Final Year Project Thesis: Autorotation Voice Cueing System

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Abstract

Autorotation is a difficult manoeuvre for helicopter pilots to perform. Pilots are trained through simulation and flight to perform the manoeuvre and practice when they can. However, there have been cases of failure of the autorotation manoeuvre discussed in section 1.1.1, some of which are due to a mishap in the manoeuvre, such as flaring at the wrong height.

Since failure of the manoeuvre can lead to death or injury, the project was to create an autorotation voice cueing system that would assist pilots in completing autorotation through voice cues. The motivation for this was the reports of pilots crashing while trying to execute this manoeuvre, reports of this have been discussed in section 2.

Research was conducted to find a possible solution and gain more knowledge on helicopter aerodynamics and controls, autorotation, flight instruments and more. The methodology can be found in section 8.

The result of this project was a theoretical solution to autorotation using a voice cueing system to assist pilots in performing autorotation, which is found in section 10. Unfortunately, the Arduino prototype was not completed due to personal circumstances affecting the project schedule.
However, the system could go further in its development, for example, by creating a prototype and improving with each study of a pilot using the prototype system, this could lead to the creation of a system that is used in helicopters as part of the emergency procedure, to ensure the safety of the pilot and others on board, as well as no damaged to the helicopter through the process.

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Abbreviations

AAIU	The Air Accident Investigation Unit Ireland
AAIB	Air Accidents Investigation Branch
MCU	Microcontroller unit
Mph	Meters per hour
RPM	Revolutions per Minute
RRPM	Rotor revolution per minute
FAA	Federal Aviation Administration
HSWA	Health & Safety at Work
HUD	Heads-up display
KIAS	Knots - indicated airspeed
Knots	Nautical miles per hour

1. Introduction

When a helicopter's engine fails during flight, the pilot must perform the autorotation manoeuvre. This is a critical manoeuvre where, if it is not executed properly, it could result in a life-threatening condition for the pilot and possible members of the helicopter.

1.1 Autorotation

1.1.1 Autorotation due to engine failure

During flight, when a helicopter engine fails, Ryan Dale (2024) states, 'the freewheel unit will cut the connection between the engine and its main and tail rotors; the freewheel unit will then allow them to continue spinning, relying on the aerodynamic forces as the helicopter descends'. The pilot will execute the autorotation manoeuvre to ensure a safe landing. However, this is not always the case, as errors are present in the procedure.

Despite pilots being trained through simulations and live training, errors do occur. Some errors SKYbrary (2024) mentioned 'pilots flaring at the wrong height, pilots flaring too aggressively or not enough force used when flaring and finally, pilot failing to maintain the rotor revolution per minute (RRPM) during descent within the limits helicopter flight manual', these errors can turn what's meant to be a safe autorotation into a dangerous autorotation landing, so it is crucial for pilots to be prepared and able to execute this manoeuvre.

1.1.2 Other Failures Leading to Autorotation

A failure within the tail rotor will result in the pilot needing to execute the autorotation manoeuvre; SKYbrary (2024) states, 'with tail rotor failure, the helicopter loses its ability to control the torque so the helicopter fuselage will spin'. A pilot would have to perform the autorotation manoeuvre, shutting off engine power to perform the autorotation manoeuvre.

2. Helicopter Autorotation Crashes

2.1 Eurocopter EC135 T2, G-IWRC Helicopter Accident

In September 2007, the Eurocopter EC135 T2, G-IWERC entered into autorotation; however, the pilot misread the sound from the helicopter and the reading on the tachometer gauge; because of this sound, he believed he was experiencing engine failure. The Air Accident Investigation Branch AAIV (2014) reported, ‘the pilot was able to manoeuvre through the autorotation procedure correctly. However, he flared at the wrong time, causing the helicopter to crash’.

2.2 Schweizer 269C-1 Helicopter Accident

On 8 September 2007, the Schweizer 269C-1 helicopter entered autorotation due to engine failure; it crashed in Medford, New Jersey. The Aviation Safety Network (2018) stated that ‘the early entry into autorotation and failure to manage the rotor RPM resulted in an uncontrolled descent’.

2.3 Schweizer 300 G-BWAV Helicopter Accident

In June 2014, the Schweizer 300 + G-BWAV Helicopter crashed as the pilot failed to practice autorotation. The AAIB (2014) reported that ‘the pilot failed to achieve needle split before practising the manoeuvre, the pilot realised his mistake however, the pilot could not gain control since the engine RPM was below the normal operating range’. This led to the helicopter being destroyed, but the pilot survived.

2.4 Bell 505 Jet Ranger X Helicopter Accident

On 31 July 2024, a student was practising the autorotation manoeuvre along with their instructor. Unfortunately, the helicopter crashed, ending the lives of both the student and the instructor. The Air Accident Investigation Unit Ireland (AAIU) (2024) reports so far, ‘the accident had occurred around the sixth autorotation manoeuvre’. This suggests there may have been a problem with manoeuvring.

2.5 UH-1H T/N 69-6666 Accident

The Air Force Global Strike Command Public Affairs (2024) released a report stating the ‘failure was due to the pilots mismanaging the helicopter controls while entering a practice 180-degree autorotation causing excessive right banking and nose low attitude; another problem was the crew's failure to recognise the need for power recovery’. The crash resulted in the crew members leaving with no serious injuries; however, the helicopter was damaged, costing them about five million dollars.

3. Helicopter Background:

3.1 Helicopter lift generation

The lift of a helicopter is generated through the rotation of the main rotor blades. Aeronautics Guide (no date) states, ‘the transmission system transfers power from the engine to the main rotor’, allowing the blades to spin at high speeds to generate enough lift to pull the helicopter upwards. Figure 3.1.1 shows an example of the transmission system.

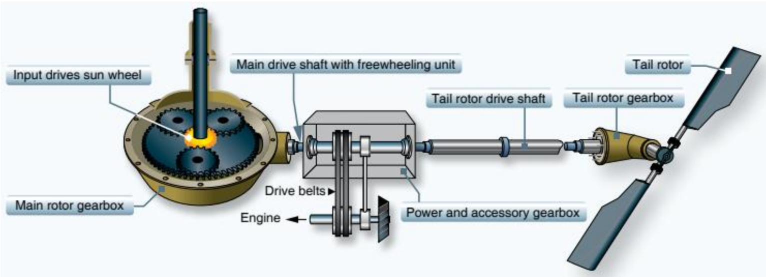

Figure 3.1. 1 - Diagram of The Transmission System by Federal Aviation Administration (2019)

As the main rotor blades rotate, the velocity of the air over the top surface of the blade is higher than the velocity on the bottom surface of the blade, NASA (2014) mentions ‘Bernoulli’s Principle is when there is an increase in velocity, there is a decrease in pressure, and because of this the pressure of the air moving above the blade is lower than the air moving below the blade it creates a suction that causes the helicopter to move upwards, resulting in the creation of lift’. This relationship between Bernoulli’s Principle and lift explains how lift is generated. There is also Newton's Third Law of Motion, which the FAA (2022) states, ‘the air striking the bottom side of the blade is deflected downwards, this creates an upwards reaction. Newton’s Third Law of Motion is that for every action, there is an equal and opposite reaction.’ Both these principles work together to generate lift for the helicopter. Figure 3.1.2 shows the airflow surrounding the aerofoil.

