

# **Gold CREST Project - WHSB**

## **Project Alpha**

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## Planning Our Project

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### Our Aim

Our aim is to design and develop a sophisticated robotic system tailored for reconnaissance missions, with the primary objective of safeguarding human lives from the inherent risks of such operations.

By employing the use of a Raspberry Pi, this robot will be equipped to gather vital information via the use of object recognition algorithms, and relay data to human operators in real-time. By delegating these dangerous tasks to the robot, we can minimise the potential for harm to human personnel, ensuring safer and more efficient reconnaissance operations in various scenarios, from disaster zones to hostile territories.

Ultimately, my endeavour seeks to harness the power of robotics to protect and support human life, advancing both the capabilities of reconnaissance missions and the safety of those involved.

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### Wider Purpose of Our Project

Beyond its immediate goal of protecting human lives during reconnaissance missions, the broader purpose of this project encompasses several key aspects. Firstly, by deploying robots for such missions, we aim to enhance the effectiveness and efficiency of data collection in high-risk environments which is particularly significant considering we live in a time called. "The Age of Data".

Furthermore, this project allows us to understand key usages and boundaries of artificial intelligence and permits us to truly acknowledge how intricate wireless scouting robots can be made. This project is also a medium of improving our hands-on learning and critical thinking skills and moreover our collaborative skills whilst We can gain deeper insights into addressing security concerns, raising awareness about the importance of secure systems and potential threats.

Lastly, the deployment of robotic reconnaissance systems contributes to strategic and humanitarian efforts by providing timely and accurate information in critical situations.

Whether aiding disaster response teams, supporting military operations, or assisting in humanitarian missions, the insights gleaned from these robots can inform decision-making processes, enabling more effective resource allocation and response coordination. Ultimately, the wider purpose of this project is to harness technology for the betterment of society, safeguarding lives, advancing knowledge, and fostering innovation in the pursuit of a safer and more sustainable future.

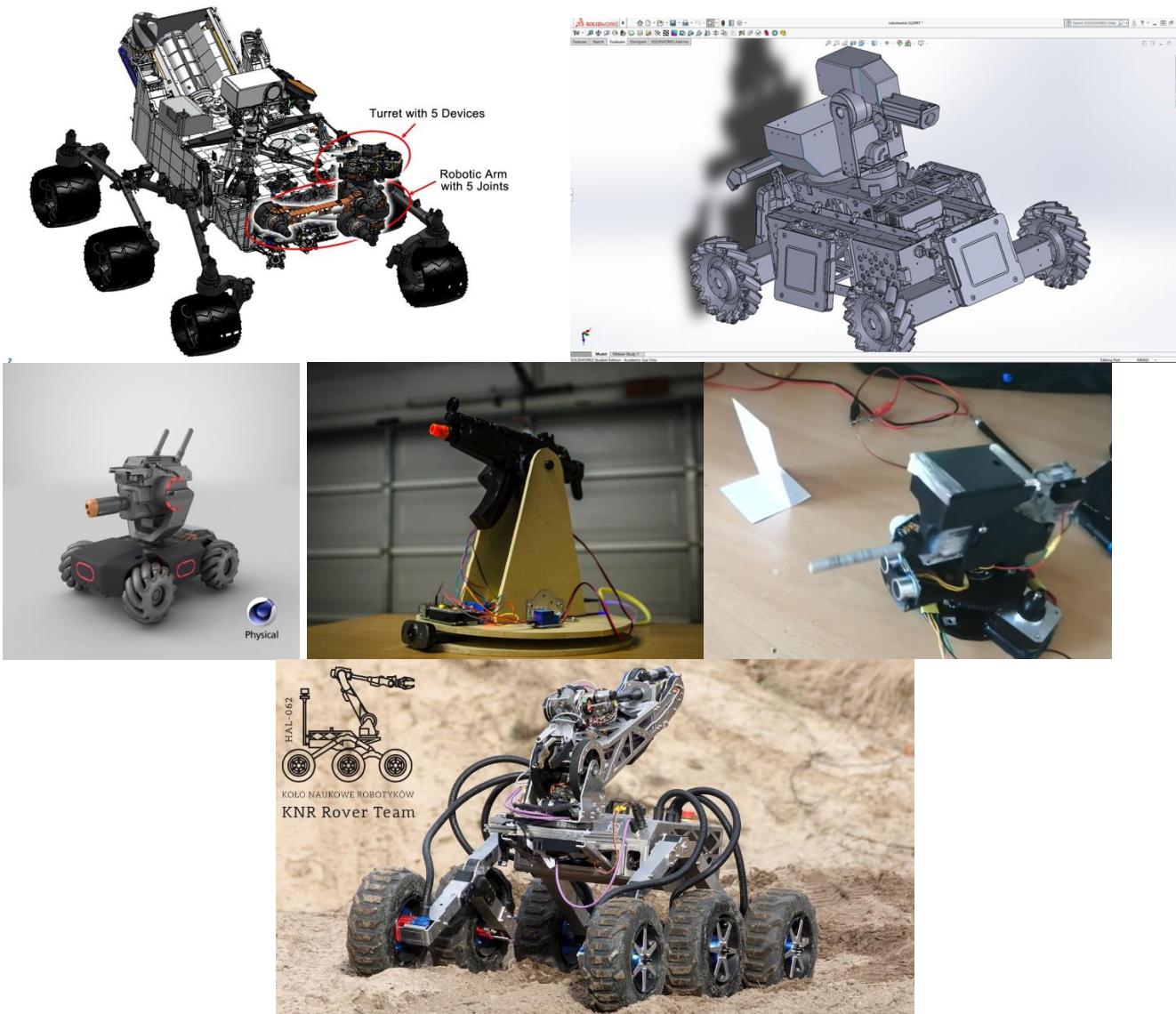
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## Project Background

In this CREST Gold Design and Technology project, we are a dedicated team of 7 working towards a unified goal: to create a reconnaissance autonomous robot. The robot we are designing features a rocker-bogie mechanism much alike to that of the Mars rovers created by NASA. The rover is accompanied with a sentry turret which uses automatic colour recognition tools to detect, aim and fire - completely autonomously.

The CREST Awards scheme is the only nationally recognised accreditation scheme for STEM project work for 5–19-year-olds. At Gold level (for 16–19-year-olds), students' work should contribute something new to the scientific or technological community or to a particular field of study, meaning that - as aspiring computer scientists, engineers, and physicists - this has so far been an excellent opportunity for us all.

## Inspiration Image Board



## Range Of Approach Towards our Brief

In the project to develop a robot for reconnaissance missions entails exploring a wide range of approaches to achieve its objectives effectively. One approach involves designing a ground-based robot equipped with advanced sensors and mobility capabilities, enabling it to traverse diverse terrains with agility and precision. Such a robot could utilise techniques like lidar, radar, and cameras for environment perception, coupled with sophisticated algorithms for mapping and navigation, however with the slim time frame given, we made the choice to not use the lidar due to the tedious process of linking motors to the lidar which would have made our project duration considerably longer.

Alternatively, an aerial drone-based approach could be considered, leveraging the advantages of aerial reconnaissance for rapid data collection over expansive or inaccessible areas. These drones could be equipped with high-resolution cameras, thermal imaging sensors, and other specialised equipment to gather detailed information from above. Advanced flight control algorithms and obstacle avoidance systems would be crucial for safe and efficient operation in complex environments. This sort of design would be incredibly efficient if done correctly with the proper equipment, in exchange for this, the drone would require testing in very specific grounds and the powerful cameras required would surpass the budget we were permitted.

The idea of a waterborne design also emerged, which was quickly shut down after realising how meticulous the project would have to be, in order to avoid water damage to electrical components, thus we deemed this design too unsafe to proceed with.

