view and lesser blind-spot can be seen upon tugging. You can put this both on rear and front area of the project.

Still for visual aids, you can use 360 degree camera on your tug and connect it to a Virtual Reality system. This will help the personnel in charge to still be in the environment or situation on a Point of View of tugging, virtually and safer.

I hope this helps and God bless on your research!

Figure 3.14: Questionnaire from google form survey

Any suggestion regarding improvisation towards this project.

17 responses

nothing

Will there be cameras on this project? If none, include all possible and needed angles with camera to allow better control and safer towing. Include a wider lens upon installing, so a bigger view and lesser blind-spot can be seen upon tugging. You can put this both on rear and front area of the project.

Still for visual aids, you can use 360 degree camera on your tug and connect it to a Virtual Reality system. This will help the personnel in charge to still be in the environment or situation on a Point of View of tugging, virtually and safer.

I hope this helps and God bless on your research!

-

None at this moment

but make sure they have been test for many times and approve because robot also got their lifetime and mistakes and even worse. need to be calibrated weekly too !

Figure 3.15: Questionnaire from google form survey

3.4.1.2 Pareto Diagram

The Pareto Chart is a very powerful tool for showing the relative importance of problems. It contains both bars and lines, where individual values are represented in descending order by bars, and the cumulative total of the sample is represented by the curved line. Pareto chart below show the possible cause of aircraft incident during towing procedure.

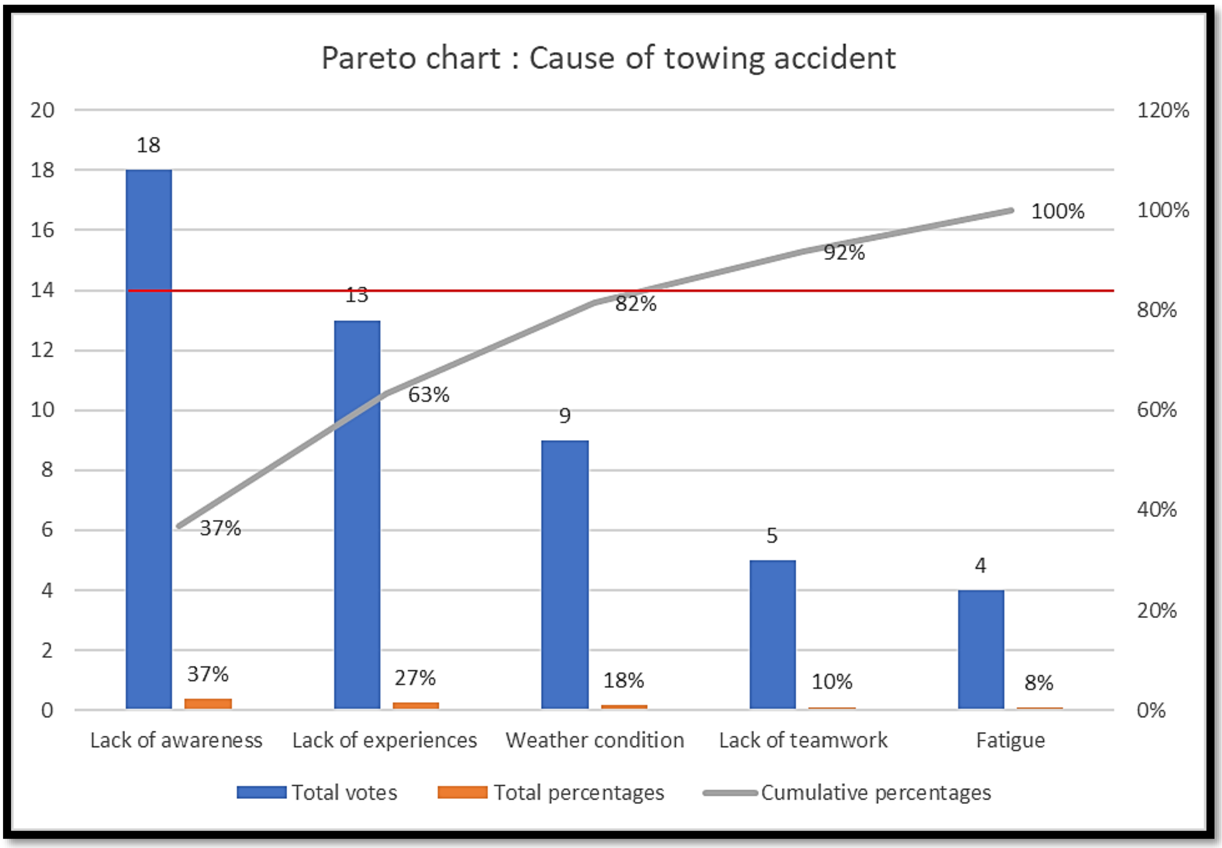


Figure 3.16: Pareto chart diagram of RCAT

- The highest vote – Lack of awareness
- The lowest vote – Fatigue
- Baseline Pareto - 80%

3.4.2 Design Concept Generation

3.4.2.1 Morphological Matrix

Table 3.2: Morphological Matrix

FUNTION	IDEA 1	IDEA 2	IDEA 3
Mobility	Chain wheel	Rubber wheel	Rubber wheel
Battery capacity	Single 24 vdc and solar panel rechargeable	24vdc and rechargable	Single 24 vdc
Motor strength value	24 v, 350 watt motor	24 v, 450 watt motor	12v, 250 watt motor
Material	Aluminium	Stainless steel	Steel
Control mechanism	Remote control	Remote control	Wire remote controller
Airaft tyre locking mechanism	Hydraulic actuation loaking	Mechanical locking	Manual locking
Shape and size	Rectanglerectangle (2.5’ * 2.0’ * 1.0’)	Rectangle (2.5’ * 2.0’ * 1.0’)	Box with a handle (3.0’ * 1.0’ * 4.0’)
Accessories	Siren light	Beacon light Fog light	None
Speed	2.5 mph	3 mph	>3 mph
Motor cooling mechanism	Cooling fan	Heat sink and cooling fan	None

3.4.2.2 Design Concept 1

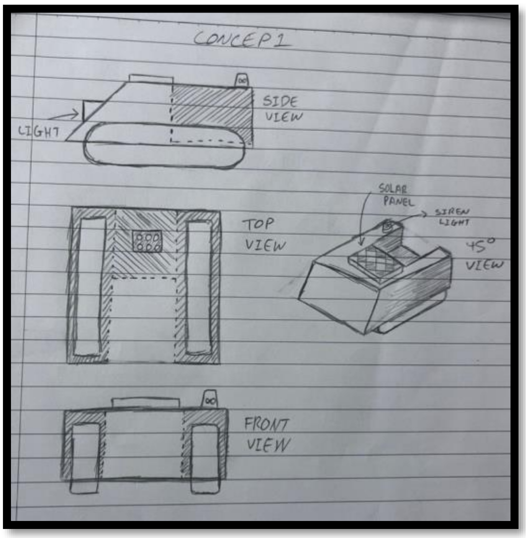


Figure 3.17: Concept 1 design diagram

As can be viewed from the details above, it states the proposed design concept 1 for Remote control aircraft tug innovation. The movement mechanism of the proposed design Concept 1 is by the chain wheel, this is due to heavy-duty usage for example for towing commercial or large aircraft meanwhile the control mechanism is by remote control as its easy accessibility. Next as for the motor strength value, it compromises of a 24 V, 350 Watt motor to produce or deliver a high torque load. The material of proposed design concept 1 is aluminium, this is because we want to produce a portable product so we use lightweight materials. As for the battery capacity of this product, it compromises single 24 VDC and solar panel rechargeable. Since we only using a single 24 VDC, it can save space and weight. When comes to accessories, this design consists of a siren light as a safety measure during conducting the towing and a cooling fan to avoid motor overheating, cheap and is the most common method of cooling.

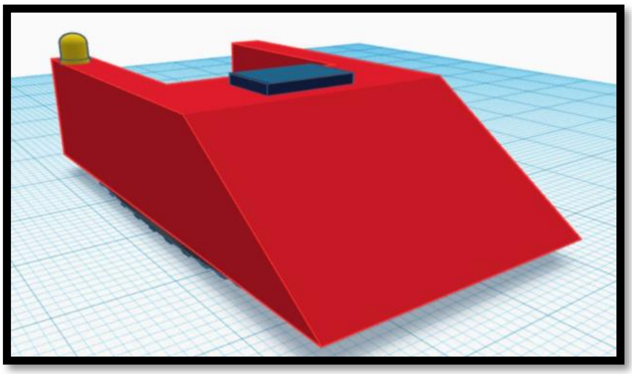


Figure 3.18: 3D Software of concept 1 design diagram

3.4.2.3 Design Concept 2

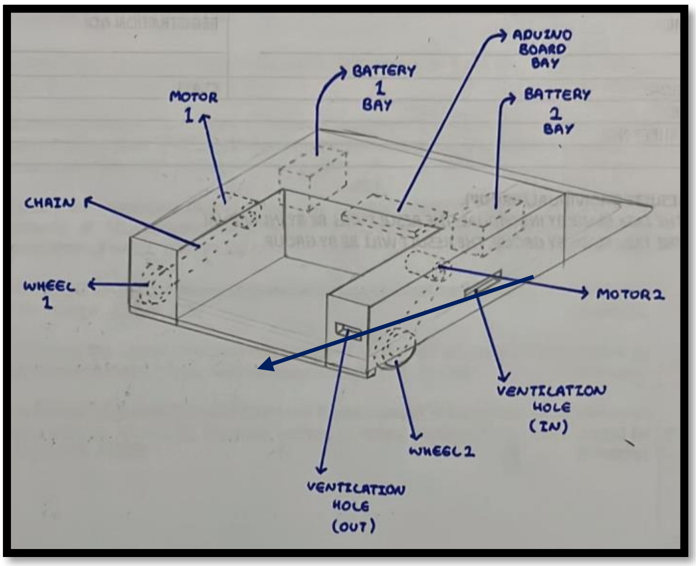


Figure 3.19: Concept 2 design diagram

As can be viewed from the details above, it states the proposed design concept 2 for Remote control aircraft tug innovation. The design powered by two battery 12 volt which connected in series and will produce total voltage of 24V. The battery then will power and turn the high torque motor 24V, 450 Watt. Then using a gearing set and chain, it will turn the wheel as desired speed. There also has a ventilation hole as part of cooling system to keep the motor operate without getting overheat and end up it will be jammed. It also provides with a control system bay to place the electronic component to control the system of remote-control aircraft tug. The main body or structure made by stainless steel which resistant to corrosion and strong.