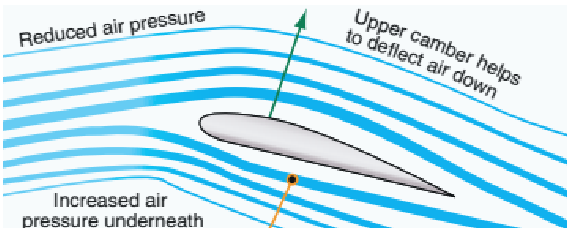

Figure 3.1. 2 - Airflow Around the Aerofoil by The Federal Aviation Administration (2022)

3.2 Helicopter lift control

The pilot can control the amount of lift generated by raising or lowering the collective lever to either increase or decrease the amount of lift produced, allowing the helicopter to climb or descend. R. Randall Padfield (1992) stated, ‘The collective pitch control is used to simultaneously change the pitch of all main rotor blades, thereby increasing or decreasing total lift or thrust’. For example, when the collective lever is raised, the pitching arm shown in Figure 3.2.1 will raise the rotor blade, and the angle of attack will then increase, allowing for more lift to be produced and the helicopter to rise. When the lever is lowered, the pitching arm will lower the angle of attack, decreasing the amount of lift produced, and the helicopter will descend.

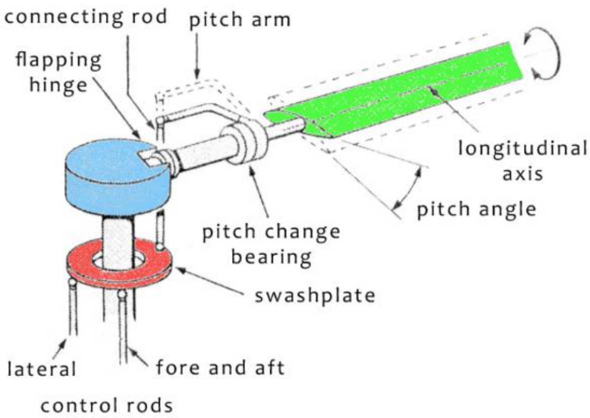

Figure 3.2. 1 - Main Rotor Collective Pitch by Redback Aviation (2017)

3.3 Helicopter direction control

To control the cyclic pitch of the helicopter's main rotor, the pilot will use the cyclic stick to move forward, backwards, and side to side along its horizontal axis. Tilting the cyclic stick in either direction will change the pitch angle on the rotor blades, increasing lift on the side tilted up of the main rotor and allowing the helicopter to move in that direction. Walter J. Wagtendonk (1996) stated, 'The cyclic control allows the pilot to tilt the rotor disk in any direction, enabling control of the helicopter's movement in the horizontal plane' For example, if the pilot wants to move forward, the pilot would tilts the cyclic stick forward, the rotor disc will tilt forward, changing the pitch angle, and lift will increase on the tilted upward section of the rotor blade, allowing for the helicopter to move forward.

Figure 3.3.1 shows different cyclic pitch controls, having the different positions of the cyclic stick and the corresponding main rotors reaction.

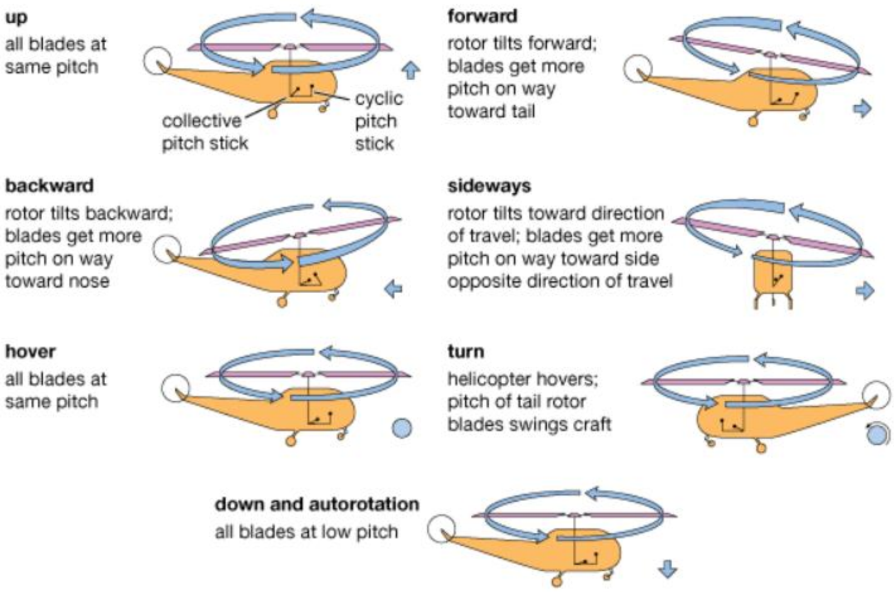

Figure 3.3. 1 - Cyclic Pitch Control Positions by Encyclopaedia Britannica (2011)

3.4 Helicopter Torque Control

To combat the torque caused by the helicopter's main rotor spinning. A rotor was added to the back of the helicopter's tail and is controlled by the antitorque pedal. This helped to keep the helicopter flying straight and to control the yaw of the helicopter. Collier Larry (1986) states, ‘ antitorque pedals are used to control the tail rotor blades' pitch, counteracting the main rotor's torque effect and controlling yaw’.

For example, if the pilot wanted to turn the helicopter to the right, the pilot would press down on the left pedal. This will cause the helicopter's tail to turn to the left, and the nose of the helicopter will turn towards the right, as shown in Figure 3.4.1. Since the helicopter's direction has changed, it continues on that path, useless, and it is changed again by the pilot.

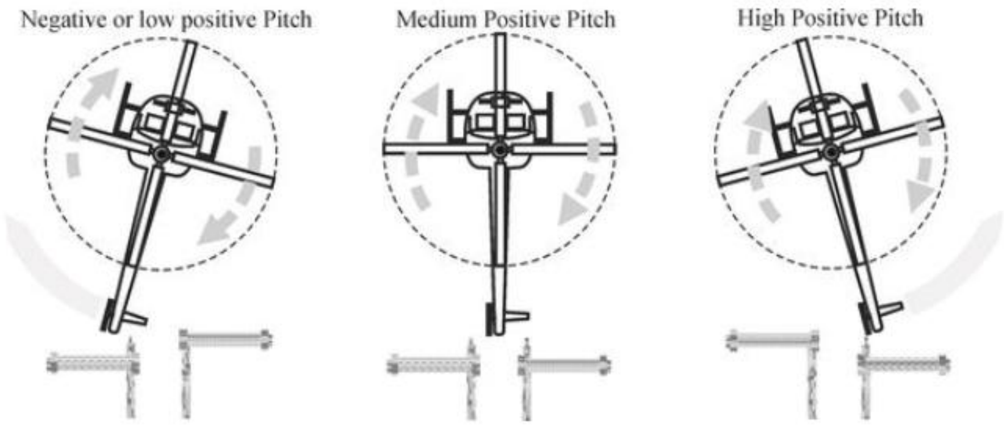

Figure 3.4. 1 - Antitorque Pedals by Rotaru and Michael Todorov (2017)

3.5 Airflow difference in normal flight and autorotation

There is a difference in airflow in normal flight versus autorotation, the figure shows an example of the different airflows.