Another consideration is the level of autonomy and human-robot collaboration desired for the project. While fully autonomous robots offer independence and scalability, they may lack the adaptability and decision-making capabilities of human operators in certain situations. Therefore, a semi-autonomous approach that combines the strengths of both humans and robots, with humans providing high-level guidance and intervention, when necessary, could be advantageous. This was also desirable since we would not need to rewire the Radio Control transmitters and receivers to the artificial intelligence. For this particular design, the rover would be controlled manually whilst the turret would function autonomously.

Additionally, the choice of a firing system plays a crucial role in determining the capabilities and performance of the robot. Whether utilising off-the-shelf components or custom-designed systems, considerations such as durability, power efficiency, and computational resources must be taken into account to ensure reliability and longevity in the field. Some of the ideas we had included: disassembling premade products, creating our own flywheel design or even using pressure in order to project water at targets.

Overall, the range of approaches considered for the project reflects the complexity and multifaceted nature of reconnaissance missions, each offering unique advantages and challenges to be addressed through careful design and implementation. Going forward, ideas such as the half autonomous, half manual and using a land-based robot will be more significant within our final design and prototype of the robot.

## Prototyping Our Project

### Prototyping and Team Members' Roles

During our prototyping phase, our team's collaborative efforts were integral to advancing our project across multiple fronts. Zain and Alex spearheaded the physical fabrication aspects, translating conceptual designs into tangible components. Zain's proficiency in CAD design using SOLIDWORKS enabled him to meticulously craft the rotational base of the sentry, ensuring precision and functionality. Meanwhile, Alex's expertise in 2D Design V2 facilitated the seamless integration of electrical components, laying the groundwork for the project's hardware infrastructure.

In tandem, Daniyal and Aman delved into theoretical explorations, conceptualising innovative solutions to enhance the project's functionality. Aman's artistic skills were pivotal in visualising concepts and sketching prototypes, such as the dual-flywheel mechanism for the shooting mechanism. Daniyal, leveraging his analytical mindset, conducted in-depth research and feasibility studies, providing valuable insights to guide our decision-making process. Together, they forged a comprehensive understanding of the project's theoretical underpinnings, informing our prototyping endeavours.

On the programming front, Mahfuzur, Orianne, and Isabel took charge, leveraging their expertise to develop the project's technological framework. Mahfuzur and Orianne collaborated closely, utilising their programming prowess to devise efficient algorithms and software solutions. Isabel, drawing upon her proficiency in software development, played a key role in integrating sensor data and optimising system performance. Together, their combined efforts ensured the seamless operation and functionality of the project's technological components.

Throughout this collaborative process, each team member's unique skills and contributions were instrumental in driving progress and overcoming challenges. By synergising our diverse expertise and perspectives, we navigated the complexities of prototyping and laid a solid foundation for the project's continued development.

In summary, our rover and turret must achieve these 5 key functionalities:

1. The turret must be able to automatically detect, aim and fire at specified targets.
2. The rover must be able to navigate through dynamic terrain to reach specified destinations.
3. The rover should be equipped with cameras and/or sensors to detect and track movement in its surroundings.
4. The rover should be cheap and easy to deploy in a variety of security scenarios.
5. The rover should have a mechanism for remote control and monitoring by security personnel.

## Final Brief Decision

After careful consideration of various approaches, our project team ultimately opted for a manually operated rover design with a turret-mounted camera device for autonomous control.

This decision stemmed from a thorough analysis of the project requirements, technological feasibility, and operational considerations.

The manually operated rover design provides several key advantages. Firstly, it allows for direct human involvement, offering operators real-time control and situational awareness during reconnaissance missions. This human oversight ensures adaptability and responsiveness in dynamic environments, where unexpected obstacles or events may require immediate intervention. Additionally, manual operation facilitates intricate manoeuvres and precise interactions with the environment, enhancing the rover's versatility and effectiveness in gathering critical intelligence.

Complementing the manual control interface, the inclusion of a turret-mounted camera device offers autonomous surveillance capabilities. This device is equipped with advanced sensors, including web cameras and possibly other specialised equipment, enabling comprehensive environmental perception and data acquisition. Through autonomous control algorithms, the turret can scan and analyse the surroundings, detecting certain objects, and identifying points of interest without constant human input.

Moreover, the decision to incorporate autonomous control features into the turret-mounted camera device aligns with our project's overarching goals of minimising human exposure to danger while maximising operational efficiency. By offloading repetitive or mundane tasks to autonomous systems, operators can focus their attention on higher-level strategic decision-making, enhancing overall mission effectiveness and safety. Additionally, the autonomous capabilities of the camera device facilitate continuous data collection and analysis, providing valuable insights into the environment over extended periods without operator fatigue or oversight.

1.	The turret must be able to automatically detect, aim and fire at specified targets.	We achieved automatic target detection, aiming, and firing for the turret by integrating computer vision algorithms for target identification, precise servo and stepper motors for aiming, and a mechanism triggered upon target alignment. Additionally, fail-safe measures were implemented for reliability, ensuring the system's effectiveness in diverse scenarios.
2	The rover must be able to navigate through dynamic terrain to reach specified destinations.	We enabled the rover to navigate dynamic terrain and reach specified destinations by integrating sensors for terrain sensing, a versatile propulsion system, and advanced software algorithms for autonomous navigation and path planning. Redundant systems and fail-safe mechanisms were incorporated to enhance reliability and safety during operation.
3	The rover should be equipped with cameras and/or sensors to detect and track movement in its surroundings.	We equipped the rover with a comprehensive sensor suite, including cameras and other sensors, to detect and track movement in its surroundings. Advanced software algorithms process sensor data in real-time, enabling the rover to identify moving objects, track their trajectories, and respond effectively. This enhances the rover's situational awareness and overall capabilities in dynamic environments.
4	The rover should be cheap and easy to deploy in a variety of security scenarios.	To meet the requirement for affordability and deployability in diverse security scenarios, we employed a modular design using off-the-shelf components to reduce costs and simplify assembly. Intuitive controls and user-friendly interfaces were prioritised to ensure ease of deployment without extensive training. Optimisation of size, weight, and manufacturing techniques such as 3D printing enhanced portability and scalability while keeping costs low.
5.	The rover should have a mechanism for remote control and monitoring by security personnel.	To enable remote control and monitoring by security personnel, we implemented a wireless communication system between the rover and a control station. This system features a user-friendly interface for intuitive interaction, live video feeds for visual monitoring, and encryption protocols for data security. Additionally, GPS tracking and telemetry data transmission enhance situational awareness. Overall, our solution ensures effective oversight and responsiveness in security operations.

## **Student Profiles**

### **Daniyal Amir**

Mathematics, Further Mathematics,  
Economics, Computer Science

As a future computer scientist looking forward to exploring the field of software engineering, the Engineering Education Scheme (EES) presents itself an excellent opportunity to exercise not only my interests in programming and algorithmic thinking, but also my soft skills in the environment in a team-based project. I am collaborating with like-minded, driven computer scientists like myself working towards a unified goal: to create a reconnaissance autonomous robot.

My role as a computer scientist has meant that I have so far exercised my coding-oriented skills through use of AI Python libraries such as TensorFlow and OpenCV for autonomous and/or remote control, further extending my computing proficiency to pursue my path in the field of Computer Science.

### **Zain Kramutally**

Mathematics, Physics, Further  
Mathematics, Computer Science

My name is Zain Kramutally, and I am delighted to introduce myself as an enthusiastic student studying Maths, Physics, Further Maths, and Computer Science. My passion lies in applying these subjects to innovate and solve real-world challenges. With a keen interest in the intersection of finance and technology, I aspire to pursue a career in the exciting realms of financial technology or software engineering.