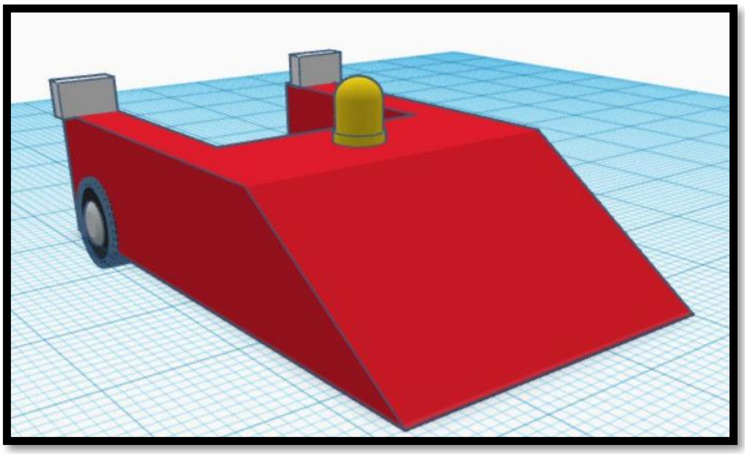


Figure 3.20: 3D Software of concept 2 design diagram

3.4.2.4 Design Concept 3

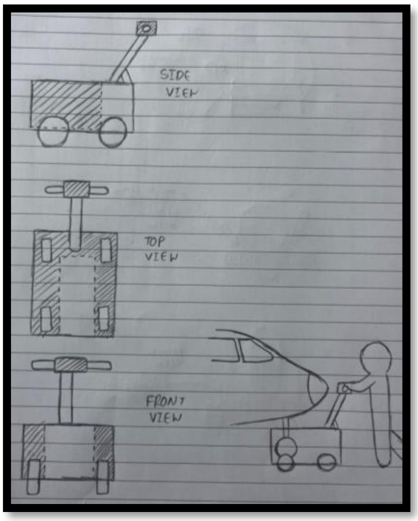


Figure 3.21: Concept 3 design diagram

As can be viewed from the details above, it states the proposed design concept 2 for Remote control aircraft tug innovation. This design based on assistance motor system which it will help the ground personnel to give extra force or torque to push or pull the aircraft. Design with handle to control the turning of this concept by the person desired. This design also provided with 4 main wheel to make this design stable and handle the load of aircraft nose landing gear. The locking mechanism also still using the manual method which the ground personnel need to lock and secure the landing gear by itself on the that platform. The motor will drive both wheel at the front of this concept to give extra power and help the ground personnel to pushback and pull and tow a heavier aircraft.

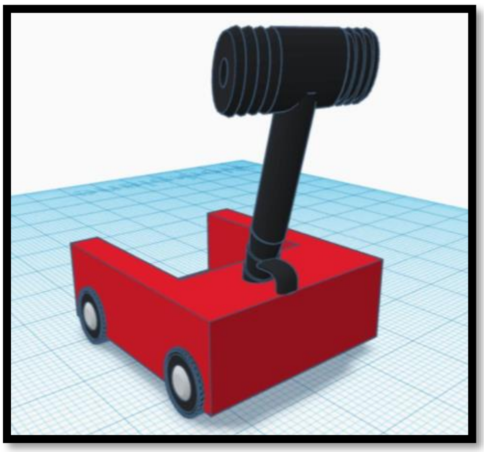


Figure 3.22: 3D Software of concept 3 design diagram

3.4.2.5 Accepted Vs. Discarded Solution

Table 3.3: Accepted and discarded concept

CRITERION	CONCEPT 1	CONCEPT 2	CONCEPT 3
Price	(Cheapest) Aluminium	(Expensive) Stainless steel	(Cheaper) Steel
Movement and mechanism	1.chain wheel cocept 2.hidraulic automatic lock 3.radio communication controller 4.two motor	1. Three tyre wheel arrangment 2. Mechanical lock 3. Radio comunication controller 4. Dual motor and gearing mechanism	1. Four tyre wheel arrangement 2. Manual locking 3. Supported work design.
Accessories	1.siren light 2.solar panel 3.cooling fan	1. Fog light 2. Beacon light 3. Cooling fan and motor heat sink	None
Finishing	1. Chrome and metalic finishing. 2. Lithium grease to avoide corrode. 3. Clear spray		1. Spray colour 2. Clear spray

Accepted Solution: Concept 2

Reasons:

- Have a good traction on operation surface or field.
- Easy and simple control movement mechanism to the crew.
- Able to pushback and pull for aircraft towing operation.
- Withstand to all operation condition and weather.
- Have extra safety features to minimize technical issues.

Discarded Solution: Concept 1 and 3

Reasons:

- Have not good traction on slippery surface like cement for concept 1.
- Concepts are costly to make.
- Less safety features fit in it.

3.4.3 Evaluation & Selection of Conceptual Design

3.4.3.1 Pugh Matrix

Table 3.4: Pugh Matrix with concept 2 as datum

CRITERION	FACTOR	CONCEPT 1	CONCEPT 2	CONCEPT 3
COST	0.125	1	D	1
COMPACT	0.125	1		1
DURABILITY	0.125	2	A	1
LONG LASTING	0.125	2		2
CONVINIENT	0.125	1	T	1
TORQUE STRENGHT	0.125	2	U	1
PRACTICALITY	0.125	3		2
PORTABILITY	0.125	3	M	1
TOTAL SCORE	1.0	1.9		1.3
RANKING	**-**	**2**	**-**	**3**

For our project we list the criteria that we want to focus on our product. Based on the Table above, those are the criteria for our project that we need to implement on our project. The concept 2 is our desired project, it means that our product will use the most suitable items that have been listed. It is also known as DATUM.

From the PUGH Matrix above, we listed the material that suit for our project based on the criteria, it shows that the concept 2 is the best among all those 3 concepts and we also put MOTOTOK which the recent product on market as our DATUM. So, we decide to use the concept 2 because it has the highest score for the PUGH Matrix table.

1 = weak

2= medium

3= Strong

Table 3.5: Pugh Matrix with MOTOK as datum

CRITERION	**FACTOR**	**CONCEPT 1**	**CONCEPT 2**	**CONCEPT 3**	**MOTOTOK**
COST	0.125	1	2	1	D A T U M
COMPACT	0.125	1	3	1	
DURABILITY	0.125	2	3	1	
LONG LASTING	0.125	2	3	2	
CONVINIENT	0.125	1	3	1	
TORQUE STRENGHT	0.125	2	3	1	
PRACTICALLY	0.125	3	3	2	
PORTABILITY	0.125	3	3	1	
TOTAL SCORE	1	1.9	2.9	1.3	
RANGKING	-	2	1	3	-