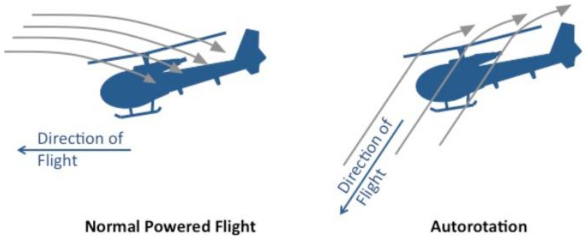

Figure 3.5. 1 - The difference in Airflow in Normal Flight and Autorotation by SKYbrary (no date)

3.5.1 Airflow in normal flight

The airflow in forward flight flows from above as shown in figure 3.5.1, as the blades are rotating, they experience varying airflow velocities from the advancing blade and retreating blade, causing more lift to be produced by the advancing blade than the retreating blade. The FAA (2022) stated, 'the relative wind from the advancing blades will increase because of the forward speed of the helicopter than the retreating blade, as the forward speed reduces the speed for the retreating blade, resulting in the advancing blade producing more lift' and an imbalance in the lift. Figure 3.5.1.1 shows a description of this.

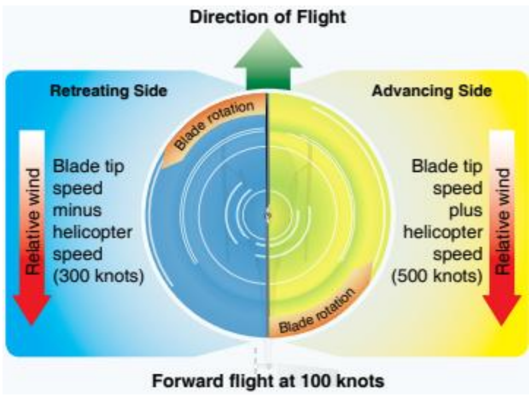

Figure 3.5.1. 1 - Dissymmetry of Lift by FAA (2022)

If this continues, it will cause the helicopter to roll and eventually stall, the FAA (2022) mentions that 'pilots will use blade flapping to manage the dissymmetry of lift' the advancing blade will flap up to reduce the angle of attack and lift and the retreating blade flaps down to increase the angle of attack and lift.

3.5.2 Airflow in autorotation

The airflow in autorotation flows upwards through the blades as shown in Figure…, since the helicopter's engine is disengaged, the continuing rotation of the blades will rely on the upward flow of air as the helicopter is descending. Figure 3.5.2.1 shows the main rotor disc in three regions during autorotation, these regions are the driven region, driving region and stall region.

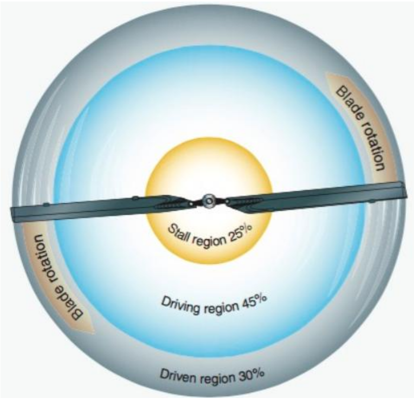

Figure 3.5.2. 1 - Three Regions of The Rotor Disc During Autorotation by Nashville CFI (no date)

- Driven region

It is about 30% of the rotor blade from the tip, Ryan Dale (2024) states, ‘creates some lift, however, a large amount of drag force that will slow down the rotor rotation’.

- Driving region

It is about 45% of the blade between the driven and stall regions, Ryan Dale (2024) states, ‘generates forces that will increase the rotor rotation’, which will keep the blades turning during autorotation.

- Stall region

It is about 25% of the blade beginning at the hub, Ryan Dale (2024) states, ‘operates above the angle of attack, causing drag, this will slow down the blade’.

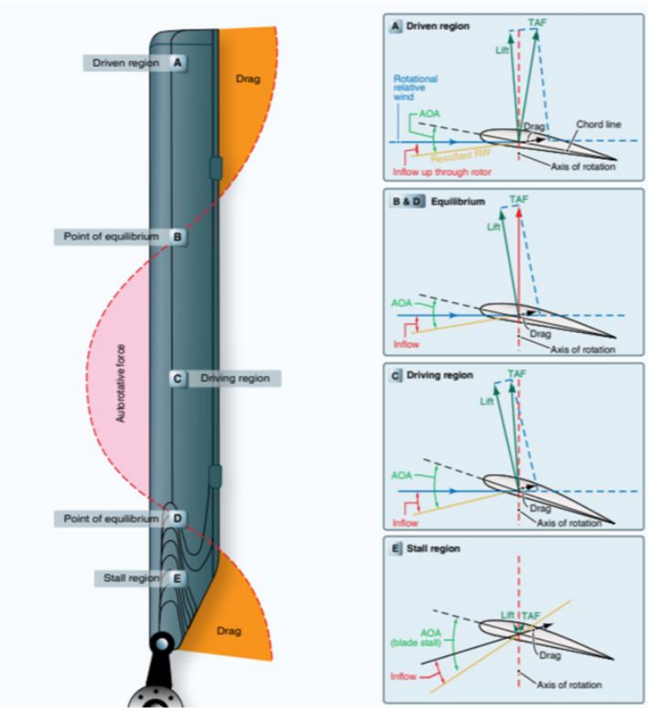

Figure 3.5.2. 2 - The Force Vectors in Autorotation by Helicopter Pilot Logic (no date)

3.6 Autorotation Phases

Markus Mauksch (2015) states, ‘there are 4 phases in autorotation, such as the entry phase, glide, flare and landing phase’. Figure 3.6.1 shows the phases of autorotation

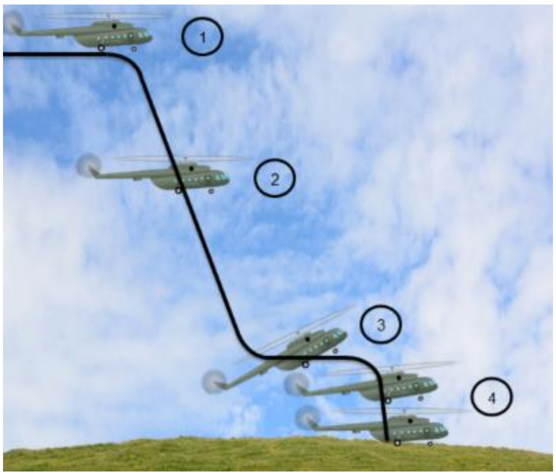

Figure 3.6. 1 - Phase of Autorotation
by Markus Mauksch (2015)

1. Entry Phase

Once engine failure happens, and the pilot must lower the collective lever. Markus Mauksch (2015) states this is done ‘to reduce the air resistance of the rotor to stop the loss of RPM, the anti-torque pedals must be used to keep the nose straight and the cyclic stick pulled back to increase the airflow through the main rotor and recover the lost RPM’. The entry phase is important as this is the beginning phase of possibly having a successful autorotation landing.

2. Glide Phase

A steady glide needs to be maintained in the second phase, which is also known as the descent phase, this is done through, as Markus Mauksch (2015) stated, ‘maintaining rotor RPM to produce enough lift, airspeed by keeping to the manufactures recommended speed for decent and in this phase a suitable landing field must be chosen for a safe touchdown’.

3. Flare Phase

Following the manufacturer recommended flare height the pilot must pull back the cyclic to flare. Markus Mauksch (2015) stated this is done to ‘reduce the sink rate and increase rotor RPM’.

4. Landing phase

Before the helicopter touched the ground, Markus Mauksch (2015) stated, ‘the collective lever must be raised to increase the lift to cushion the impact of the helicopter with the ground’.

3.7 Helicopter Instruments

For navigation and to help guide the flight, the helicopter has six instruments, which are as IVAO (no date) states, ‘the airspeed indicator, attitude indicator, altimeter, turn coordinator, heading indicator and vertical speed indicator’, that are shown in figure… below. Figure.. shows an example of the Robinsons R22.