### **Orianne Otchere**

Mathematics, Physics, Further  
Mathematics, Computer Science

As a computer scientist, I am eager to contribute to the Engineering Education Scheme project with my technical expertise and collaborative spirit. Working within a team environment, I am driven to solve complex problems and create innovative solutions. I thrive on the opportunity to exchange knowledge, learn from my teammates, and actively participate in the project's success. With a passion for programming and a strong foundation in computer science principles, I aim to deliver exceptional results while elevating the overall team performance.

### **Isabel Ogbeide-Ihama**

Mathematics, Physics, Further  
Mathematics, Economics

I am an aspiring engineer, with aims to specialise in the electrical and electronic sectors. I am eager to learn about the future opportunities that await me in this field. Making use of my creativity, knowledge and passion towards engineering, I hope to develop intricate and useful concepts regarding the project.

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## Student Profiles

### Alexander Eklund

Mathematics, Physics, Further Mathematics, Economics

I am currently studying Maths, Further Maths, Physics and Economics. I hope to use my knowledge gained from these topics and apply these on current problems to find solutions. I view the Engineering Educational Scheme as a way to display my passion for engineering. With an interest in both economics and engineering, I hope to pursue a career where these intersect such as in fintech.

### Mahfuzur Rahman

Mathematics, Physics, Chemistry, Computer Science,

Being a computer scientist, I am eager to tackle the Engineering Education Scheme project as part of a team. With my technical prowess and collaborative spirit, I thrive in solving complex problems and creating innovative solutions. I strongly believe in exchanging knowledge and learning from my teammates, as active participation is crucial for success. By leveraging my passion for programming and solid computer science principles, I aim to deliver exceptional results while elevating overall team performance. Together, we can overcome challenges and contribute to the project's growth and development.

### Aman Varshney

Mathematics, Physics, Further Mathematics, Economics

I am an aspiring engineer looking to further my interests via the Engineering Education Scheme. To me, this is the perfect opportunity to extend my passion for Physics and Mathematics and dedicate myself to a team project in which I can demonstrate my abilities. I hope to take the skills and ideas I learn from EES and apply them to my future endeavours.

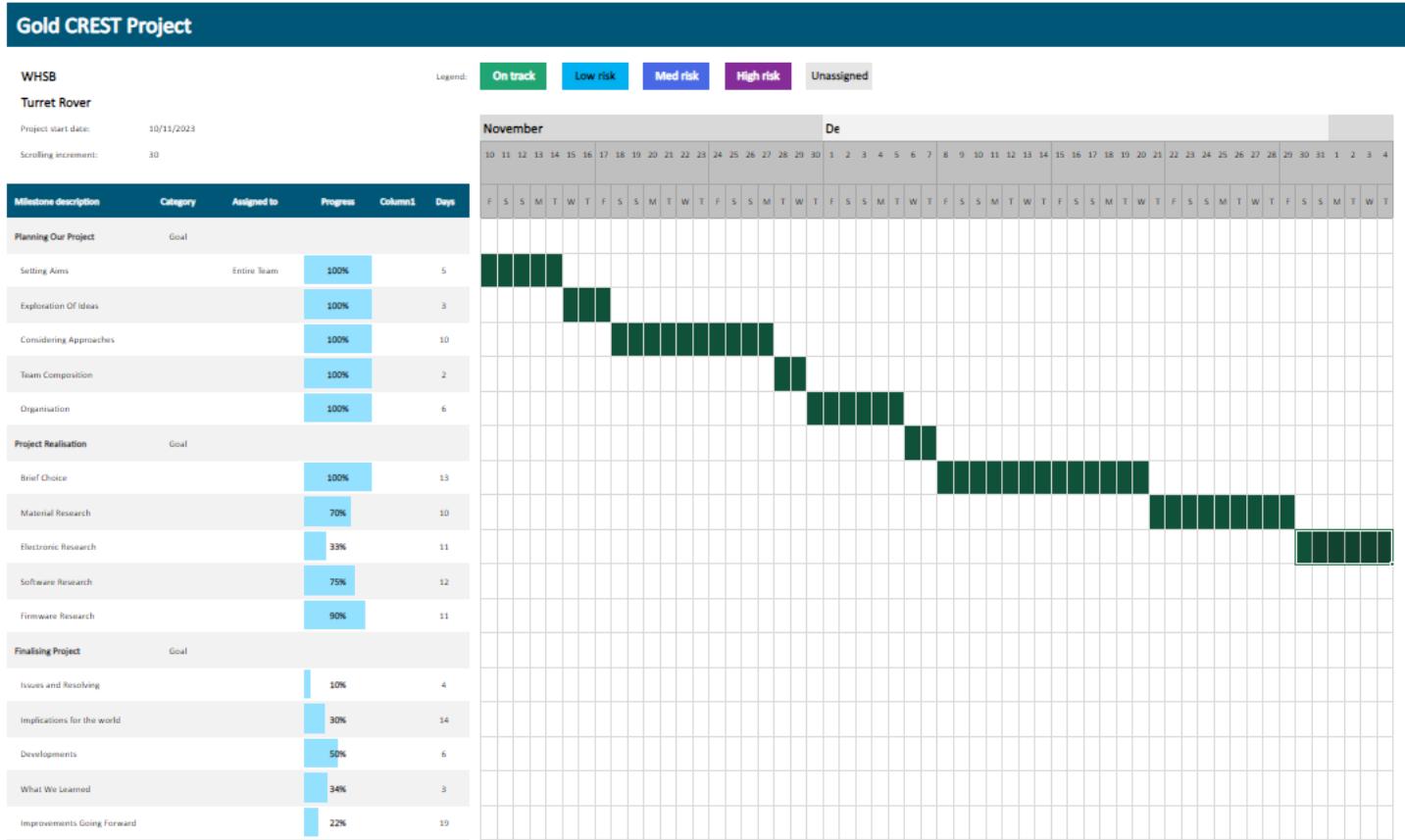
# Organising Our Project

In planning for our reconnaissance robotics project, we recognised the importance of structured project management to ensure efficient progress and timely completion. To facilitate this, we utilised a Gantt chart to decompose the project into manageable tasks and create a flexible time schedule that accommodated potential challenges and adjustments along the way.

The Gantt chart served as a visual roadmap, outlining the sequential steps required for the project from inception to deployment. We began by identifying the major milestones and deliverables, such as research and requirements gathering, design and prototyping, testing and validation, and final implementation. These milestones were then broken down into smaller, actionable tasks, each with its own timeframe and dependencies.

By decomposing the project in this manner, we gained clarity on the scope of work and the sequence of activities needed to achieve our goals. This allowed us to allocate resources effectively, identify critical path tasks, and anticipate potential bottlenecks or dependencies that could impact the project timeline.

Importantly, the Gantt chart provided a flexible framework that enabled us to adapt to changes and uncertainties as they arose. By assigning durations and dependencies to each task, we could easily reschedule or adjust timelines in response to shifting priorities, resource constraints, or unforeseen challenges. This flexibility allowed us to maintain momentum and progress towards our objectives, even in the face of setbacks or unexpected developments.



Before each EES (Engineering Education Scheme) session, team leaders set out specific weekly goals for the team to reach every week. To ensure progress and maximise productivity, these goals are designed to align with our current objectives and targets. The team leaders carefully evaluate our current performance and identify areas that need immediate attention. For example, if a measurement or weight distribution error is to be found, team leaders may set a weekly goal to: "Deduce set measurements for certain components so that legs of the rover can physically support the base of the rover."

To ensure efficient completion of our reconnaissance robotics project, we adopted a strategic approach by splitting the project team into two specialised groups, each focused on a distinct aspect of the overall system: the rover and the turret. This division of labour allowed us to leverage the expertise and resources of each team to tackle specific challenges and accelerate progress towards our shared goal.