3.5 PRODUCT DRAWING / SCHEMATIC DIAGRAM

3.5.1 General Product Drawing

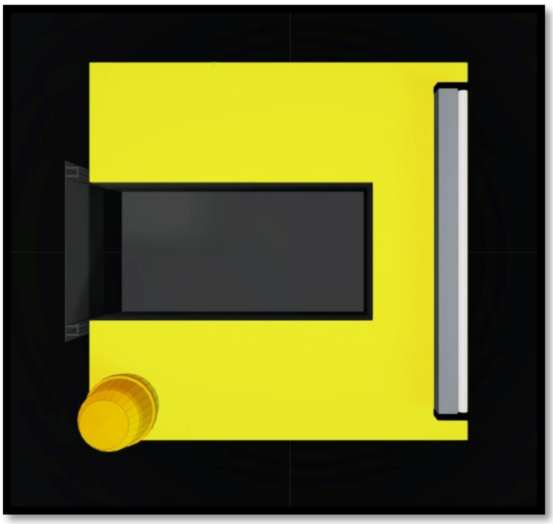


Figure 3.23: Top view of RCAT

Figure 3.24: Top view of inside component of RCAT

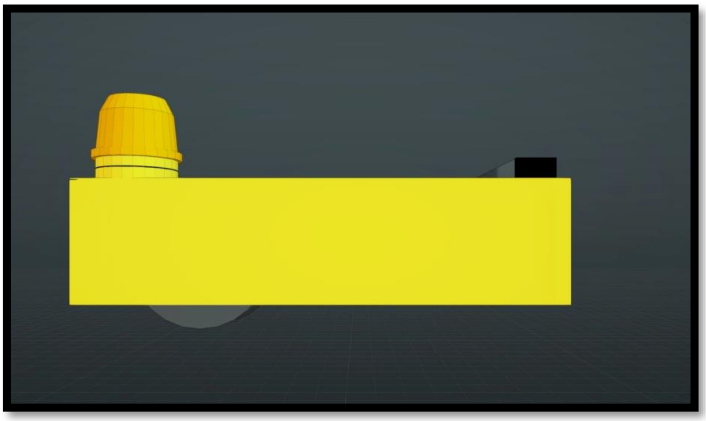


Figure 3.25: Side view of RCAT

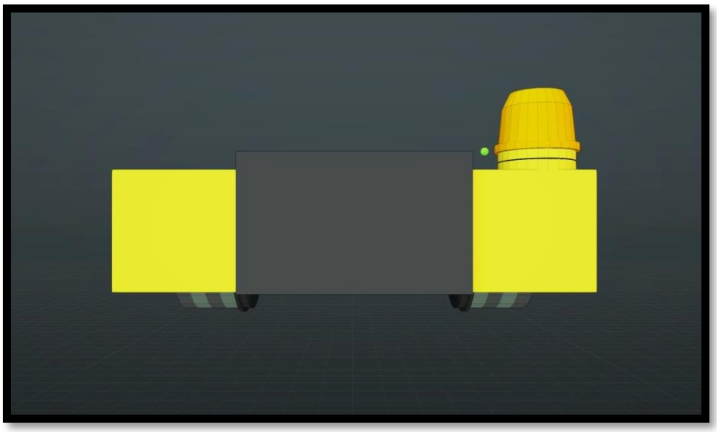


Figure 3.26: Front view of RCAT

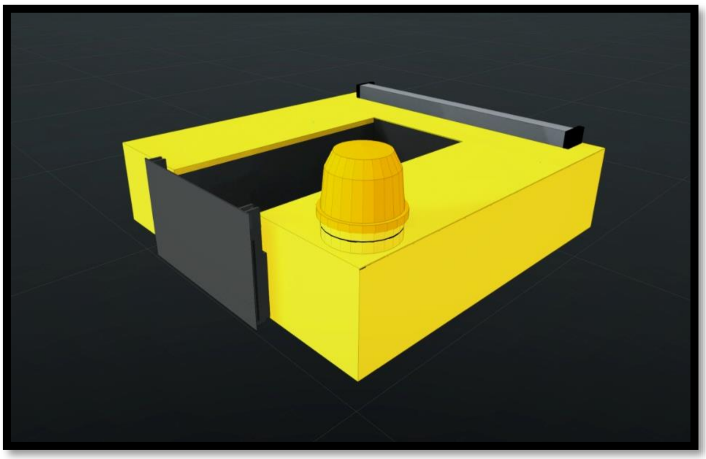


Figure 3.27: Isometric view of RCAT

3.5.2 Specific Part Drawing / Diagram

3.5.2.1 Product Structure

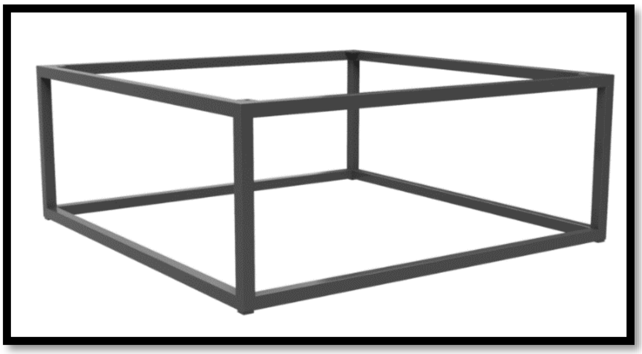


Figure 3.28: Base structure of RCAT

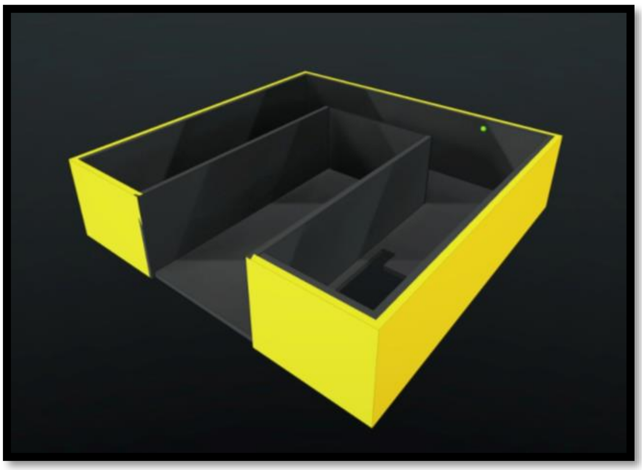


Figure 3.29: Structural of RCAT plus adding side wall

3.5.2.2 Product Mechanism

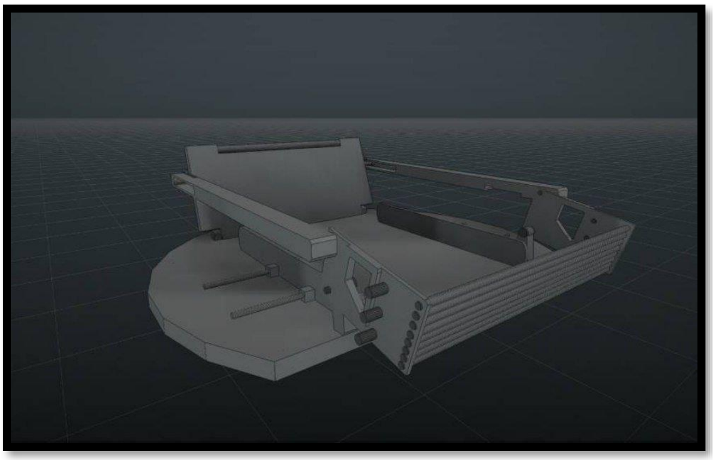


Figure 3.30: Locking device of RCAT

3.5.2.3 Electronic Circuit Diagram

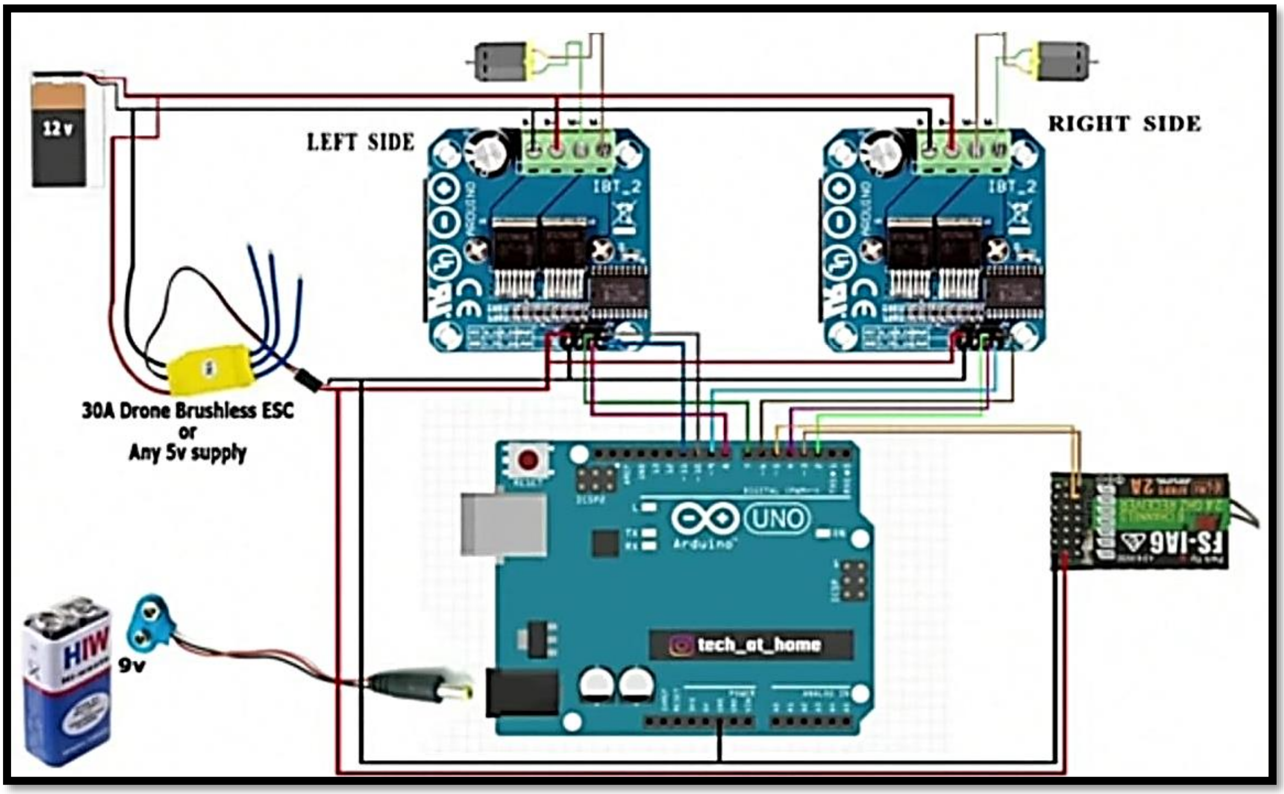


Figure 3.31: Circuit diagram of RCAT

3.5.2.4 Arduino Programming Code

```
//Receiver signal pins
double ch1_pin = 3;  //PWM pin
double ch2_pin = 5;  //PWM pin

//Right motor driver pins
int R_EN_right = 2;
int L_EN_right = 4;
int R_PWM_right = 6; //PWM pin
int L_PWM_right = 9; //PWM pin

//Left motor driver pins
int R_EN_left = 7;
int L_EN_left = 8;
int R_PWM_left = 10; //PWM pin
int L_PWM_left = 11; //PWM pin

// ---**---   Rx threshold values - Update based on your TX values
//FWD
int Ch1Ch2_start_Fwd = 1530;
int Ch1Ch2_End_Fwd = 1980;
//BACK
int Ch1Ch2_start_Bac = 1460;
int Ch1Ch2_End_Bac = 960;

// ---------***----------------***----------

void setup()
{
  Serial.begin(9600);
  pinMode(3,INPUT);
  pinMode(5,INPUT);
  pinMode(2,OUTPUT);
  pinMode(4,OUTPUT);
  pinMode(6,OUTPUT);
  pinMode(9,OUTPUT);
  pinMode(7,OUTPUT);
  pinMode(8,OUTPUT);
  pinMode(10,OUTPUT);
  pinMode(11,OUTPUT);
}

void loop()
{
//Receiver signal pins data
double ch1 = pulseIn(3,HIGH);
double ch2 = pulseIn(5,HIGH);

Serial.print("ch1: ");
Serial.println(ch1);
//Serial.print("\t");
//Serial.print("ch2: ");
//Serial.print(ch2);
//Serial.println("");

//Speed mapping for right motor driver
int spdFwd_RightLeft = map(ch1, Ch1Ch2_start_Fwd, Ch1Ch2_End_Fwd, 0, 255);
int spdBac_RightLeft = map(ch1, Ch1Ch2_start_Bac, Ch1Ch2_End_Bac, 0, 255);

digitalWrite(R_EN_right, HIGH);
digitalWrite(L_EN_right, HIGH);
digitalWrite(R_EN_left, HIGH);
digitalWrite(L_EN_left, HIGH);
```

Figure 3.32: Full arduino Programming Code

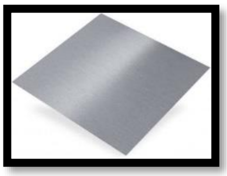
```
Serial.print("ch1: ");
Serial.println(ch1);
//Serial.print("\t");
//Serial.print("ch2: ");
//Serial.print(ch2);
//Serial.println("");

//Speed mapping for right motor driver
int spdFwd_RightLeft = map(ch1, Ch1Ch2_start_Fwd, Ch1Ch2_End_Fwd, 0, 255);
int spdBac_RightLeft = map(ch1, Ch1Ch2_start_Bac, Ch1Ch2_End_Bac, 0, 255);

digitalWrite(R_EN_right, HIGH);
digitalWrite(L_EN_right, HIGH);
digitalWrite(R_EN_left, HIGH);
digitalWrite(L_EN_left, HIGH);

if((ch1==0)&&(ch2==0))
{
analogWrite(R_PWM_right,0);
analogWrite(L_PWM_right,0);
analogWrite(R_PWM_left,0);
analogWrite(L_PWM_left,0);
}
//FWD
else if((ch1>Ch1Ch2_start_Fwd)&&(ch2>Ch1Ch2_start_Fwd))
{
analogWrite(R_PWM_right,spdFwd_RightLeft);
analogWrite(L_PWM_right,0);
analogWrite(R_PWM_left,spdFwd_RightLeft);
analogWrite(L_PWM_left,0);
}
//RIGHT
else if((ch1>Ch1Ch2_start_Fwd)&&(ch2<Ch1Ch2_start_Bac))
{
analogWrite(R_PWM_right,0);
analogWrite(L_PWM_right,spdFwd_RightLeft);
analogWrite(R_PWM_left,spdFwd_RightLeft);
analogWrite(L_PWM_left,0);
}
//LEFT
else if((ch1<Ch1Ch2_start_Bac)&&(ch2>Ch1Ch2_start_Fwd))
{
analogWrite(R_PWM_right,spdBac_RightLeft);
analogWrite(L_PWM_right,0);
analogWrite(R_PWM_left,0);
analogWrite(L_PWM_left,spdBac_RightLeft);
}
//BACK
else if((ch1<Ch1Ch2_start_Bac)&&(ch2<Ch1Ch2_start_Bac))
{
analogWrite(R_PWM_right,0);
analogWrite(L_PWM_right,spdBac_RightLeft);
analogWrite(R_PWM_left,0);
analogWrite(L_PWM_left,spdBac_RightLeft);
}
else
{
analogWrite(R_PWM_right,0);
analogWrite(L_PWM_right,0);
analogWrite(R_PWM_left,0);
analogWrite(L_PWM_left,0);
}

}
```

Figure 3.33: Full Arduino Programming Code

3.6 DEVELOPMENT OF PRODUCT

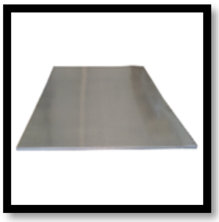
3.6.1 Material Acquisition

Table 3.6: Type of material for main structure

No	Material	Description
1	 Mild steel sheet	It was used for base of the structure and rear sidewalls. The thickness of this material was 3mm.
2	 Aluminium alloy sheet	It was used for sidewalls because of the light weight. The thickness of this material was 0.5mm.
3	 Angle mild steel	It was used for main frame RCAT device because of the strength for carry the high load.
4	 Bold and nuts 8mm	It was used for tight the side walls and mounting the DC motor on RCAT device.
5	 Bold and nuts 13mm	It was used for tight the rear sidewalls and tight the sprocket on the rear tires.

6	 Rubber strips	It was used for covering the sharp edges on the mild steel sheets and aluminium alloy sheets.
7	 Hinges	It was used for allowing the upper hood easily accessible inside the RCAT device.
8	 Pilot tire	It was used for piloting the direction of the RCAT device. The diameter of this tire is 4 inches.
9	 Trolley tires	It was used for transferring the torque force from the DC motor to road surface. The diameter of this tire is 8 inches.
10	 Solid steel rod	It was used for sub rod to give the rear tire rolling elements. The diameter of this rod is 2.5mm
11	 Chain	It was used for transferring the torque load from the DC motor to the rear tires. The type of this chain are 25H.

Table 3.7: Type of materials for mechanism

No	Material	Description
1	 Table hinge	It was used for the support the locking device for locking elements and support the mild steel as a ramp.
2	 Mild steel sheet	It was used for the locking device wall and as a ramp. The thickness of this material is 3mm.
3	 Bold and nuts 13mm	It was used for tight the mild steel on the table hinges.
4	 Solid steel rod	It was used as a safety pin to secure the locking elements on locking device.
5	 Wire rope	It was used for holding the safety pins on rear sidewalls.