Figure 3.7. 1 – Robinson R22 Instrument Panel by National Air and Space Museum (no date)

The function of these instruments:

- Altimeter

The altimeter, as shown in figure 3.7.2, it is to as Helicopter Aviation (no date) states ‘display the height above sea level based on the barometric pressure’.

Figure 3.7. 2 – Altimeter by National Air and Space Museum (no date)

- Vertical Speed Indicator

The vertical speed indicator, as shown in figure 3.7.3, it is to display to the pilot the helicopter's rate of climb and descent. Helicopter Aviation (no date) states, ‘The marks above zero represent the climb rate, 100 feet per minute, and the mark below zero represent the descent rate, 100 feet per minute’.

Figure 3.7. 3 – Vertical Speed Indicator by National Air and Space Museum (no date)

- Attitude Indicator

The attitude Indicator, as shown in figure 3.7.4, it is to as Mid Continent states, ‘to show the aircraft's relation to the horizon’.

Figure 3.7. 4 – Attitude Indicator by National Air and Space Museum (no date)

- Airspeed Indicator

The airspeed indicator, as shown in figure 3.7.5, it is to display the airspeed. Helicopter Aviation states, ‘the outer scale is measured in knots (nautical miles per hour) and the inner scale is measured in mph (miles per hour)’.

Figure 3.7. 5 – Airspeed Indicator by National Air and Space Museum (no date)

- Dual Tachometer

The Dual Tachometer, as shows in figure 3.7.6, it is to as Helicopter Aviation (no date) states ‘display the engine RPM and the main rotor RPM. Green is normal, yellow is caution and red is prohibited.’ This indicates the range the engine RPM or main rotor RPM should and should not be operating in.

Figure 3.7. 6 – Dual Tachometer by National Air and Space Museum (no date)

- Manifold Pressure

The manifold pressure, as shown in figure 3.7.7, is to as Pilot Institute (2025) states, ‘measures air pressure in the intake manifold of the engine to reflect the engine's power’.

Figure 3.7. 7 Manifold Pressure by National Air and Space Museum (no date)

3.7.1 Helicopter Instruments in autorotation

Not all but a few of the helicopter instruments need to be monitored during autorotation, such as the airspeed indicator, dual tachometer, altimeter and the vertical speed indicator.

- Airspeed Indicator,

To maintain a good glide after entering into autorotation, Robinson (2024) states, ‘to maintain a glide at 65 KIAS’ This is for the R22; if the speed is high, this will increase the rate of descent. If it is too slow, the pilot could lose the rotor RPM.

- Dual Tachometer

Maily, the right side of the tachometer is used to monitor the rotor RPM as the left side of the tachometer is for the engine, and the engine failed in this case. Keep the RPM in green as the pilot will lose lift and control if the RPM is too low.

- Altitude Indicator

Monitor the altitude and help the pilot decide when to flare.

- Vertical Speed Indicator

The pilot needs to know how fast the helicopter is descending.

4. Autorotation Procedure by the Robinson Helicopter Company

The autorotation procedure for the Robinson Model R22 in the R22 Pilot's Handbook by the Robinson Helicopter Company, which gives a look into the manufacturer guide to autorotation with their aircraft shown in figure 4.1, as different helicopters, many have slight differences when completing the autorotation process.

ROBINSON
MODEL R22

SECTION 3
EMERGENCY PROCEDURES

POWER FAILURE ABOVE 500 FEET AGL

1. Lower collective immediately to maintain RPM and enter normal autorotation.
2. Establish a steady glide at approximately 65 KIAS (See "Maximum Glide Distance Configuration", page 3-3).
3. Adjust collective to keep RPM in green arc or apply full down collective if light weight prevents attaining above 97%.
4. Select landing spot and, if altitude permits, maneuver so landing will be into wind.
5. A restart may be attempted at pilot's discretion if sufficient time is available (See "Air Restart Procedure", page 3-3).
6. If unable to restart, turn off unnecessary switches and shut off fuel.
7. At about 40 feet AGL, begin cyclic flare to reduce rate of descent and forward speed.
8. At about 8 feet AGL, apply forward cyclic to level ship and raise collective just before touchdown to cushion landing. Touch down in level attitude with nose straight ahead.

NOTE

If power failure occurs at night, do not turn on landing lights above 1000 feet AGL to preserve battery power.

POWER FAILURE BETWEEN 8 FEET AND 500 FEET AGL

1. Takeoff operation should be conducted per the Height-Velocity Diagram in Section 5.
2. If power failure occurs, lower collective immediately to maintain rotor RPM.
3. Adjust collective to keep RPM in green arc or apply full down collective if light weight prevents attaining above 97%.
4. Maintain airspeed until ground is approached, then begin cyclic flare to reduce rate of descent and forward speed.
5. At about 8 feet AGL, apply forward cyclic to level ship and raise collective just before touchdown to cushion landing. Touch down with skids level and nose straight ahead.

FAA APPROVED: 6 JULY 1995 3-2

Figure 4. 1 Autorotation Emergency Procedure by Robinson Helicopter Company (1995)

5. Project Rationale

An autorotation voice cueing system could be a part of a solution to a safe autorotation landing or power recovery, whether during flight or practice, to avoid a potential crash landing due to a misstep within the process.

5.1 When engine failure happens, the system would

Section 10.2 contains a block diagram, and section 10.3 contains the system cues, how they would work, and what the helicopter would sense and monitor, to better explain how the system would function.

1. Sense and alert the pilot of engine failure

This will make the pilot aware of the situation and help the system guide the pilot in performing the processes through vocal cues.

2. Give vocal cueing to the pilot

These pointers will be done at specific points of the autorotation process to make sure they are on track.

3. Track the rotor RPM

Alert the pilot if the RPM is too high or too low so they can make adjustments to keep the RPM in the green arc and control the descent rate.

4. Track the helicopter's Altitude

For the system to then know when to prompt the pilot the flare as these a prompt for a specific hight.

5. Monitor forward airspeed

To maintain the glide so the helicopter does not descend too fast or slow to keep a good RPM rate. The system will prompt the pilot in stages of glide to keep a good RPM and glide rate.

6. Monitor rate of decent

To know how fast the helicopter is descending and prompt the pilot if the rate is too fast or slow.

6. Aims

To develop an autorotation monitoring system to assess pilots through autorotation, enabling them to land safely or achieve power recovery.

7. Objectives

1. To understand what controls are used in the normal flight and autorotation of the helicopter
2. To understand the helicopter aerodynamics in normal flight and in autorotation
3. To understand what autorotation is and how it is executed by the pilot
4. To understand the causes of autorotation failure
5. Explore autorotation crashes
6. To understand autorotation from a pilot's point of view
7. To design a theoretical autorotation monitoring system

8. Methodology

1. Researched autorotation, to have a better understanding of the process and what leads to autorotation
2. Researched what causes failure in the autorotation process
3. Researched helicopter controls in normal flight and autorotation
4. Researched helicopter aerodynamics in normal and autorotation
5. Researched helicopter lift generation
6. Designed a voice-cueing autorotation monitoring system
7. If possible, develop a microcontroller system to display the voice commands for a visual display of how the system would work

9. Literature Review

9.1 Existing Research in Autorotation Aiding Systems

Since autorotation is a critical manoeuvre to perform, there have been mistakes in successfully performing the manoeuvre, which has led to accidents, with some leaving with injuries and others dead. Can a voice cueing autorotation monitoring system aid a pilot in performing a successful autorotation landing?