The rover team was responsible for designing, building, and testing the mobile platform that would serve as the foundation for our reconnaissance robot. This included tasks such as selecting and integrating movement systems, developing robust chassis and suspension mechanisms, and implementing navigation and control algorithms. By dedicating a team to the rover, we could streamline development efforts, iterate rapidly on design iterations, and optimise performance without being encumbered by concurrent work on other system components.

Simultaneously, the turret team focused on the design and implementation of the camera device mounted atop the rover. This involved selecting and integrating Raspberry Pi components, developing pan-tilt mechanisms for precise positioning, and implementing algorithms for autonomous data collection and analysis. By concentrating on the turret subsystem, this team could delve deeply into sensor technologies, optimise imaging algorithms, and ensure seamless integration with the rover platform.

Throughout the project, close collaboration and communication between the rover and turret teams were maintained to ensure alignment of goals, compatibility of subsystems, and coherence of the overall system architecture. Regular meetings, progress updates, and cross-team reviews facilitated integration efforts and addressed any emerging challenges or dependencies.

By splitting the team into specialised groups, we capitalised on individual strengths and expertise while promoting parallel development and efficient resource utilisation. This division of labour enabled us to expedite the project timeline, mitigate risks, and deliver a cohesive reconnaissance robot that met our performance objectives within the allocated timeframe.

Throughout the project lifecycle, regular monitoring and updates to the Gantt chart helped us track progress, identify deviations from the plan, and make informed decisions to keep the project on track. By maintaining transparency and accountability through the Gantt chart, team members remained aligned and motivated, knowing their contributions were integral to achieving the project's success.

## Existing Product Analyses

Conducting existing product analyses plays a pivotal role in informing and guiding the development of our design idea by providing valuable insights, inspiration, and benchmarks from established products in the field. Firstly, by examining existing products, we can gain a comprehensive understanding of the current market landscape, including prevailing trends, technologies, and user preferences.

Additionally, existing product analyses allow us to evaluate the strengths and weaknesses of competing products, providing valuable lessons and best practices to inform our design decisions. By identifying successful features and functionalities, as well as areas for improvement or innovation, we can refine our design idea to better meet the needs and expectations of our target users.

Moreover, existing product analyses serve as a source of inspiration and creativity, sparking ideas and possibilities for our own design concept. By studying innovative and well-designed products, we can draw inspiration from their design elements, materials, technologies, and user experiences.

### DJi Robomaster S1

The RoboMaster S1 is a game-changing educational robot built to unlock the potential in every learner. Inspired by DJI's annual RoboMaster robotics competition, the S1 provides users with an in-depth understanding of science, math, physics, programming, and more through captivating gameplay modes and intelligent features.

Cost: £500.00



**Weight**

Approx. 3.3 kg

**Dimensions**

320×240×270 mm (length × width × height)

**Chassis Speed Range**

0-3.5 m/s (forward)  
0-2.5 m/s (backward)  
0-2.8 m/s (sideways)

**Max Chassis Rotational Speed**

600°/s

Detection Requirements	For the Hit Detector to be activated, the following conditions must be met: Gel bead diameter ≥ 6mm, launching speed ≥ 20m/s, and the angle between the hit direction and hit detector plane is no less than 45°.
Maximum Detection Frequency	15 Hz
FOV	120°
Max Still Photo Resolution	2560x1440
Max Video Resolution	FHD: 1080/30fps HD: 720/30fps
Max Video Bitrate	16 Mbps
Photo Format	JPEG
Video Format	MP4
Sensor	CMOS 1/4"; Effective pixels: 5 MP
Operating Temperature Range	-10 to 40 °C (14 to 104 °F)

The DJI RoboMaster S1 is a versatile educational robot designed to provide users with an immersive and interactive learning experience in robotics, programming, and AI. Inspired by the innovative features and capabilities of the DJI RoboMaster S1, our product analysis aims to highlight the key aspects that influenced the development of our own robotic project.

Customer Reviews: 4.7/5.0

Product Score: 8.3/10.0

Design and Aesthetics	Functionality and Features	Technological Innovation	Adaptability and Resilience	Conclusion
The DJI RoboMaster S1 embodies a modern and futuristic design, characterised by its modular architecture, dynamic LED lights, and distinctive angular contours. Drawing inspiration from its sleek aesthetics, our robotic project seeks to emulate a similar design ethos, prioritising adaptability and resilience in both form and function to create a visually striking and durable product.	At the core of the DJI RoboMaster S1 lies its unparalleled functionality, boasting omnidirectional movement, programmable AI modules, and an array of sensors for robust environmental perception. In parallel, our robotic project aims to replicate this versatility by integrating comparable functionalities, such as omnidirectional movement for agile manoeuvrability, AI-driven decision-making for adaptive responses, and advanced sensor suites for real-time situational awareness.	The DJI RoboMaster S1 exemplifies technological innovation, harnessing cutting-edge technologies such as machine learning, computer vision, and advanced sensors to deliver a seamless and immersive user experience. Similarly, our robotic project leverages state-of-the-art technologies to achieve comparable levels of performance and functionality, pushing the boundaries of innovation in the realm of robotics and automation.	Central to the design philosophy of the DJI RoboMaster S1 is its adaptability and resilience, enabling it to navigate diverse environments and withstand the rigours of intensive use. Inspired by this ethos, our robotic project places a strong emphasis on adaptability and resilience, incorporating rugged construction, modular components, and robust programming capabilities to ensure optimal performance in challenging conditions.	In conclusion, the DJI RoboMaster S1 serves as a catalyst for our own robotic project, inspiring design choices, functional implementations, and strategic objectives. By embracing the adaptability and resilience of the RoboMaster S1, we aspire to create a dynamic and robust product that empowers users to explore the limitless possibilities of robotics and technology in an ever-changing world.

## Classroom Sentry Rover M.A.R.R (GoodGuyBot)

GoodGuyBot is a ground-breaking initiative aimed at enhancing safety measures in educational environments, particularly in response to the growing concerns surrounding school shootings. Drawing inspiration from the Classroom Sentry concept, GoodGuyBot introduces a remote Aerosol dispenser system designed to deploy a non-lethal pepper spray and tear gas mix as a deterrent against potential attackers. This innovative approach represents our first step towards empowering students and teachers with a proactive defense mechanism in challenging scenarios. GoodGuyBot's compact design allows for easy mounting over a closed classroom door, offering quick access to its capabilities in times of need. With just eight simple steps, users can assemble GoodGuyBot in approximately five minutes, thanks to its streamlined construction comprising five key components. By adopting the principles of mutually assured rapid response (M.A.R.R), GoodGuyBot aims to mitigate the impact of school shootings and provide a sense of security to educational communities. Watch the DIY video below for step-by-step instructions on building your own GoodGuyBot and taking control of safety measures in your school environment.

### What is the goal?

The optimal outcome of any school shooting is that the event never occurred. The goal is to deter any such event at your school. Mutually Assured Rapid Response (M.A.R.R.) is a deterrent.