3.6.2 Machines and Tools

Table 3.8: Type of machine

No	Machine	Description
1	 Cordless drill	Project purpose: It was used for drilling the aluminium alloy sheet.
2	 pneumatic	Project purpose: It was used for drilling the aluminium alloy sheet when cordless drill battery was drained.
3	 Hand grinder	Purpose project: It was used for grinded all rough surface on mild steel sheet and aluminium alloy sheet before spraying this material.
4	 Welding machine	Purpose project: It was used for attached the angle mild steel frame.
5	 Bench drill	Purpose project: It was used for drilling the mild steel sheet with 3mm thickness.

Table 3.9 Type of tools

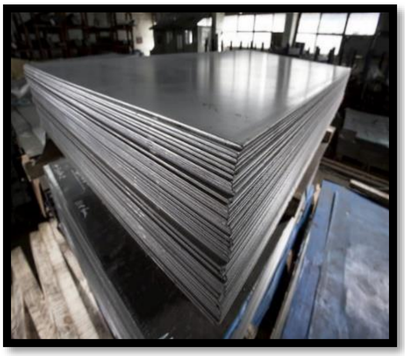
No	Tools	Description
1	 Spanner 8mm	Project purpose: It was used for tightening the bold and nuts 8mm on sidewalls and dc motor.
2	 Spanner 13mm	Project purpose: It was used for the tightening the bold and nuts 13mm on rear sidewalls, mounting pilot tire and sprocket on rear tire.
3	 Plier	Project purpose: It was used for the cutting and twisting wire.
4	 Cutter	Project purpose: It was used for cutting the rubber strips on sidewalls and seal on the rear tire hub.
5	 Steel ruler	Project purpose: It was used for measured the length and make the straight line on mild steel sheet and aluminium alloy sheet.
6	 L-square	Project purpose: It was used for ensuring the datum of the square measurement on mild steel sheet and aluminium alloy sheet.

7	 Centre punch	Project purpose: It was used for making the center point on point that want to drill.
8	 Hammer	Project purpose: It was used for hitting the center punch.
9	 Scriber	Project purpose: It was used for making the line on the mild steel sheet and aluminium alloy sheet.

3.6.3 Specific Project Fabrication

3.6.3.1 Phase 1 (Base Structure)

Table 3.10: Phase 1 of structure progression

No	Fabrication process	Description
1	 Material was checked	The quality of the raw material was checked for the any physical damage such as corrosion and crack.
2	 Material was measured	The length all the dimension was measured and marking on the mild steel sheet and aluminum alloy steel before cutting.
3	 Material was cutting	All the pieces of the frame components were cute using the grinder.

4	 Material was welded	All angle mild steel as a frame and mild steel sheet as a base was welded using the welding machine.
5	 Frame strength was tested	The main frame structure was tested it strength with 4 members of the group will stand above the frame.
6	 Mounting hole was drilled	All the mounting holes on base main frame structure was drilled using the bench drill.

7	 Inner components were mounted	All the inner components were attached on the base main frame structure and was tight used the bold and nuts 8mm.

3.6.3.2 Phase 2 (Mechanisms)

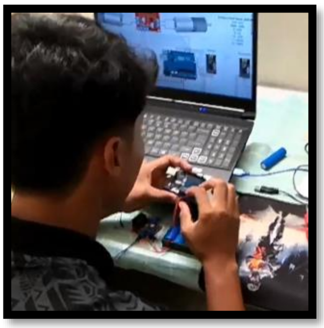
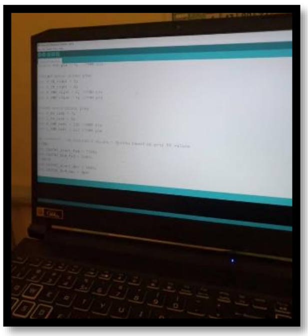
Table 3.11: Phase 2 of mechanism progression

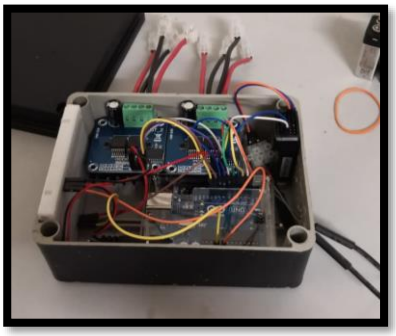
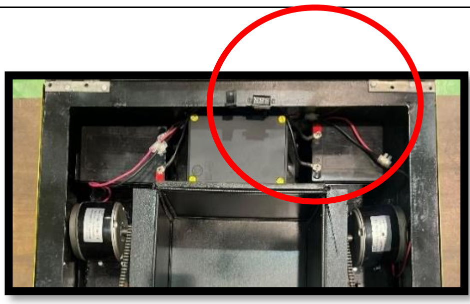
No.	Fabrication Process	Description
1.	 Measure the size of sprocket before drilling process	This sprocket was measured for drilling process to make a hole for inserting a bolt.
2.	 Cutting the mild steel plate	The mild steel plate was cut into rectangular shape for locking device mechanism.

3.	 Measure and grind before bracket hinge installation	The rail bracket hinge was measured before drilling to make a hole for a bolt and attach to the mild steel plate.

3.6.3.3 Phase 3 Programming & Electrical Circuit)

Table 3.12: Phase 3 of programming progression

No	Fabrication Process	Description
1.	 Component assembly	All components have been assembled according to the circuit diagram.
2.	 Programming	Arduino Uno 3 have been coded and programmed via Arduino IDE.

3.	 Programming test run	All the components have been assembled and the code also have been uploaded. Then the components fitted to the software housing and tested right away.
4.	 Circuit wiring connection to the project mechanisms	Wiring from battery and motor have been connected to component of the software housing.
5.	 Overall test run	All the switch and light have been tested. The movement of project also have been tested using the remote control.

3.6.3.4 Phase 4 (Accessories & Finishing)

Table 3.13: Phase 4 of accessories and finishing progression

No	Process	Description
1.	 Spray paint the main structure	• Paint application on main frame structure • The main frame structure was painted black in colour meanwhile the sidewalls were painted yellow in colour • Multiple layers were painted to provide a good texture and consistent tone on the product
2.	 Fastener installation	• Installation of the fasteners, bolt and nut • Fasteners such as bolts and nuts are installed on the main frame structure and sidewalls
3.	 Motor installation	• Reinstallation of components • Components such as the DC motor were mounted on the main frame structure using bolts and nuts
4.	 Illumination installation	• The beacon light and LED tube lights are installed on the hood • The sharp edges on the main frame structure were covered by rubber strip

3.8 Product Testing

Overall after this project successfully is completed, it must be tested especially about all the functionality and features. First of all, RCAT's structure have been tested to examine it strength. All of our group members were stood on top of the structure at the same to ensure it can handle high load. The structure was approved to handle the high load,

Next, our project also has been tested to test all the light to ensure all the light like beacon light and LED light were function properly. It was to ensure our project have a good element of illumination for personnel's safety reason. All the light was function and in good condition.

Figure 3.34: RCAT full assembly

After that, we also tested our project from the software aspect to ensure the movement of RCAT was normal. This project was tested to ensure the wheels were not stuck between the fastener and bracket. This project also was tested for the chain tension and make sure it not too loose.

Lastly, the final test of RCAT was using the real Cessna 172 by towing it along the hangar. We test our project in all aspect from maneuvering, turning and handle the weight of Cessna 172 itself. We done this testing with real process and procedure of towing lightweight aircraft.