Some research has been conducted to develop possible systems to aid a pilot in achieving autorotation successfully. However, the studies found are focused on visual cueing systems for autorotation.

9.1.1 Time-To-Contact Autorotation Cueing System

The Time-To-Contact Autorotation Cueing System was conducted at the University of Liverpool in collaboration with Georgia Tech by Michael Jump, Mushfiqul Alam, Jonathan Rogers and Brain Eberle.
The Authors (2020) stated the focus of this research was to 'develop a head-up display to aid pilots in time and magnitude of longitudinal cyclic and collective inputs during the autorotation manoeuvre'. They developed a visual cueing system to improve the pilot's situational awareness during autorotation and allow them to land safely in autorotation.

9.1.1.1 Key features of the research

- Predictions

The system can calculate the time before ground contact based on flight parameters such as the descent rate, airspeed, rotor RPM, and pitch attitude.

- Pilot Cueing

It gives the pilot a head-up display (HUD) cues to help the pilot glide and flare timing to reduce the risk of a hard landing.

- Simulation & Testing

The university flight simulator allowed the researchers to refine the algorithm and assess the pilot's responses to the visual cues.

- Enhancement in Safety

The HUD aims to improve the pilot's decision-making and reduce errors in high-stress emergency situations.

Although the Time-To-Contact Autorotation Cueing System is a visual cueing using a head-up display autorotation system and the autorotation system for this paper is a voice cueing system, they both would work to cue the pilot into making a safe autorotation landing.

9.2 Current Working Systems

9.1.1 Skyrise – Fully Automated Autorotation

Skyryse has developed an automated autorotation while still allowing the pilot to remain in control; Skyryse (no date) stated, 'Skyryse One will recognise a power failure and automatically enter autorotation, the glide, flare and touchdown. They developed this system to enhance the safety of autorotation and reduce the workload placed on the pilot, as Skyryse (no date) noticed. 'if the pilot is slow in reaction during descent or reducing the collective, it can lead to an accident or mishap', they wanted to ensure that all parts of the autorotation process where covered so there is no misstep.

This is a great development for a helicopter as pilots can rely on the automated system while still having control of the helicopter; Aviation International News (2023) reported 'Skyryse achieved the first automated autorotation landing 22 July 2023'. This is a massive achievement performed by Skyryse as this shows their system can aid in the safe autorotation landing while reducing the workload for the pilot.

Skyrise can be found at https://www.skyryse.com/resources/what-is-helicopter-autorotation-and-how-does-skyryse-automate-it

10. Deliverables

10.1 The outcome

With limited resources, such as not having access to a helicopter, their systems or access and knowledge to program this in a helicopter simulation. The outcome was designing a theoretical autorotation voice cueing system that uses voice cues.

There was an idea to program this system using microcontroller systems, however, due to personal circumstances, lessening the time to create the microcontroller system using the Arduino representing the function of the system, the coding was started, however due to the problems this idea had to be abandoned, as there was not much time left to the due date. Only a theoretical design was created.

Section 10.2 contains a block diagram, and section 10.3 contains the system cues, how they would work, and what the helicopter would sense and monitor. To better explain how the system would function.

10.2 Block diagram of how the system operates

This is a simple block diagram of what the system would do, with an example.

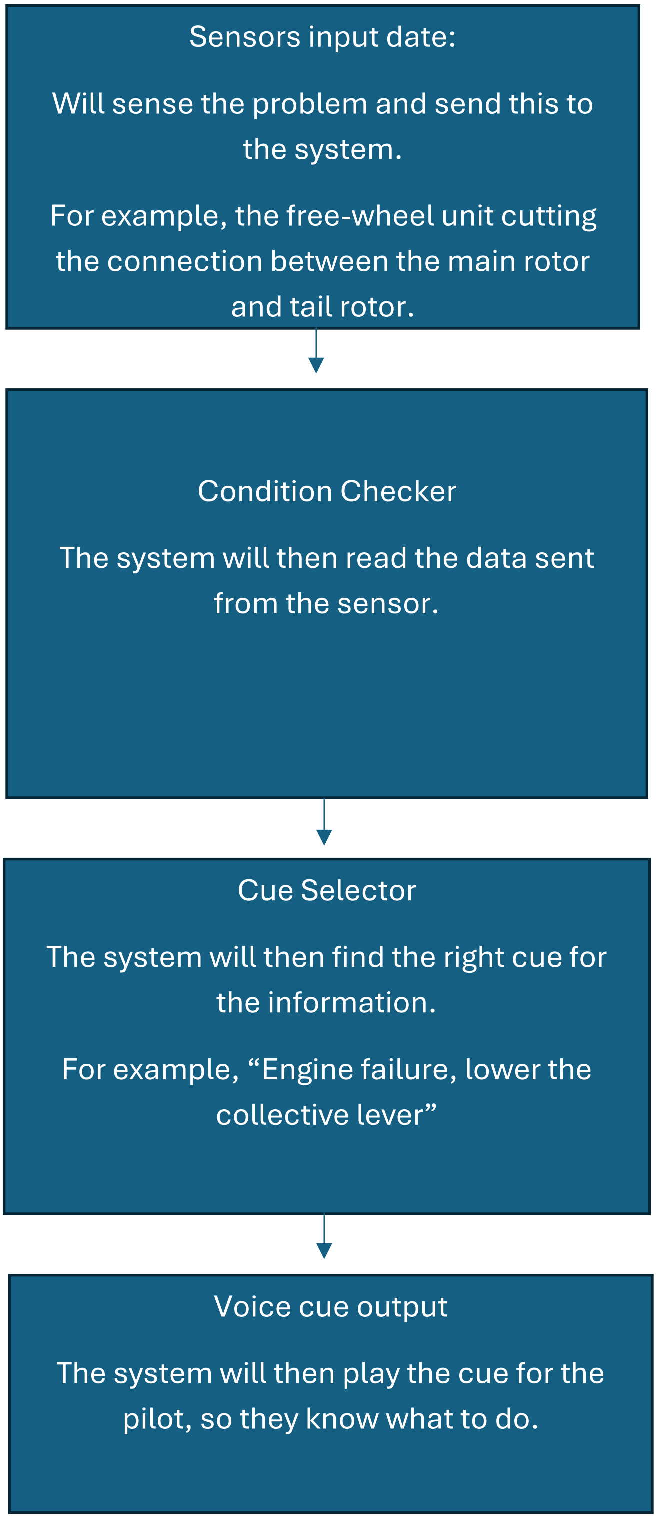

Diagram 10.2. 1 Block Diagram of Autorotation Voice Cueing System

10.3 The system's vocal cues and how it functions

1. “Engine failure, lower the collective lever”

This voice cue is so the pilot knows there is an engine failure, and to lower the collective lever, then this voice cue will play once.

- Free-wheel unit sensor

This sensor will sense the cut between the engine and the rotors, and then the voice cue will play so that the pilot is aware of the situation and can act.

For autorotation, the pilot needs to lower the collective as soon as possible, to avoid any mishap during the entry phase that will affect the entire process.

2. “At an airspeed of 65 - 70 KIAS, push the cyclic stick forward to enter into a steady glide”

This voice cue is so the pilot knows once the airspeed is between 65 – 70 KIAS to push the cyclic stick then forward to have a smooth entry into glide.

- Airspeed indicator sensor

This sensor is to sense the increasing airspeed, once the airspeed reaches 60 KIAS, it will start the voice cue to give the pilot enough time to act on entering the glide.