### Where are operators located?

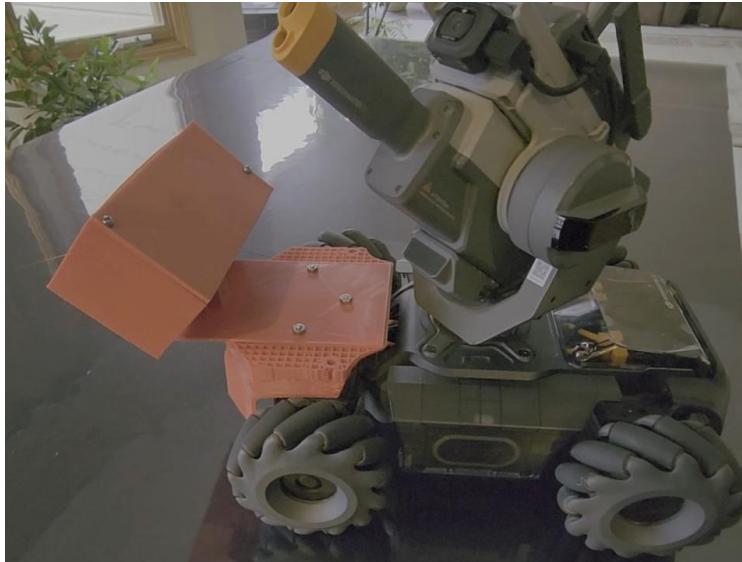
Remote control and remote trigger allow the operators to be anywhere in the building or across the country from a monitoring location. F.P.V live video feed is available from the DJI's Robomaster S1 tanks. This live feed can be projected to law enforcement in real time to make informed and efficient decisions.

### When is it triggered?

Currently, the whole defense system initiates in the event of the detection of an active shooter. This manual process means a person must confirm and activate the system, similar to a code red voiced over a school intercom.

### Why do I need it?

First responders and lawmakers are doing their best to protect you and your school. Their actions prevent many adverse events; however, a M.A.R.R. system could provide an additional layer of deterrence to school safety. It also helps the school to have some control over an active shooter situation.



In researching GoodGuyBot, I've delved into an innovative initiative aiming to address the pressing issue of security in educational environments. GoodGuyBot introduces the concept of Mutually Assured Rapid Response (M.A.R.R), drawing parallels to natural defense mechanisms observed in animals like the pufferfish or porcupine. This approach resonates with the idea of providing a deterrent against potential threats, promoting safety and security within schools.

The core of GoodGuyBot's vision lies in the development of an automated M.A.R.R system, leveraging advanced technologies such as cameras, sensors, and Artificial Intelligence (AI) to detect and respond to threats in a non-lethal manner. This cutting-edge solution seeks to empower individuals and communities by providing them with the tools necessary to defend themselves effectively.

While exploring GoodGuyBot's initiatives, I've come across their Classroom Sentry—a remotely operated pepper spray delivery system designed to enhance security in educational settings. This simple yet practical solution underscores GoodGuyBot's commitment to making safety accessible to all. By mounting over classroom doors, the Classroom Sentry offers a swift and effective response to potential threats, creating a safer learning environment for students and teachers alike.

Through my research, I've gained insight into GoodGuyBot's mission to provide proactive security measures and promote a culture of safety within schools. Their innovative approach and dedication to empowering individuals with the means to protect themselves are commendable, and I look forward to seeing how their initiatives continue to evolve and make a positive impact in the field of security.

Design and Aesthetics	Functionality and Features	Technological Innovation	Adaptability and Resilience	Conclusion
GoodGuyBot's design embodies a sleek and modern aesthetic, integrating seamlessly into educational environments while conveying reliability and security. Its compact size allows for discreet mounting over classroom doors, ensuring it blends into its surroundings without compromising on effectiveness. With a focus on durability and longevity, GoodGuyBot's robust construction ensures it withstands daily use while maintaining aesthetic appeal. The design strikes a balance between modern sophistication and functional efficiency, reinforcing the company's commitment to safety and security. Overall, GoodGuyBot sets a new standard for design excellence in security technology, empowering users to enhance safety in educational settings confidently.	GoodGuyBot offers a comprehensive security solution for educational environments, featuring advanced functionality and key features such as remote operation, automated threat detection, compact design, non-lethal defense mechanisms, and a user-friendly interface. With its innovative approach to security, GoodGuyBot empowers users to respond effectively to potential threats while prioritizing safety and security for all occupants. GoodGuyBot revolutionizes security in educational settings with its advanced functionality and key features, including remote operation, automated threat detection, compact design, non-lethal defense mechanisms, and a user-friendly interface. Additionally, its fully 3D printable construction ensures cost-effectiveness and customization options. By combining innovation with affordability.	GoodGuyBot represents a technological leap forward in security solutions for educational settings. It incorporates cutting-edge technologies such as AI, remote operation capabilities, and automated threat detection to provide a multifaceted approach to security. The system's use of 3D printing technology enhances cost-effectiveness and customization options. Overall, GoodGuyBot sets a new standard for safety and security in schools, empowering users to respond effectively to threats.	GoodGuyBot epitomizes adaptability and resilience in the realm of security solutions for educational settings. Its design seamlessly integrates into various school infrastructures while withstanding daily use and potential tampering. The system's non-lethal defense mechanisms provide an effective response to threats, prioritizing safety for all. Furthermore, GoodGuyBot's technological capabilities can be updated to address evolving security needs, ensuring its relevance and reliability over time. Overall, GoodGuyBot's adaptability and resilience make it a versatile and dependable security solution, enhancing safety and security in schools.	In conclusion, GoodGuyBot's innovative approach to security in educational environments provides valuable inspiration for our project. By leveraging 3D printing technology to manufacture most of the parts, we can achieve cost-effectiveness and customization like GoodGuyBot's approach. Additionally, adapting previous vehicles and repurposing materials aligns with GoodGuyBot's sustainable and resilient design ethos, ensuring that our project remains adaptable to various challenges and environments. Drawing inspiration from GoodGuyBot, we aim to create a robust and versatile solution that prioritizes safety while embracing innovation and sustainability in educational settings.

### Material Research

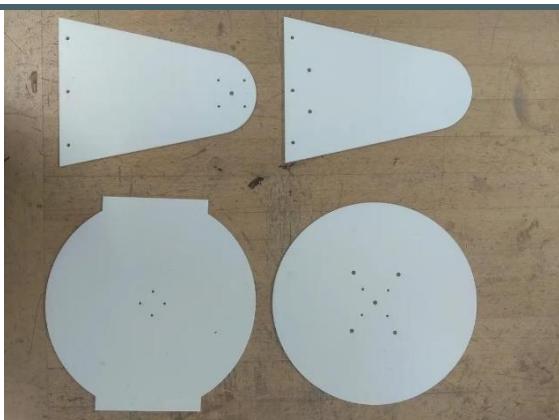
In our material research phase, we carefully evaluated various options for fabricating the components of our reconnaissance robot, ultimately opting to use acrylic instead of medium-density fibreboard (MDF) for laser cutting our parts. This decision was based on several factors. Firstly, acrylic offered superior strength-to-weight ratio and durability compared to MDF, making it well-suited for the rugged conditions our robot may encounter during reconnaissance missions.

Moreover, acrylic's compatibility with laser cutting technology offered precise and intricate fabrication capabilities, enabling us to produce complex shapes and designs with high accuracy and repeatability. This was crucial for achieving the desired functionality and aesthetics of our robot's components, such as the chassis, enclosure panels, and mounting brackets.

Furthermore, accessibility played a key role in our material selection process. By sourcing acrylic and steel from the school's resources, we were able to streamline production and minimise lead times, avoiding the need to order external resources which would have increased our carbon footprint through transportation and packaging. Leveraging the school's materials also allowed us to benefit from existing infrastructure and expertise, reducing costs and enhancing sustainability.

Through collaboration with the school's workshops and fabrication facilities, we were able to access a wide range of materials and machining capabilities, including laser cutting, pillar drilling, and 3D printing with polylactic acid (PLA). This enabled us to efficiently prototype, iterate, and manufacture our robot's components in-house, optimising production time and resource utilisation.