Figure 3.35: RCAT towing the Cessna 172

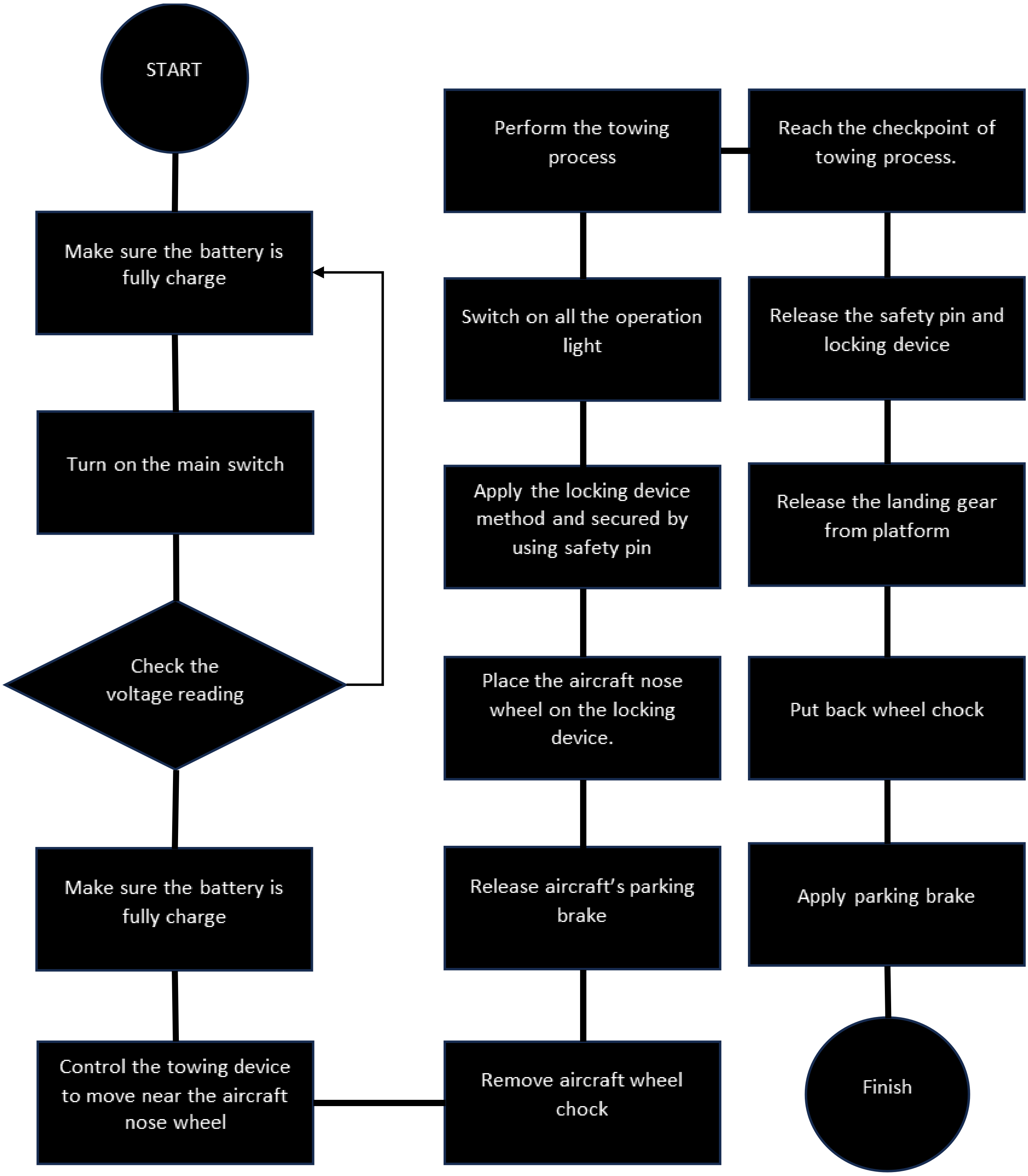


Figure 3.36: Product testing flow chart

3.9 LIST OF MATERIALS & EXPENDITURES

Table 3.14: List of Materials & Expenditures

Product Structure				
No.	Items Detail	Unit	Price	Total(RM)
1.	Mild Steel Plate (3.0mm x 4' x 8	1	278.00	278.00
2.	¾ 12"2 Steel Shaft	1	12.00	12.00
3.	Bolt & Nut	10	1.50	15.00
4.	Screw Set YLT-78-3	5	3.10	15.50
5.	Cable Wire 4MM 1 METER	1	3.00	3.00
Product Mechanism				
1.	250W Electric Motor	2	125.00	250.00
2.	24 VDC Battery	2	100.00	200.00
a.	25H Chain (144L)	2	14.00	28.00
4.	25H Rear Sprocket 190CM	2	33.00	66.00
5.	Adjustable Small Pilot Tyre	1	9.00	9.00
6.	Wheel Bearing Hand Truck Trolley Tyre	2	22.00	44.00
Product Software/Programming				
1.	Joystick Module (Dual Axis XY)	1	7.00	7.00
2.	2AA Battery Holder	1	2.80	2.80
3.	20CM Male to Male wire jumper	2	2.50	5.00
4.	20CM Male to Female wire jumper	2	2 50	5.00
5.	L298N Motor Driver Module-H Bridge	1	15.00	15.00
6.	Arduino Uno Ra Atme,a 16U2 with Cable	1	54.00	54.00
7	Arduino Pro Mini Atme,a 328P (SV 16MHZ)	1	37.50	37.50
8.	GY-521 MPU-6050	1	12.50	12.50
9	Breadboard Power Supply MB102 DC 3.3V-5V	1	12.50	12.50
10.	2-Wheel Car Chassis Kit (Compact)	1	29.90	29.90
11.	20CM Female To Female Wire Jumper	1	2 50	2.50
12.	Rocker Switch 2 Pin	1	2.00	2.00
13.	LED Red Colour	2	0.30	0.60
14.	Led Blue Colour	2	0.30	0.60
15.	5-Band Resistor	4	0.10	0.40
16.	Nano v3.o CH340 Atmega328P USB	1	30.00	30.00
17.	Cable Lug 6mm	4	0.70	2.80
18.	Heat Shrinkable Sheering 5MI 0.5Meter	1	1.00	1.00
19.	Cable Wire 4mm 1Meter	1	3.00	3.00
Others Product				
1.	Epoxy Putty	1	10.00	20.00
2.	Spray Paint Yellow	1	9.00	9.00
3.	Spray Paint Black	1	9.00	9.00
4.	Hazard Tape	1	6.00	6.00
5.	3 Second Glue	1	2.50	2.50
6.	Grinding Wheel	4	2.70	10.80
			GRAND TOTAL	RM1201.90

CHAPTER 4

RESULT & DISCUSSION

4.1 PRODUCT DESCRIPTION

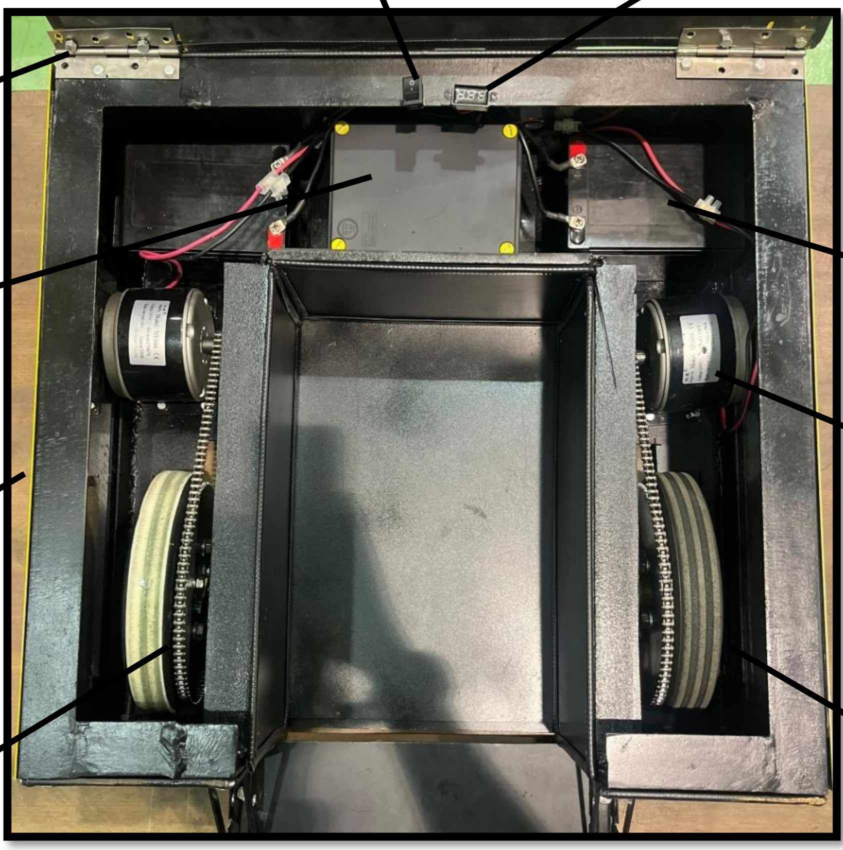


Figure 4.1: Components arrangement inside RCAT

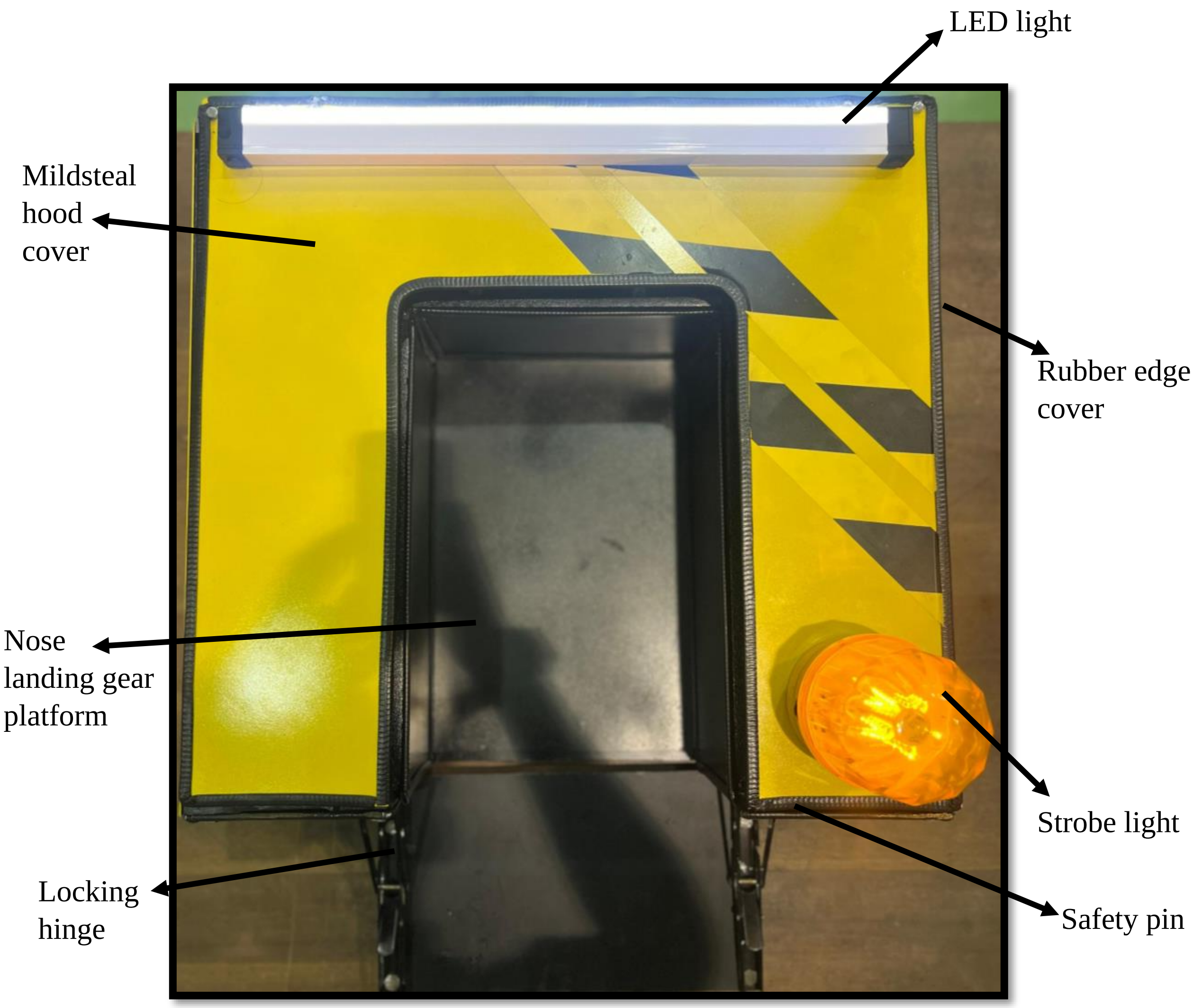


Figure 4.2: Outside look of RCAT

4.1.1 General Product Features & Functionalities

RCAT is an innovation in manoeuvring lightweight aircraft utilizing remote control technologies. In general, this product consists of two different compartments which had been attached. The primary section is the main frame section which would be the area where the nose landing gear is placed, and the part carries the load of the aircraft. Besides, the second section is the locking device which acts as a ramp for loading and unloading the aircraft wheel and securing it from the aircraft wheel falling back.

The first purpose of this product development is to Design a remote control aircraft tug capable of manoeuvring aircraft efficiently and precisely, considerably minimizing the time required for aircraft towing as compared to traditional methods. Enhance tug operations by using innovative control automation and user-friendly interface approaches to ensure smooth and efficient aircraft transportation throughout the operation.

Secondly, the product is developed to construct a remote control aircraft tug system that prioritizes safety throughout its operations. Implement strong safety measures and fail-safe systems to avoid crashes, injuries, and damage to aircraft or airport infrastructure. Utilize modern sensors and obstacle detection systems to provide safe and controlled pull manoeuvres in all situations.

Finally, the purpose of RCAT is to reduce the reliance on manual labor for aircraft towing. Automate the aircraft towing process with remote control aircraft tug, minimising the requirement for manual labour and ground crew personnel's exposure to possible risks. This move will not only improve safety but will also help airlines save money by lowering labour costs.

4.1.2 Specific Part Features

4.1.2.1 Product Structure

RCAT has two main parts. Which is main frame structure and locking device structure. The main frame structure was made by mild steel angle with measurement 1.5” x 1.5”. The dimension of the main structure frame is ¾ ft height, 2.5ft wide and 2.5 feet length. The method of joint all this mild steel angle was using the arc welding. The side walls for the main frame structure were build up by using aluminum alloy sheet metal but the rear side walls and upper side wall was using the mild steel sheet with 0.12” thickness. As for the locking device structure was made by mild steel sheet with 0.12” thickness. The function of the main frame structure was to carry all the stress load when towing the aircraft and mount all the inner components. the function of the locking device structure was to pull nose landing gear and lock the tire.

In general word, the structure of the Remote-Control Aircraft Tug (RCAT) has two main parts. Which is main frame structure and locking device structure. The feature that has on main frame structure are all the edge side walls was covered by using rubber steel bend to avoid any injury causes by the sharp edges and damage for the nose landing gear especially tire. Then, all the attachment side walls to main frame structure were tied with the bold and nuts to secure all the attachment when occurs the vibration in operation towing the aircraft. The shape of the main frame structure also plays main role with the height only ¾ ft make it easy to through in and throughout under small aircraft of its landing gear. For the locking device structure was made by mild steel sheet with 0.12” thickness to secure the strength of this structure when hold and locking the nose landing gear.