3. “Lower collective lever to maintain RPM” or “raise collective lever to maintain RPM”

This voice cue will only play to manage the rotor RPM. If the rotor RPM is too high, it can cause the pilot to lose control of the helicopter, and if it is too low, it will cause the helicopter’s blades to lose lift.

- Tachometer rotor RPM sensor

This sensor will be used to monitor the RPM. The appropriate cue will play once the RPM is above or below the green arc.

4. “nose down” or “nose up”

This voice cue is to control airspeed. Nose down increases the airspeed while nose up decreases the airspeed, controlling this will help to manage the descent rate.

- Airspeed indicator sensor and Vertical speed indicator sensor

These two sensors will work together to signal to the pilot if the airspeed and descent are too high or low, and then will send the appropriate cue to play, and the pilot will make the adjustments.

5. "Look out for a landing spot"

This voice cue is so the pilot looks for a good landing spot, so they do not have a hard touchdown, making sure there is nothing that can latch onto the tail rotor or uneven ground that could flip the helicopter.

- Altimeter sensor

Once the helicopter reaches between 100 and 300 feet, it will play the cue.
The pilot may have already found a landing spot, which is fine; this cue could make them double-check for another spot in case the first choice has a problem.

6. "At 40 feet, pull the cyclic stick back for flare"

This cue is so the pilot will flare at 40 feet.

- Altimeter sensor

This sensor at 50 feet will play the cue to give the pilot enough time to act at 40 feet.

- Attitude indicator

Pilots themselves will need to look at the attitude indicator reading to make sure they are in line with the horizon, another cue added for the flare phase can possibly cause a problem with the other cues.

7. "At 8 feet, push the cyclic stick forward, and ensure you are level with the horizon on the attitude for touchdown."

This cue is so that at 8 feet, the pilot will push the cyclic forward for landing.

- Altitude

At 18 feet, the cue will play to give the pilot enough time act for a smooth as can be landing.

- Airspeed indicator and Vertical speed indicator sensors

These two sensors will work together to signal to the pilot if the airspeed and descent are too high or low, and then will send the appropriate cue to play, and the pilot will make the adjustments, “nose up” or “nose down”

- Attitude indicator

Pilots will need to look at the attitude indicator reading to ensure they are in line with the horizon, as shown in Figure 10.3.1.

Figure 10.3. 1 – Attitude Indicator by IVAO (no date)

10.4 Arduino Code

If the code had been finished, it would have simulated the system starting from 600 to 0 feet. Displaying how the system would work to assist the pilot. Figures 10.4.1 – 10.4.2 show the start of the system, which only simulates the altitude count down and serial monitor triggers at certain altitudes, which, if the code were finished, would have been a part of some of the cues.

FinalYearProject-ArduinoUnfinishedCode | Arduino IDE 2.3.6

File Edit Sketch Tools Help

Arduino Uno

FinalYearProject-ArduinoUnfinishedCode.ino

```
//Final Year Project Title - Autorotation Voice Cueing System Code

// This code is to simulate an example of the system at 600 feet, cue and alarms

#include <LCD03.h>                                        // Inclued LCD03.h library
#include <Wire.h>                                         // Inclued wire library, which let us communicate with the i2c
#include <LiquidCrystal_I2C.h>                            // Inclued this specific i2c LCD library.
LiquidCrystal_I2C lcd(0x27, 16, 2);                       // Pre wired i2c LCD module pins

int altitude = 600;                                       // System starts at 600 feet
unsigned long lastUpdate = 0;                             // Declares a variable to store time in milliseconds of the last cycle

void setup() {                                            // Begin void setup
  Serial.begin(9600);                                     // Serial transmission activated baud rate 9600 bits per second.
  lcd.init();                                             // Initialize the LCD for priniting
  lcd.backlight();                                        // LCD backlight on
  lcd.setCursor(0, 0);                                    // Set cursor to column 0, row 0
  lcd.print("Autorotation");                              // LCD print message in brackets

  //  Display initial altitude
  lcd.setCursor(0, 1);                                    // Set cursor to column 0, row 1
  lcd.print("Alt: ");                                     // LCD prints what is in the breaks to show this is for the altitude
  lcd.print(altitude);                                    // LCD print altitude, altitude starts at 600 feet
  lcd.print(" ft");                                       // LCD print ft, to display the altitude is counting down in feet

  Serial.println("Starting Autorotation Simulation...");  // Serial print message in brackets, at start
  Serial.print("Altitude: ");                             // Serial prints what is in the breaks to show this is for the altitude
  Serial.println(altitude);                               // Serial print the altitude as it decreases

}                                                         // End void setup

```

Figure 10.4. 1 - Arduino Code Part 1

Figure 10.4. 2 - Arduino Code Part 2

11. Project Management

11.1 Project Time

A list of tasks and a Gantt Chart was created to manage all the tasks of the project, which can be found in the Appendix C.

The Gantt Chart shows the project started off well, keeping in time with the planned timeline, which is shown in yellow, and the actual timeline is shown in green. Then, the week beginning 25/11/2024 – 16/12/2024, you can see there was no activity during this time. The planned time to work on the research tasks was missed due to stress, and the work was pushed back, beginning on 23/12/2024. It also shows the actual time spent on that task, which are much longer than the planned, as breaks need to be taken to manage stress due to juggling university work, part-time job and personal circumstances.

Having to have tasks pushed back affected the project, as what ended up being created was a theoretical solution to autorotation. The practical representation using the microcontroller system Arduino was meant to represent how the system would work for a better understanding. Tasks for the practical are highlighted in red, showing that the tasks were not completed. If stress had been managed better, more time could have been given to the project.

Although there were setbacks, regular meetings were set up with the project supervisor for the project's progression, which led to the creation of the theoretical system.

.

11.2 Project Costs

Although the particle side could not be completed as the microcontroller system kit was ordered, the material was brought with the mindset was that the practical representation using a microcontroller system would be built.

11.2.1 Materials/Resources

The table shows all the project costs, which is higher than the original cost. The original cost was £114.78, and now this cost is £126.36, a £11.55 difference. This was spent in order to build the representation system; however, since there is only a theoretical solution, this cost was wasted.

Resources/Materials	Quantity	Description	Cost	Comments
Arduino Uno R3	1	Communicates software with the hardware Can memories code	£49.00	Amazon
Microcontroller hardware kit	1	Hardware for the prototype monitoring system	£25.06	Amazon
Arduino Uno Software	1	Software to type code for the monitoring system	£0	There is no cost, as the software is free to download for students
Micro Speaker	1	To play the voice cue	£7.98	Amazon
Memory Card	1	To save the recorded sound and upload it to Arduino	£9.88	Amazon
Breadboard Kit	1	To build a system and connect to Arduino	£7.99	Amazon
Micro SD SPI Storage Board	1	For the memory card to connect to the Arduino	£6.99	Amazon
I2C LCD 1602 Module	1	To display instrument readings	£10.95	Amazon
Wires	1	Wires to connect the hardwire to each other and the Arduino	£7.49	Amazon
Total			£126.36	

Table 11.2. 1 Total Cost

12. Health & Safety

The health and safety of this project was maintained by following the completed risk assessment, found in Appendix A, keeping in mind recommendations of the Health and Safety at Work Act 1974 (HSWA) and the Display Screen Equipment (DSE) regulation 1992, since this project was research-based.

All possible hazards were ranked as A in the risk assessment, as they could all be adequately controlled. For example, since it is a research based project most of the time would be spent on a laptop or computer, one of the hazards for this listed in the risk assessment is eye strain, to management eyes strain the measures were to take breaks from the screen, the Health and Safety Executive (no date) recommends taking '5 – 10 minute breaks every hour' when more than an hour was spent, the amount of time for the break also increased. Another measure was to adjust the screen brightness and the room light, which was able to be done since this is an individual project and most of the time is spent in a room alone, so making adjustments would not cause any problems.