Overall, our decision to use acrylic for laser cutting our parts, coupled with access to materials and facilities provided by the school, exemplifies our commitment to sustainability, efficiency, and innovation in the development of our reconnaissance robot. By leveraging locally available resources and minimising environmental impact, we were able to realise our project goals while contributing to a more sustainable future.



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## Electronics Research

In our electronics research phase, we conducted thorough investigations into various components crucial to the functionality and performance of our reconnaissance robot. This included motors, batteries, microcontrollers, input-output devices, breakout boards, and programming software, among other elements. Our decisions were driven by considerations of functionality, efficiency, and compatibility with our project requirements.

For motor selection, we opted for stepper motors over servos due to their precise control and positional accuracy, which are essential for tasks such as navigation and manipulation during reconnaissance missions. Stepper motors offer finer resolution and are capable of precise incremental movements, making them well-suited for applications requiring controlled motion and precise positioning, such as navigating rough terrain or manipulating sensors.

In terms of processing power and control, we chose the Raspberry Pi 5 as our microcontroller platform. The Pi 5's quad-core processor, increased RAM, and enhanced connectivity options provided ample computational resources and versatility to handle complex tasks, including sensor data processing, navigation algorithms, and communication with external devices. Its open-source nature and extensive community support also facilitated rapid development and troubleshooting.

To interface with the stepper motors and other peripherals, we employed breakout boards to provide the necessary connectivity and signal conditioning. These breakout boards acted as interface modules, allowing seamless integration of the Raspberry Pi with external components while providing protection against voltage spikes and noise. By using breakout boards, we simplified the wiring and interfacing process, reducing the risk of electrical issues and ensuring reliable operation of the system.

Additionally, we meticulously evaluated various power sources to sustain the operational demands of our reconnaissance robot. Among these considerations, we opted for a Lithium Polymer (LiPo) battery over traditional Lithium-ion options. LiPo batteries were chosen for their exceptional energy density, compact form factor, and suitability for high-performance applications. Their lightweight nature and high discharge rates made them ideal for powering our robot, providing ample energy while minimising overall weight. This choice of battery not only ensured extended operational durations but also contributed to the robot's agility and manoeuvrability in the field. Additionally, LiPo batteries are rechargeable, offering the convenience of multiple use cycles, further enhancing the sustainability and efficiency of our robotic system.

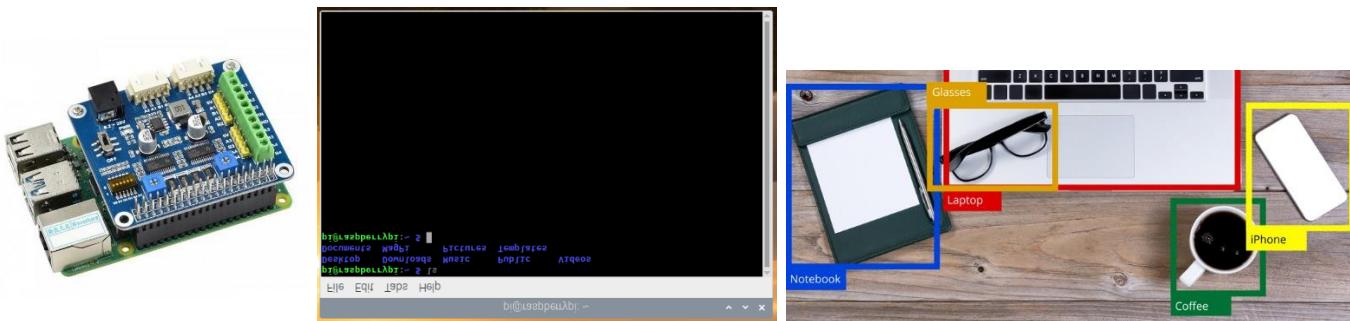
Overall, our electronics research and component selection were guided by the need for reliability, performance, and scalability in realising our reconnaissance robot's capabilities. Through careful evaluation and integration of motors, microcontrollers, breakout boards, and software tools, we were able to create a robust and versatile platform tailored to the demands of reconnaissance missions.

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## Software Research

In our software research, we focused on leveraging advanced artificial intelligence techniques to enhance the capabilities of our reconnaissance robot. A key aspect of this effort was the integration of TensorFlow, a powerful machine learning framework, to enable object recognition functionality. By harnessing TensorFlow's deep learning capabilities, we empowered our robot with the ability to autonomously identify and classify objects in its environment. This allowed for more sophisticated decision-making and situational awareness during reconnaissance missions, enhancing the robot's effectiveness and versatility in various scenarios.

We utilised a pre-trained model which is able to detect general objects such as vehicles, items of clothing, stationery and computing accessories. This allowed us to test the accuracy of the code used to control the stepper motors for object tracking.



## Environmental Impact Research

In our environmental impact research, we prioritised sustainability and eco-conscious practices throughout the project lifecycle. One key aspect of our approach was sourcing materials from local suppliers whenever possible, minimising transportation-related emissions and supporting local economies. By sourcing locally, we reduced the carbon footprint associated with the procurement of materials and promoted sustainable practices within our community.

Furthermore, our commitment to environmental responsibility extended to recycling and repurposing materials to minimise waste and conserve resources. An example of this was our decision to repurpose a broken RC car as the base for our Raspberry Pi and turret assembly. By salvaging components from the discarded RC car, we avoided the need to manufacture new parts from scratch, reducing both waste generation and the consumption of raw materials. This not only minimised our environmental impact but also demonstrated our innovative approach to sustainable engineering practices.

Overall, our environmental impact research emphasised the importance of adopting sustainable strategies and minimising waste throughout the project lifecycle. By prioritising local sourcing and recycling/reuse initiatives, we aimed to mitigate the environmental footprint of our reconnaissance robot while promoting a more sustainable approach to engineering and design.

## Sources of Materials

In our quest for sustainable and reliable sourcing of materials, we strategically leveraged resources available within our school environment. Our primary source of PLA, a biodegradable thermoplastic commonly used in 3D printing, was obtained from the school's supply, ensuring a consistent and dependable source of high-quality material. By utilising locally available PLA, we not only minimised transportation-related emissions but also supported sustainable practices within our educational community.

Additionally, our commitment to sustainability extended to the acquisition of steel components for our project. Rather than relying on newly manufactured steel, we opted to upcycle materials from old and disused models or projects within the school. This approach not only reduced the demand for new steel production but also diverted materials from the waste stream, promoting resource efficiency and circular economy principles.

Furthermore, our dedication to minimising environmental impact led us to explore innovative solutions for sourcing mechanical components. In a creative and eco-conscious effort, we repurposed a broken RC car model, salvaging usable parts and materials to breathe new life into our project. By repairing and recycling the RC car, we not only avoided the carbon emissions associated with manufacturing new components but also reduced waste and extended the lifespan of existing materials.

Through these sustainable sourcing practices, we were able to minimise our project's environmental footprint while ensuring the reliability and quality of our materials. By prioritising local resources, upcycling materials, and repurposing existing assets, we demonstrated our commitment to environmental stewardship and responsible project management.



# Purchasing Decisions and Budget Analysis

## 1. Servo Motors vs Stepper Motors

We had to decide between servo motors or stepper motors for the firing mechanism of our project.

### Cost Considerations:

Servo motors offer higher precision and control over position, speed and torque compared to stepper motors. This level of accuracy is instrumental for applications where precise movement control is required such as CNC machines. However, for a far lower average cost, stepper motors provide a cost-efficient solution for applications that do not necessitate the advanced control features of servo motors, such as torque control and precise synchronisation across components.