4.1.2.2 Product Mechanisms

Remote Control Aircraft Tug consist of two mechanism section, the locking device section and moving mechanism. The locking device is to ensure the safety of the aircraft tire while doing aircraft tug. The locking device consist of several components which is bracket, mild steel plate and safety pin. Bracket is attached to the mild steel plate for the locking operation. The mild steel plate function is to close the back of the tire area to ensure the tire will not slip out of the area while the towing process is occurred. The last component of locking device is safety pin. The safety pin is to ensuring the safety and reliability of equipment and also reduce the risk of unintentional deployment.

Next, moving mechanism consist of one tire driven by a motor individually and linked via a chain. The motor will move the tire which attach directly to the big sprocket, 93 teeth of sprocket. In fact. The motor able to move the tire forward and backward independently depending on the signal input from the remote control.

4.1.2.3 Software / Programming

The electronic components of RCAT is consist of one microcontroller board which is Arduino Uno. The main purpose of it is to process the input from the receiver by doing some programming set up. Next, two of motor driver BTS7960 also fits in to control the motion, direction and speed of the motor independently. The input signal form the motor send from the Arduino Uno after the signal has been process and finally the output signal from BTS 7960 to move motor. After that, the Arduino Uno and Receiver are powered by two different 9V battery to power those electronic components. Furthermore, the receiver which consist of 6 channel fit and connected to the Arduino where it used to receive signal from the transmitter form remote control FlySky FS-I6X.S. Lastly, all the component and wiring are fit inside the software housing as a proper place and make it easy if to be remove as maintenance purpose.

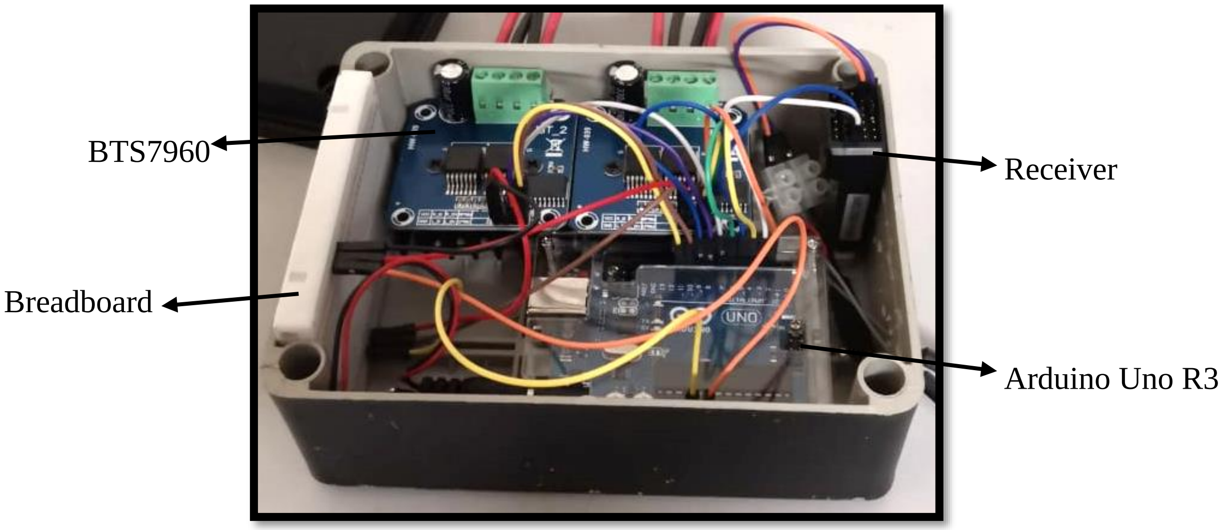


Figure 4.3: Wiring inside the software housing

4.1.2.4 Accessories & Finishing

On the hood of the RCAT device, it is equipped with an LED tube light to provide illumination during operation at night and in places with a lack of illumination. Besides that, there do consist of Beacon lights which act as warning mechanisms for situational awareness to keep other ground crews safe, particularly in unpredictable situations.

For the finishing part, we used reflector stickers at the front surface of the locking device to enhance the visibility of the remote control aircraft tug, allowing ground crews and other airport personnel to monitor the tug in low-light or dark circumstances. This is helpful in the prevention of accidents and increases safety.

Furthermore, as for the sharp edges at the parts such as the main frame structure, the hood of the structure and critical parts were covered with rubber strips. This rubber strip prevents maintenance personnel from getting injuries due to the sharp edges during the accessibility of components.

4.1.3 General Operation of Product

When compared to conventional tow tugs, a RCAT operation has several advantages. The RCAT are transforming aircraft ground handling. They provide user friendly interface, productivity, and efficiency. Remote control aircraft tugs can boost efficiency with fewer crew members needed and better sight. They run on batteries rather than gasoline, they are safer to use because no one has to be below the aircraft. Additionally, this RCAT offers cost saving by reducing the cost of maintenance and increasing production. This type of remote-control aircraft tug can be operated within up to 20 meters range. Nowadays, remote control aircraft tug has will be the game changer to aviation industry to tow the aircraft.

4.1.4 Operation of the Specific Part of the Product

4.1.4.1 Product Structure

Before that the main structure was divided by two structure which is main frame structure and locking devices. So, for the main frame structure it will function as main shape for the RCAT. After that, the three layers of the mild steel will be the base which are to carry the load nose landing gear light aircraft and will be mounting of the inner components such as DC electric motor and pilot tire. Then, the function of the pilot tire is to piloting the direction of the RCAT.

Next, the rear tires will be the medium to transfer the torque load from the DC electric motor to the road surface when towing the aircraft. Besides that, the function of the side wall are to avoid any dust, foreign object and covering the inner electric components from the rains. For the locking devices structure, the function of the mils steel sheet with 3mm thickness is to be a ramp and locking mechanism for the nose landing gear when during the towing procedure. After that, two biggest hinges will be moving the mild steel sheet to be a ramp or be the locking mechanism.

4.1.4.2 Product Mechanisms

The locking device is the only section that makes up the RCAT. The locking device function makes sure that the aircraft's nose landing gear being towed and the tug have a steady and safe connection. In order to avoid any unintentional separation during the towing operation, this locking device is essential. To enable safe and regulated movement on the ground, the locking mechanism is made to firmly fasten the tug to the aircraft. The locking mechanism is intended to be simple to use. Simple engagement and disengagement processes are part of this and safety pin to secure the landing gear become falling back.

Next, the movement mechanism performs by the 24V DC motor. The sprocket attached directly to the back wheel and it links via a chain. Each wheels move independently, and direction of the RCAT perform by the small pilot wheel at the front of the RCAT.

4.1.4.3 Software / Programming

Both motor driver BTS7960 is function to control motion, direction and speed of the both DC motor. The input has been processed from the Arduino Uno R3 after all the programming language is uploaded. The function of Arduino Uno R3 is as microcontroller or brain to RCAT project to control the signal input and output to control movement of motor. Lastly, the transceiver of remote control of FlySky FS-I6X. RCAT only use two channel of the transceiver which channel 1 to control movement of forward and backward while the channel 2 to control the turning.

4.1.4.4 Accessories & Finishing

A beacon light is mounted on the hood of the main frame structure to serve as a warning device to other maintenance professionals. Because manually operated beacons require less maintenance and are easier to repair than automated systems, they are utilized. The beacon light is powered by two 1.5-volt batteries. The similar solution is applied to the LED tube light installed on the hood of the main frame construction.

In addition, the main frame structure and locking device have been painted with matt black spray paint. The paintings were initially painted with primer and then completed with matt black spray paint to ensure that the primer spray can help protect metal surfaces from rust and corrosion. Aside from that, it helps to keep the paint from peeling, breaking down, or flaking off.

4.2 PRODUCT OUTPUT ANALYSIS

Table 4.1: Product output analysis

No.	Parameters	Results	Remarks / Descriptions	Analysis
1.0	Speed Limit			
1.1	Speed limit (unloaded)	4.5 km/h	A maximum speed that a towing device can reach during unload.	In terms of speed limit, Remote Control Aircraft Tug (RCAT) is capable to reach 4.5km/h top speed during unloaded. However, its speed capability will drop up to 67% during FULL load condition.
1.2	Speed limit (Partially Load)	3.5 km/h	A maximum speed that a towing device can reach during 50% loaded.	
1.3	Speed limit (Fully loaded)	1.5 km/h	A maximum speed that a towing device can reach during FULL load.	
2.0	Time of Operation			
2.1	Max Time	25 minutes	A maximum time of operation that towing device can reach is 25 minutes	In terms of time operation, Remote Control Aircraft Tug (RCAT) is capable to reach about 25 minute. Even the load of the towing device is 40kg it can turning about 90 degree of angle during towing process. RCAT also can produce 24V of output power and 250W of power motor which is very capable for this device load.
2.2	Weight / Load	40kg	A maximum load of RCAT is 40kg.	
2.3	Turning Radius	90 degrees	A maximum turning radius of towing device can reach is 90 degrees.	
2.4	Capacity / Volume	20 Litres	A maximum capacity or volume that towing device can reach is 20 Litres.	
2.5	Output Power / Voltage	24V	A maximum output power that towing device can reach is 24V	
2.6	Output Power Motor	250W	A maximum output power of motor that towing device can reach is 250W	

4.3 ANALYSIS OF PROBLEM ENCOUNTERED & SOLUTIONS

4.3.1.1 Product Structure

The project objectives have been successfully achieved. Locking device of the Remote Control Aircraft Tug can be operated successfully. However, during construction of the Remote-Control Aircraft Tug, some problems were encountered.

Table 4.2: List of problems encountered & Solution of structure

List of Problems	Solution
Use a hinge which is not heat resistance	Use a folding shelf brackets which is heat resistance.
Inappropriate safety pin is unavailable in the market	Make our own safety pin.
Aluminium sheet metal for the base area is easy to dent.	Use a mild steel plate which is high strength and withstand load.

4.3.1.2 Product Mechanisms

The RCAT product was using the mild steel material. The advantages when using this material are the strength and durability of the product was secure because of the all-mild steel will doing the heat treatment process to improvise the strength and durability of this material.

The main problems that have been encounter on main frame structure are when doing the drill hole process on the mild steel sheet with thickness 0.12 inch. It more difficult when this sheet in doubler and triplet layer. The drill bits easy to dent and break. Basically, the problem was solved by initially beginning with pilot drill and gradually increases the drill bits size. Then, the next problems are the mild steel angle has a flaws such as the pitting hole and uneven surface. This problem was solved by putting the epoxy putty on his flaw.

4.3.1.3 Software / Programming

Table 4.3: List of software and programming problems and solution.

List of Problems	Solution
Short circuit while performing a wiring of motor driver.	Buy all new set of burned and broken component inside the software housing
Arduino Uno R3 broken and overheat	Change to a new one
All component does not fit inside the software housing	Custom the software housing

All the electronic of component to control the mechanism of RCAT is fitted inside the software housing. There are a few problems that we faced during the process to finish this project such as the Arduino Uno found broken and over heat. This probably because I was doing the Arduino coding inside the general workshop where lot of metal debris cause by drilling, cutting and filling. The Arduino Uno is a very sensitive component where the soldered leg of Arduino Uno cannot be touched on any metal surface or it will be a short circuit of the Arduino Uno and make it overheat. So, we solve this problem by buying and changing the Arduino Uno with a new one.

Next, all the component are does not fit inside the software box. We could not change the software because we only have a limited space to put the software box inside the RCAT hood. So we need to custom the box by drilling removing the unnecessary compartment dividend of the software housing.

After that, we also faced problem where the BTS 7960 is exploded. This is cause by unproper wiring of the battery terminal and motor terminal of BTS7960. The capacitor of BTS7960 exploded and the debris and heat also cause other electronic components also burned and broken. So the next day morning, I need to buy a new set of electronic component that burned and broken inside the software housing which it cost over RM200.