Although the practical side to this project could not be conducted due to stress pushing certain tasks back, there was no time to complete the practical. However, a measure was in place for when using the microcontroller components, such as the power supply. The hazard was the circuit overheating; the measure was to connect the right power source to the circuit, so the procedure could be conducted safely.

Only one incident occurred throughout the project, which was the stress due to juggling university, working part-time and personal circumstances. The measures in place for the risk assessment were to look into stress management techniques, set schedules, and take breaks. Although those measures did help, a further step was taken with GP, and over time, stress management improved.

13. Ethical Considerations

The ethical approval for the project was obtained by the university, where they reviewed the project from the proportionate review form shown in Appendix B however, there were no participants as the questionnaire was no longer needed since finding helicopter pilots to review the autorotation voice cueing system would have been unlikely, so this project fits under the disclaimer form. It did not meet the requirements for a full ethical review form as this project was research-based, did not involve flying a helicopter or any participants, to keep within the RAeS (2018) Code of Professional Conduct, which states ‘ to prevent avoidable danger to health or safety’.

14. Summary

This project aimed to design an autorotation monitoring system to assist pilots in completing the manoeuvre. This aim was achieved through a theoretical approach, although the practical microcontroller system could not be created due to stress and the schedule being pushed back. The project's practical part could have been made if there had been better stress management.

However, further work can be done on the project to make it into a possible system through moving to the practical side of the project, building the system, testing it to collect data and improve on it, and understanding what pilots like and dislike about the system to make it comfortable for pilots and keeping to the main focus of creating a autorotation voice cueing system to aid pilots to safely complete the autorotation procedure.

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Appendix A: Ethical Form

RESEARCH ETHICS

Proportionate Review Form

The Proportionate Review process may be used where the proposed research raises only minimal ethical risk. This research must: focus on minimally sensitive topics; entail minimal intrusion or disruption to others; and involve participants who would not be considered vulnerable in the context of the research.

PART A: TO BE COMPLETED BY RESEARCHER

Name of Researcher:	Thembekile Mhlope
School	Staffordshire University

Student/Course Details (If Applicable)			
Student ID Number:			21018902
Name of Supervisor(s)/Module Tutor:			Martin Fiddler (Project Supervisor) Andrew Cash (Module Tutor)
PhD/MPhil project:	☐		
Taught Postgraduate Project/Assignment:	☐	Award Title:	BEng Aeronautical Engineering
Undergraduate Project/Assignment:	☒	Module Title:	Individual Engineering Project

Project Title:	Helicopter - Autorotation Moniter		
Project Outline:	To develop an autorotation monitor system to asisst pilots to land safely when they have to preform the autorotation manoeuvre		
Give a brief description of participants and procedure (methods, tests etc.)	A qeustionaire of what they think of the design.		
Expected Start Date:	10/2024	Expected End Date:	12/2024

Relevant professional body ethical guidelines should be consulted when completing this form.

Please seek guidance from the School Ethics Coordinator if you are uncertain about any ethical issues arising from this application.

There is an obligation on the researcher and supervisor (where applicable) to bring to the attention of the School Ethics Coordinator any issues with ethical implications not identified by this form.

Researcher Declaration

I consider that this project has no significant ethical implications requiring full ethical review	☒

I confirm that:

University Research Ethics Committee (February 2018)

Figure A - Proportionate Review Form Part 1

1.	The research will **NOT** involve members of vulnerable groups. Vulnerable groups include but are not limited to: children and young people (under 18 years of age), those with a learning disability or cognitive impairment, patients, people in custody, people engaged in illegal activities (e.g. drug taking), or individuals in a dependent or unequal relationship.	☒
2.	The research will **NOT** involve sensitive topics. Sensitive topics include, but are not limited to: participants' sexual behaviour, their illegal or political behaviour, their experience of violence, their abuse or exploitation, their mental health, their gender or ethnic status. The research must not involve groups where permission of a gatekeeper is normally required for initial access to members, for example, ethnic or cultural groups, native peoples or indigenous communities.	☒
3.	The research will **NOT** deliberately mislead participants in any way.	☒
4.	The research will **NOT** involve access to records of personal or confidential information, including genetic or other biological information, concerning identifiable individuals.	☒
5.	The research will **NOT** induce psychological stress, anxiety or humiliation, cause more than minimal pain, or involve intrusive interventions. This includes, but is not limited to: the administration of drugs or other substances, vigorous physical exercise, or techniques such as hypnotherapy which may cause participants to reveal information which could cause concern, in the course of their everyday life.	☒
6.	The research **WILL** be conducted with participants' full and informed consent at the time the study is carried out: • The main procedure will be explained to participants in advance, so that they are informed about what to expect. ☐ • Participants will be told their involvement in the research is voluntary. ☐ • Written consent will be obtained from participants. *(This is not required for self-completion questionnaires as submission of the completed questionnaire implies consent to participate)*. ☐ • Participants will be informed about how they may withdraw from the research at any time and for any reason. ☐ • For questionnaires and interviews: Participants will be given the option of omitting questions they do not want to answer. ☒ • Participants will be told that their data will be treated with full confidentiality and that, if published, every effort will be made to ensure it will not be identifiable as theirs. ☐ • Participants will be given the opportunity to be debriefed i.e. to find out more about the study and its results. ☐	YES ☒ N/A ☐
7.	A risk assessment has been completed for this research project	YES ☒ N/A ☐

Figure A.1 - Proportionate Review Form Part 2

8. Information and Data Please provide answers to the following questions regarding the handling and storage of information and data:
a) How will research data be stored (manually or electronically)? ELectronically
b) How is protection given to the participants (e.g. by being made anonymous through coding and with a participant identifier code being kept separately and securely)? Participants will be kept anonymous, personal data not need for this questionnaire, only thing that will be asked a side from filling out questions about the project is the field they work or study in.
c) What assurance will be given to the participant about the confidentiality of this data and the security of its storage? They will be told and it will be written on the questionaire that there personal data is not needed, they will be anonymous.
d) Is assurance given to the participant that they cannot be identified from any publication or dissemination of the results of the project? Yes
e) Who will have access to this data, and for what purposes? Myself and project supurviser, when looking over feedback from the questionaires. The module tutor Andrew Cash and another lecturerer unknown to grade my project.
f) How will the data be stored, for how long, and how will it be discarded? All questionnair's will be upload to a PFD file and saved in my University OneDrive up until project is finished.

Supporting Documentation

All key documents e.g. consent form, information sheet, questionnaire/interview schedule are appended to this application.	☐

Signature of Researcher:	T.Mhlope	Date:	09/10/2024

NB: If the research departs from the protocol which provides the basis for this proportionate review, then further review will be required and the applicant and supervisor(s) should consider whether or not the proportionate review remains appropriate. If it is no longer appropriate a full ethical review form **MUST** be submitted for consideration by the School Ethics Coordinator .

Next Step:

STUDENTS: Please submit this form (and supporting documentation) for consideration by your Supervisor/ Module Tutor.

STAFF: Please submit this form to your Head of Department or a Senior Researcher in your School. Once they have reviewed the form, this should be forwarded to the Research Administrators in RIIS (ethics@staffs.ac.uk) who will arrange for it to be considered by an independent member of the School's College of Reviewers .