### Direct Cost Comparison:

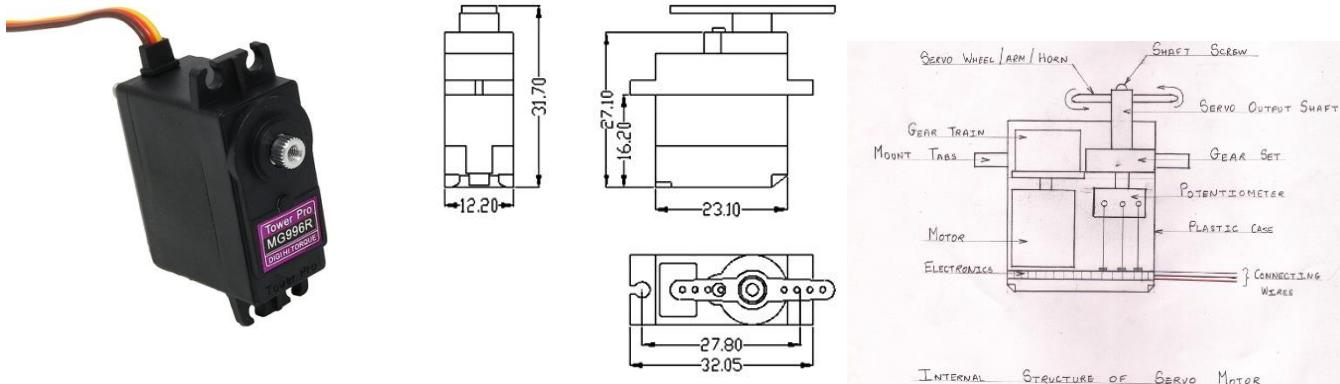
Average cost of servo motors: £25-40

Average cost of stepper motors: £10-25

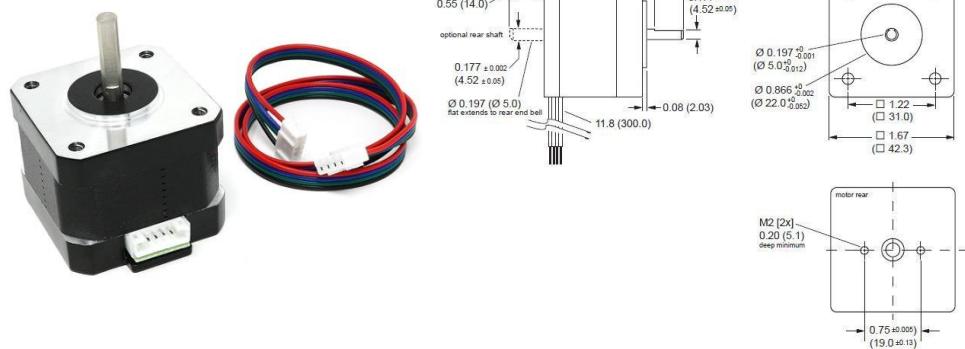
For the compromise of high accuracy and torque, the benefits of a stepper motor from its significantly lower cost far outweighs the benefits of servo motors for our specific project requirements.

### Decision:

We chose stepper motors over servo motors for our project.



Versus



## **2. Raspberry Pis vs Arduinos**

We had to decide between Raspberry Pis and Arduinos for the processing capabilities and computer control for the electronics of our project.

### **Cost Considerations:**

Raspberry Pis offer a more powerful processor, more memory, and more connectivity options compared to Arduinos. This makes them suitable for more complex projects that require advanced processing capabilities and connectivity to various peripherals. While Raspberry Pis come at a higher average cost than Arduinos, the additional processing power and features can provide significant advantages for certain projects.

The newest Raspberry Pi 5 specifications include a quad-core Arm Cortex A76 processor running at 2.4GHz, which was around three times faster than the previous generation. In comparison with an Arduino Uno, which uses a ATmega328P processor running at only 16 MHz, we absolutely required the Raspberry Pi's unparalleled processing power for the sake of real-time image processing capabilities in our project, despite the significantly higher cost.

### **Direct Cost Comparison:**

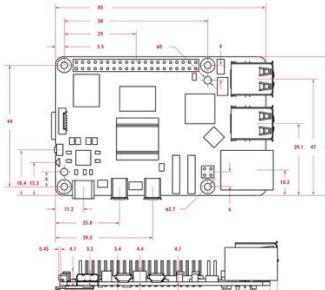
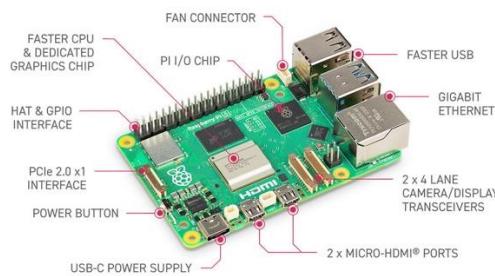
Average cost of Raspberry Pis: £30-50

Average cost of Arduinos: £5-25

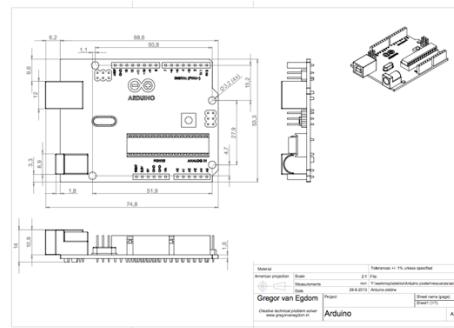
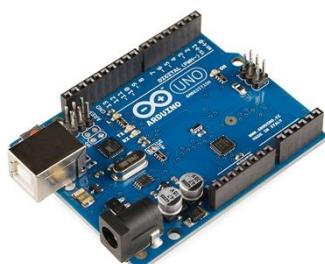
Considering the need for advanced processing capabilities in our project, the benefits of Raspberry Pis in terms of performance far outweigh the higher costs associated with them.

### **Decision:**

We chose Raspberry Pis over Arduinos for our project.



Versus



### **3. Web Camera vs Raspberry Pi Camera**

We had to decide between a web camera and Raspberry Pi cameras for the vision system of our project.

#### **Cost Considerations:**

Web cameras are available at more affordable prices and offer plug-and-play functionality, making them a cost-effective option for projects with budget constraints. On the other hand, Raspberry Pi cameras are specifically designed for use with Raspberry Pi boards and can be more expensive due to their specialised features, such as higher-resolution image sensors.