4.3.1.4 Accessories & Finishing

A beacon light is mounted on the hood of the main frame structure to serve as a warning device to other maintenance professionals. Because manually operated beacons require less maintenance and are easier to repair than automated systems, they are utilized. The beacon light is powered by two 1.5-volt batteries. The similar solution is applied to the LED tube light installed on the hood of the main frame construction.

In addition, the main frame structure and locking device have been painted with matt black spray paint. The paintings were initially painted with primer and then completed with matt black spray paint to ensure that the primer spray can help protect metal surfaces from rust and corrosion. Aside from that, it helps to keep the paint from peeling, breaking down, or flaking off.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 ACHIEVEMENT OF AIM & OBJECTIVE OF THE RESEARCH

5.1.1 General Achievement of the Product

"With a simplistic, remote-controlled interface, this electric vehicle enables more ground personnel to perform pushbacks and increases turnaround efficiency." **(Josh Smith, 15 March 2029)**

Upon the final product testing just as the statement above stated, RCAT able to produce an outcome greater than expected. The RCAT with a simplistic design it able manoeuvre a lightweight aircraft without any hindrance. The factor that approve that this innovation is a success was the ability of this product to manoeuvre a lightweight aircraft in shorter period of time, without damaging any components and sustainability to hold the load stress during manoeuvring the lightweight aircraft.

Besides that, this product was innovated based on some suggestion from respondents therefore a post survey been carried out to determined the user's satisfaction upon product. Based on the date gather, the majority number of respondents had agreed upon that RCAT enhance the efficiency of manoeuvring lightweight and also improve the safety standard of personal maintenance during towing an aircraft.

5.1.2 Specific Achievement of Project Objectives

5.1.2.1 Product Structure

For the achievement that RCAT structure archive are the maximum load that RCAT can easy pull is 600kg to 750kg. After that, for the maximum load for the forward light aircraft that RCAT can withstand and carry is about to 300kg to 450 kg.

5.1.2.2 Mechanisms

Throughout the process of designing the real product of the Remote Control Aircraft Tug,the objectives and aim that were stated at the beginning of the work are considered successfully accomplished. The main purpose of this product mechanism is to design a Remote-Control Aircraft Tug with a locking device to secured the tyre while doing a towing process.

A product of Remote-Control Aircraft Tug that comes with a locking device has been developed and design first, using mild steel plate as the base for landing gear and the back of the product which attach with the semi auto hinge. Before the product was designed a, series of experimental phases were carried out to determine the most suitable locking device that can secure and protect the tyre perfectly. A safety pin that was made up by steel was also designed to ensure that sure lock couplings will not become accidentally disconnected.

5.1.2.3 Software & Programming

Achievement from the software aspect is at the end of this project all the electronic component and programming work without any error. There is no such thing like short circuit or circuit burned or any unwanted electrical spark. The motor move as we wanted where it can move and turn smoothly. Other than that, the remote of RCAT is able to control from range 20 meter far from the receiver at the main body of RCAT.

5.1.2.4 Accessories & Finishing

The commercial value of our product is a user-friendly interface whereby it can be comprehended by the operator or any personnel who controls the remote control, with ease. Thus, the accessories and furnishing were prioritized as the supporting elements and finishing elements of this product which can improve the standard. The first component is The beacon light, it can improve the safety standard as it operates, and it is indicated as the warning mechanism to the ground crews.

Other than that, the LED tube light is also used to provide support as illumination during operation at night. On The interior and exterior of the main frame structure, Rubber strips are used as they improve the safety standard of this product regarding the sharp edges and it allow easy accessibility. Furthermore, the front part of the locking device is attached with a reflector sticker and this improves the visibility of this device throughout the operation.

5.2 CONTRIBUTION OR IMPACT OF THE PROJECT

The contribution of the project to our society especially in aviation sector is optimizing the towing procedure to move the aircraft form one checkpoint to another checkpoint. It will reduce overall towing time and increases aircraft turnaround efficiency where it has 360 degrees pilot wheel. It provides and improve safety during the towing procedure and reduce the likelihood of accident, injuries or collision during towing by increasing visual range of ground personnel. Meanwhile, RCAT also contribute to environment by reducing emission of hazardous gasses to atmosphere. RCAT only use electrical source from the two main battery to fully operate it. Lastly, the impact this project to industry is RCAT significantly reduces labour costs associated with aircraft towing operations. Only one authorize personnel can handle the aircraft towing procedure compare to normal or conventional towing using big towing truck.

5.3 IMPROVEMENT & SUGGESTION FOR FUTURE RESEARCH

5.3.1.1 Product Structure

We hope that in the future with continuous effort and commitment. This project can be upgraded or improved to a better product. Certain place or technology that are wish to be added to the Remote-Control Aircraft Tug:

- Using a lightweight durable material and anti-corrosion material.
- Use a lightweight main frame for better movement and reduce the load of product.

5.3.1.2 Mechanical Mechanism

The improvement and suggestion for future research are install the damper on the upper casing to the main frame structure to easy excess insides the RCAT. After that, improvise the locking device mechanism to simpler and safety with put the safety pins for the locking device in line with the gravity to more secure the safety pins when in the towing procedure operation. The next improvement is file all the steel edges into the curve shape to avoid any injuries when during the maintenance. Lastly, the suggestion for this future research are ensure the hole of the pilot tire slightly away from the main frame structure to allows the 360-degree rotation of the pilot tyre to improvise the mobility the RCAT.

5.3.1.3 Software & Programming

The improvement of software and programming aspect could be adding a camera infornt of the RCAT which the ground personnel can monitor it from the digital screen on the remote control. Next, in future our project could have a distance sensor on every edge of RCAT. So when the RCAT is very close the aircraft body, the ground personnel will be aware before any unwanted accident can be happened. Lastly, The beacon light and LED light can be automatically control and turn on from the remote control not as manual switch.

5.3.1.4 Accessories & Finishing

Regarding the accessories, firstly we plan to improve the beacon light from manually operated to automatic. This is to ease up the operator’s job and also to revolutionize our product with modern technology. Besides that, a pair of cooling fans are to be added to the sidewalls. This is to ensure to improve the efficiency of the DC motor and to ensure that the DC motor from overheats and burnt out. Furthermore, a 360 camera is to be added on the hood of the main frame structure, this is to improvise the vision of the operator and also to provide aid in situational awareness.

Figure 5.1: Camera (google, n.d.)

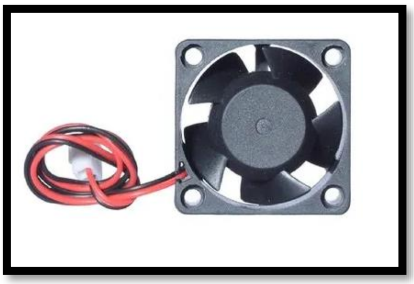


Figure 5.2: Fan (google, n.d.)

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APPENDIX A: DECLARATION OF TASK SEGREGATION

SUB-CHAPTER	DESCRIPTION
AHMAD HAFIZ DANIEL BIN AHMAD HAFIZUL	
1.3.2.1	Specific Individual Project Objectives: Product Structure
1.5.2.1	Specific Individual Scopes: Product Structure
2.2.1	Specific Literature Review: Product Structure
2.3.1	Review Related Patented Product
2.3.1.1	Aircraft Power Dolley
2.3.1.2	Towbarless Airplane Tug
2.3.1.3	Plane Tractor
3.3.2.1	Specific Project Design Flow / Framework: Product Structure
3.5.1	General Product Drawing
3.5.2.1	Specific Part Drawing / Diagram: Product Structure
3.7.1	Material Acquisition
3.7.2	Machines and Tools
3.7.3.1	Specific Project Fabrication: Phase 1 (Base Structure)
4.1.2.1	Specific Part Features: Product Structure
4.1.4.1	Operation of the Specific Part of the Product: Product Structure
4.3.1	Analysis of Problem Encountered & Solutions: Product Structure
5.1.2.1	Specific Achievement of Project Objectives: Product Structure
5.3.1	Improvement & Suggestions for Future Research: Product Structure

MUHAMMAD HAZIQ HAZIRUL BIN MOHSIN	
1.3.2.2	Specific Individual Project Objectives: Product Mechanism
1.4	Purpose of Product
1.5.2.2	Specific Individual Scopes: Product Mechanism
2.2.2	Specific Literature Review: Product Mechanism
2.3.2	Review Recent Market Product
2.3.2.1	SMARTug Remote Control Aircraft Tug
2.3.2.2	TOWFLEXX – ELECTRIC TOWBARLESS AIRCRAFT TUGS
2.3.2.3	MOTOTOK
3.3.1	Overall Project Flow Chart
3.3.2.2	Specific Project Design Flow / Framework: Product Mechanism
3.4	List of Material & Expenditures
3.5.2.2	Specific Part Drawing / Diagram: Product Mechanism
3.7.3.2	Specific Project Fabrication: Phase 2 (Product Mechanism
4.1.2.1	Specific Part Features: Product Mechanism
4.1.4.2	Operation of the Specific Part of the Product: Product Mechanism
4.3.2	Analysis of Problem Encountered & Solutions: Product Mechanism
5.1.2.2	Specific Achievement of Project Objectives: Product Mechanism
5.3.2	Improvement & Suggestions for Future Research: Product Structure
AHMAD SHOFI KUMAENI BIN ABDUL MUNIF	
1.3.2.3	Specific Individual Project Objectives: Software / Programming
1.5.1	General Project Scope
1.5.2.3	Specific Individual Scopes: Software & Programming
2.2.3	Specific Literature Review: Software / Programming
2.4	Comparison Between Recent Research And Current Project
3.2	Overall Gantt Chart
3.3.2.3	Specific Project Design Flow / Framework: Software / Programming
3.5.2.3	Specific Part Drawing / Diagram: Software / Programming
3.7.3.3	Specific Project Fabrication: Phase 3 (Programming & Electrical Circuit)
3.7.4	Product Testing
4.1.2.3	Specific Part Features: Software / Programming

4.1.4.3	Operation of the Specific Part of the Product: Software / Programming
4.3.3	Analysis of Problem Encountered & Solutions: Software / Programming
5.1.1	General Achievements of the Project
5.1.2.3	Specific Achievement of Project Objectives: Software / Programming
5.3.3	Improvement & Suggestions for Future Research: Software / Programming
THIVENESH KUMAR A/L SIVA KUMAR	
1.1	Background Study
1.2	Problem Statement
1.3.1	General Product Objective
1.3.2.4	Specific Individual Project Objectives: Accessories & Finishing
1.5.2.4	Specific Individual Scopes: Accessories &Finishing
2.1	General Literature Review
2.2.4	Specific Literature Review: Accessories & Finishing
3.1.1	Utilisation of Polytechnic's Facilities
3.3.2.4	Specific Project Design Flow / Framework: Accessories & Finishing
3.7.3.4	Specific Project Fabrication: Phase 4 Finishing
4.1.1	General Product Features & Functionalities
4.1.2.4	Specific Part Features: Accessories & Finishing
4.1.4.4	Operation of the Specific Part of the Product: Accessories & Finishing
4.3.4	Analysis of Problem Encountered & Solutions: Accessories & Finishing
5.1.2.4	Specific Achievement of Project Objectives: Accessories & Finishing
5.2	Contribution or Impact Of The Project
5.3.4	Improvement & Suggestions for Future Research: Accessories & Finishing

APPENDIX B: TURNITIN SIMILARITY REPORT

RCAT DRAFT THEISIS

ORIGINALITY REPORT

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APPENDIX C: CARBONLESS TAXIING ELECTRICAL METHODE

green SKY

1

CARBONLESS TAXIING

A new aircraft towing system which uses electric tow dollies and an underground monorail could save airports and MRO companies a huge amount of fuel, emissions and time

Fixing the inefficiencies of aircraft taxiing at airports could result in a significant reduction in fuel usage and carbon dioxide emissions.