Figure A.2 - Proportionate Review Form Part 3

PART B: TO BE COMPLETED BY SUPERVISOR/MODULE TUTOR (If student) OR Head of Department/ Senior Researcher (if staff)

I consider that this project has no significant ethical implications requiring full ethical review by the Faculty Research Ethics Committee.	☐
I have checked and approved the key documents required for this proposal (e.g. consent form, information sheet, questionnaire, interview schedule).	☐

Signature of Supervisor/ Head of Department/ Senior Researcher:		Date:	

Next Step: Please forward this form to the Research Administrators in RIIS (ethics@staffs.ac.uk) who will arrange for it to be considered by an independent member of the School's College of Ethical Reviewers , having no direct connection with the researcher or his/her programme of study.

PART C: TO BE COMPLETED BY A MEMBER OF THE SCHOOL'S COLLEGE OF ETHICAL REVIEWERS

This research proposal has been considered using agreed University Procedures and is now approved.	☒
Or	
This research proposal has not been approved due to the reasons given below.	☐
Recommendation (delete as appropriate): Approve/ Amendments required/ Reject	

Name of Reviewer:	Dr Md Asaduzzaman	Date:	25/10/2024
Signature:			

Signed (School Ethical Coordinator)		Date:	

Figure A.3 - Proportionate Review Form Part 4

Appendix B: Risk Assessment

GENERAL RISK ASSESSMENT FORM			**Severity** multiplied by **Likelihood** equals **Risk Rate**. NB: Calculated after taking in to account existing precautions				
School/Service		Severity Likelihood	Insignificant-cant (1)	Minor (2)	Moder-ate (3)	Serious (4)	Fatal / Critical (5)
Task/Activity/Area: investigating the possibility of a helicopter autorotation monitoring system to assist pilots when performing the manoeuvre. This will involve research, problem-solving, and the use of software to create a system. This will occur in the Mellor building and at home using the software and other resources such as Microsoft Word.		Almost Certain (5)	**5**	**10**	**15**	**20**	**25**
		Likely (4)	**4**	**8**	**12**	**16**	**20**
Assessed By: Thembekile Mhlope	Signature: T.Mhlope	Possible (3)	**3**	**6**	**9**	**12**	**15**
Dept Manager: Martin Fidder	Signature:	Unlikely (2)	**2**	**4**	**6**	**8**	**10**
Date of Assessment: 10/11/2024	Review Date: 15/11/2024	Rare (1)	**1**	**2**	**3**	**4**	**5**

Figure B. 1 - Risk Assessment Guide

	Activity/Process/Machines	**Hazard**	**Persons in Danger**	**Severity 1-5**	**Likelihood 1-5**	**Risk Rate**	**Measures/Comments**	**Result**
1	Laptop and computer usage	Back and leg pain	Myself	2	4	10	Properly adjust the chair so it is fit for me. Take breaks from sitting, get up and move around.	A
2	Laptop and computer usage	Eye Strain	Myself	3	4	12	Take breaks from the screen. Adjust the screen brightness. Adjust the light in the room.	A
3.	Walking around my workstation	Slips and trips	Myself	2	3	6	Do not walk into any spills. Make sure wires are tucked away. Make sure the chair is tucked under the desk. Keep the area clean and tidy.	A
4	Trying to juggle university assessments and working a part-time job.	Stress	Myself	3	4	12	Look into stress management techniques. Set a schedule to stay on top of tasks. Take breaks where needed.	A
5	Laptop and computer usage	Bad posture	Myself	2	3	6	Sit up straight close to the desk and avoid twisting or cramping while using the laptop	A
6	Monitoring system power supply	Circuit components overheat	Myself	2	3	6	Make sure to connect the right power source to the circuit	A

Key to result **T** = Trivial Risk **A** = Adequately Controlled **N** = Not Adequately Controlled **U** = Unable to decide (further information required).

Figure B. 2 Risk Assessment

Appendix C: Project Lists Tasks and Gantt Chart

The Gantt Chart is found on the next page below the table.

		Planned		Actual	
	Task	Start date	End date	Start date	End date
Planning	Research Project Ideas	27/09/2024	03/10/2024	27/09/2024	03/10/2024
	Pick a Project Idea	03/10/2024	09/10/2024	03/10/2024	05/10/2024
	Project Supervisor Form	09/10/2024	25/10/2024	05/10/2024	09/10/2024
	Project Ethics form	21/10/2024	15/11/2024	09/10/2024	29/10/2024
	Risk assessment	28/10/2024	15/11/2024	09/10/2024	14/11/2024
	Project Proposal	01/10/2024	22/11/2024	11/11/2024	22/11/2024
Research	Research Helicopter Controls	25/11/2024	29/11/2024	26/12/2024	29/12/2024
	Research Helicopter Aerodynamics	25/11/2024	29/11/2024	02/01/2025	05/01/2025
	Research Helicopter Systems	29/11/2024	02/12/2024	06/01/2025	10/01/2025
	Research Helicopter Lift Generation	29/11/2024	02/12/2024	13/01/2025	17/01/2025
	Research Autorotation and Failures	04/12/2024	06/12/2024	20/01/2025	24/01/2025
	Research the Autorotation Process	09/12/2024	13/12/2024	27/01/2025	31/01/2025
	Research Microcontroller System	06/01/2025	10/01/2025	03/02/2025	14/02/2025
	Literature Review	13/01/2025	07/02/2025	26/12/2024	28/03/2025
	Journal	01/10/2024	14/03/2025	06/01/2025	11/03/2025
	Thesis	25/11/2024	02/05/2025	26/12/2024	29/05/2025
	Design Theoretical Monitoring System	27/01/2025	31/01/2025	31/03/2025	13/04/2025
	Order Autorotation Monitoring System Parts	03/02/2025	07/02/2025	03/03/2025	12/03/2025
	Develop Code For Prototype Autorotation Voice Cueing System	10/02/2025	14/02/2025	01/04/2025	04/04/2025
Prototyping	Build Prototype Autorotation Voice Cueing System	17/02/2025	21/02/2025	0	0

	Test and Improve Prototype	24/02/2025	28/02/2025	0	0
	Review Prototype	03/03/2025	14/03/2025	0	0
	Create a Project PowerPoint Presentation	17/03/2025	18/04/2025	28/04/2025	02/05/2025
Presentation	Present Presentation	12/05/2025	12/05/2025	12/05/2025	12/05/2025

Table C. 1 - List of Tasks

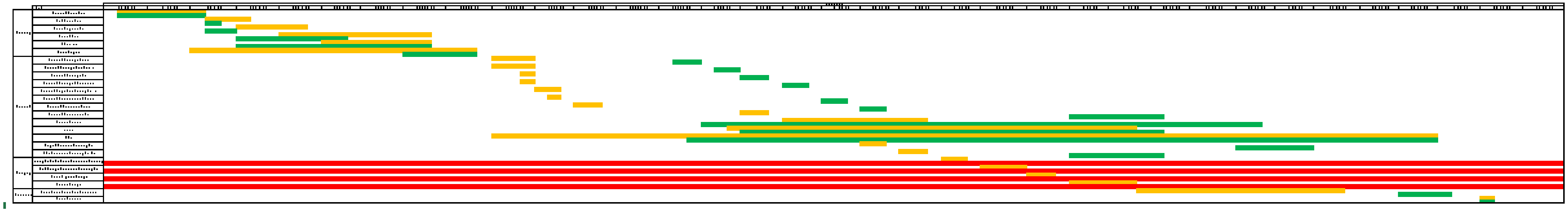

Figure C. 1 Gantt Chart

Planned
Actual
Not completed