That was the driving force behind the development of a new ground vehicle technology system which reimagines how aircraft are moved around airports and MRO facilities, created by Oklahoma City-based Aircraft Towing Systems World Wide (ATS).

After a pilot lands at the airport, the aviator taxis and drives onto ATS' aircraft towing system. Once the aircraft's nose wheel is secured onto the ATS dolly, the pilot simply shuts off the main engines. Then, in a pre-engineered pattern, the fully automatic and electric powered pull cart/tow dolly automatically tows the aircraft from the runway to the gates and back, riding on a monorail in a below-ground channel.

"When you shut down the engines you start saving fuel, emissions and noise, increase engine and component life, and there's less stress on the airplane by towing," says ATS World Wide's CEO Vince Howie. "It's also a much safer system as we know exactly where the aircraft is going to be, which gate it's going to and we know the clearances, so it should help radically reduce collisions."

The ATS system is modular and can be installed in a variety of ways: as a pushback system at gates, as a point-to-point system – which could benefit MRO facilities – or as a fully configured airport system. A prototype is already in place at Ardmore Airpark in Oklahoma. "We're testing now, but it's in the ground and it works," says Howie. "Our goal is to have a public unveiling in September."

It can take up to 16 people to move an aircraft – with this system, they could do it with one person

ATS is currently in discussions with airports in the US and around the world. "We've mainly targeted the hubs, because that's where the biggest payback comes – when you have a tremendous amount of movement," says Howie. "But a lot of small airports are interested in the pushback aspect of it."

From an MRO perspective, an ATS point-to-point system could be installed between and in various hangars where aircraft are being serviced.

The system is ideal for moving aircraft in tight spaces such as hangars that require several personnel to check for wing tip clearances. The path of the aircraft is predetermined and cannot be deviated from.

Howie says that ATS has had discussions with American Airlines, with the company potentially installing a system at its Tulsa, Oklahoma maintenance facilities.

"When aircraft come in on a regular flight, then American Airlines sometimes performs opportunistic maintenance on them overnight. It can take up to 16 people sometimes to move an aircraft a mile and a quarter to a maintenance bay, they told us," says Howie. "With this system, they could do it with one person. Anyone that has a moving line concept, you can put a system in."

The prototype at Ardmore will prove out both the pushback to the gate and point-to-point ferry systems, with both ready for market "right now", according to Howie. And should a company such as American Airlines – which performs maintenance at 31 different airports around the world – end up installing the ATS system at all its facilities, then the opportunities for fuel saving and emissions reduction are immense.

"The main challenge now is getting people used to the idea, and getting some systems installed," says Howie.

2

1. ATS' aircraft towing system uses tow dollies and underground rails
2. A closer look at the pull cart

APPENDIX D: RESEACH PAPER ABOUT SELF-DRIVING AIRCRAFT TOWING VEHICLES

Artificial Intelligence for Transportation: Advice, Interactivity and Actor Modeling: Papers from the 2015 AAAI Workshop

Self-Driving Aircraft Towing Vehicles: A Preliminary Report

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Abstract

We introduce an application of self-driving vehicle technology to the problem of towing aircraft at busy airports from gate to runway and runway to gate. Autonomous towing can be supervised by human ramp- or ATC controllers, pilots, or ground crew. The controllers provide route information to the tugs, assisted by an automated route planning system. The planning system and tower and ground controllers work in conjunction with the tugs to make tactical decisions during operations to ensure safe and effective taxiing in a highly dynamic environment. We argue here for the potential for significantly reducing fuel emissions, fuel costs, and community noise, while addressing the added complexity of air terminal operations by increasing efficiency and reducing human workload. This paper describes work-in-progress for developing concepts and capabilities for *autonomous engines-off taxiing* using towing vehicles.

Introduction

Congestion at airports is recognized as one of the most prominent problem areas in the international airspace. Airports are expected to address this problem through expansion of their airfields. However, the addition of runways and taxiways will increase the complexity of air terminals, which will penalize the efficiency of the system by adding to human workload, thus restricting the potential benefits of the surface expansion. The increased complexity will also increase the risk of human error, resulting in potentially hazardous situations. In addition, the increasing number of taxiing aircraft will contribute significantly to an increase in fuel burn and emissions. The quantities of fuel burned as well as different pollutants, such as carbon dioxide, hydrocarbons, nitrogen oxides, sulfur oxides and particulate matter, increase with aircraft taxi duration, and also vary with throttle setting, number of running engines, and pilot and airline decisions regarding engine shutdown during delays.

The economic pressures and increasing environmental awareness have recently fostered the development of new taxi operation technologies and procedures. The contribu-

APPENDIX E: NEWS ABOUT AIRCRAFT TOWING ACCIDENT AIR INDIA 2006

Pics: K K Choudhary

PILOTS DIDN'T WAIT FOR THUMBS UP SIGN FROM ENGINEER?

The wife and son (centre) of engineer Ravi Subramanium (inset) on Thursday

Avoidable Tragedy

Aircraft | A319, VT-SCQ

Flight | AI 619 Mumbai-Hyderabad, was scheduled to depart at 7.30pm

Action Against Pilots | Both pilots have been grounded

Compensation | AI chairman announced an ex-gratia payment of ₹5 lakh to the technician's kin. A family member will be given a job in the airline

The Deceased

Ravi Subramanium (52) was a service engineer (technician) with Air India and lived in Sanpada

He is survived by his parents, wife and 20-year-old son

Procedure for Pilots, Engineers, Technicians

- The technicians and pilots communicate with each other over a headset. The headset socket is located under the aircraft nose. The headset has a long cord which allows for ground personnel's movement on the tarmac
- After the aircraft has been readied for departure, the engineer informs the pilots. "Ok, bye, Capt. Signal from the right/ left". Engineer unplugs the headset and starts walking towards the right or left from the aircraft nose, as indicated, with his back facing the pilots. He walks till he is at a safe distance beyond the wing clearance of the aircraft. He then turns back, faces the pilots and signals with a thumbs up. The pilots wait for this thumbs up, reciprocate and then rev up the engines. The pilot never revs up engines before the service engineer gives the thumbs up sign

Previous Incidents

2006 An Air India 747 taxied out from London's Heathrow airport even as the ground engineer was still near the aircraft. He lay on the ground and was saved as he happened to be in between the two engines of the jumbo jet

1995 A person was crossing the Hyderabad runway on his moped when an aircraft landed and he got sucked in

1980 Engines of a Boeing 737-200 operated by Indian Airlines were revved up on the tarmac of Palam, Delhi. An engineer was sucked into the engine. He died two days later

What Could Have Happened?

Since the aircraft's auxiliary power unit was not functional, as per the procedure, using externally attached equipment, the first engine was started when the aircraft was in the bay and the second too was started before the pushback was completed. Once the aircraft was positioned for taxi, the technician's assistant released the tow bar from the aircraft nose and then the tow tractor

Scenario 1

- The technician completed his job, disconnected the headset from its socket, informed co-pilot that he would signal from the right for engine start up and started walking towards the right of the aircraft
- The co-pilot does not confirm that the technician is at a safe distance and misinforms the commander. The commander does not verify it independently
- Neither of them wait for the thumbs-up sign from the technician. The commander starts the engine, which sucks in the technician

Scenario 2

- The technician was near the aircraft nose with headset on, when the co-pilot assumed area near aircraft was clear
- The commander relied on the co-pilot's word and did not confirm it himself, as is required. He revved up the engines. The aircraft surged ahead and sucked in the technician. His assistant collapsed to the ground and held on to the nose wheel to save himself from being pulled into the engine

APPENDIX F: ARTICLE OF AIRCRAFT GROUND DAMAGE PREVENTION.

APPENDIX G: ARTICLE FROM AIRFORCE ABOUT REMOTE CONTROL AIRCRAFT TUG

AIR FORCE

Robins AFB remote control aircraft tug creates safer work environment

Published Dec. 5, 2021

By Joseph Mather

Robins Public Affairs

ROBINS AIR FORCE BASE, Ga. (AFNS) -- Remote controlled tugs are being used to move **F-15 Eagles** around the flight line and through hangars at **Robins Air Force Base**.

F-15 aircraft maintenance workers with the **Warner Robins Air Logistics Complex** (WR-ALC) have 10 TowFLEXX 5.4 (TF-5), low profile aircraft tugs to move the aircraft around hangars where traditional tugs can't maneuver.

Carl Motter Jr., 402nd Aircraft Maintenance Group (AMXG) TowFLEXX program manager, said they researched new technology that could turn an F-15 aircraft in a 65-foot circle inside the high bay area of

APPENDIX H: ARTICLE ABOUT AIRCRAFT LANDING GEAR SYSTEM SAFETY DEVICES

Aircraft Landing Gear System Safety Devices

There are numerous landing gear safety devices. The most common are those that prevent the gear from retracting or collapsing while on the ground. Gear indicators are another safety device. They are used to communicate to the pilot the position status of each individual landing gear at any time.

Landing Gear Safety Switch

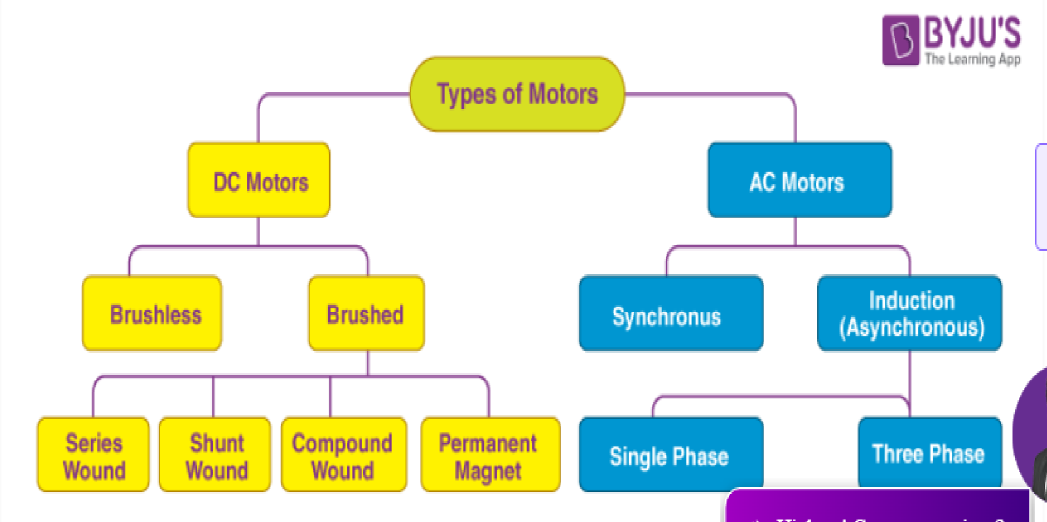
A landing gear squat switch, or safety switch, is found on most aircraft. This is a switch positioned to open and close depending on the extension or compression of the main landing gear strut. [Figure 1] The squat switch is wired into any number of system

APPENDIX I: TYPE OF AC AND DC MOTOR

We know there are generally two types of motors, AC motor, and DC motor. AC motors are flexible for speed control and demand low power during start. On the other hand, DC motors are widely used due to its initial cost of low power units is less compared to AC and can be easily installed.

Types of AC and DC motors are listed below:

- Synchronous
- Asynchronous(Induction)
- Brushed
- Brushless



Hi there! Got any questions? I can help you...

Synchronous Motors

In this kind of motors, the speed remains constant with varying loads and the supply current frequency is synchronized with rotor rotation. That is why this motor