#### **Direct Cost Comparison:**

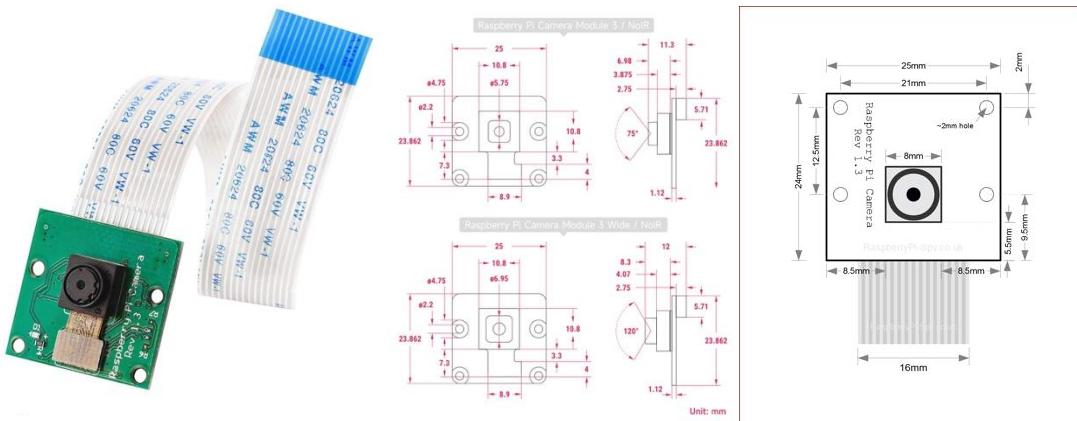
Average cost of a web camera: £5-15

Average cost of a Raspberry Pi camera: £10-25

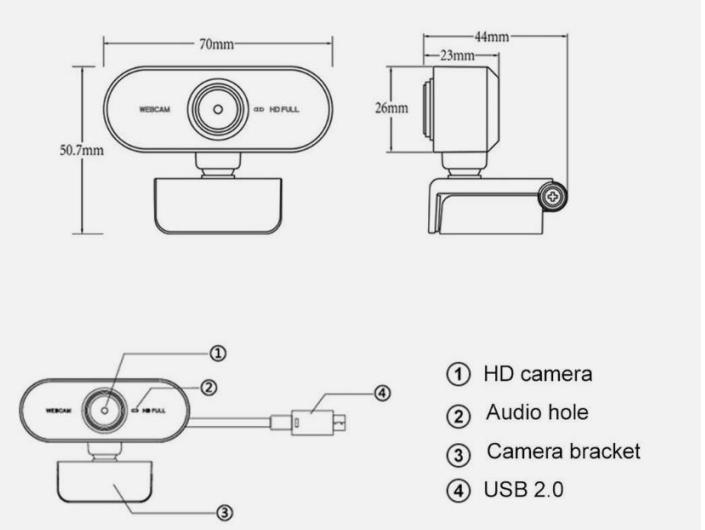
Given our limited budget and the need for a simple and cost-effective solution for visual input, the more affordable and easier to use web camera is a more suitable decision for our project.

#### **Decision:**

We decided to use a web camera for the visual input component of our project.



Versus



## 4. LIDAR vs Cameras

We had to decide between using LIDAR (Light Detection and Ranging) technologies and cameras for the sensing and imaging system of our project.

### Cost Considerations:

LIDAR technology offers accurate distance measurements by measuring the time it takes for light to travel to an object and back. However, LIDAR systems can be significantly more expensive compared to cameras due to the complex technology and components involved. On the other hand, cameras provide a more cost-effective solution for capturing images and videos with the potential for image processing and analysis – this is exactly what we needed for our image recognition systems to detect and lock on to targets on screen.

### Direct Cost Comparison:

Average cost of LIDAR sensors: £50-100  
Average cost of other cameras: £10-50

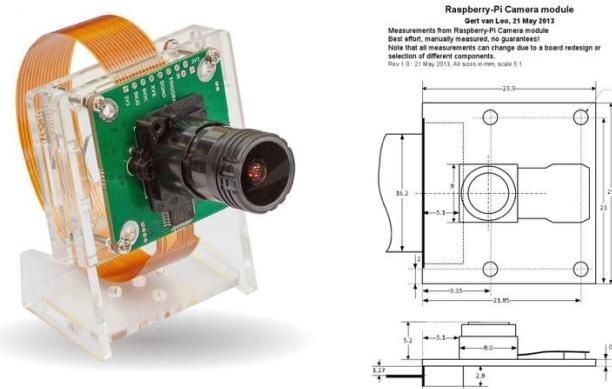
While LIDAR technology provides precise distance measurements, cameras offer more versatility in specifically capturing, processing and interpreting visual data. Additionally, LIDAR sensors have a restricted detection range and may struggle to capture data from objects that are far away.

### Decision:

We decided to use camera technology for sensing and imaging system of our project.



Versus



## **5. Manual Control (Radio Transmitters and Receivers) vs Semi-Automatic Control (Ultrasonic Sensors) for Rover Navigation**

We had to decide between manual control using radio transmitters and receivers and semi-automatic control using ultrasonic sensors for the navigation of our project.

### **Cost Considerations:**

Manual control using radio transmitters and receivers offers precise control over the robot car's movement, direction and speed which is reasonable for its overall cost. On the other hand, semi-automatic control using ultrasonic sensors can detect obstacles and avoid collisions autonomously. However, the cost of ultrasonic sensors and necessary components can be expensive compared to manual control options.

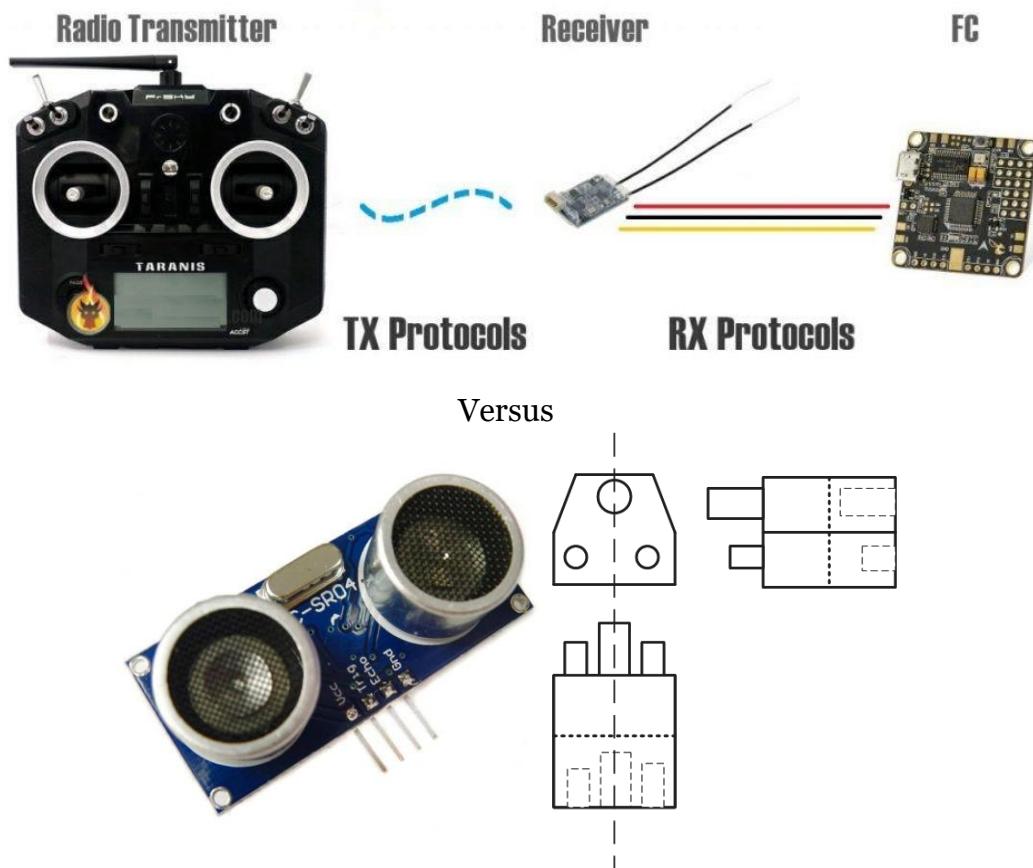
### **Direct Cost Comparison:**

Average cost of radio transmitters and receivers: £10-30  
Average cost of ultrasonic sensors: £20-40

The ability to have precise control over the robot car's movements and direction outweighs the added expense of ultrasonic sensors for obstacle detection.

### **Decision:**

We decided to use manual control with radio transmitters and receivers for the navigation of our project.



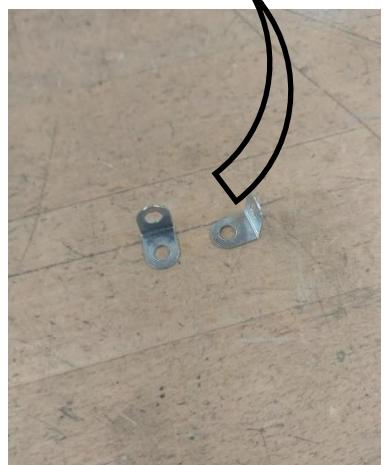
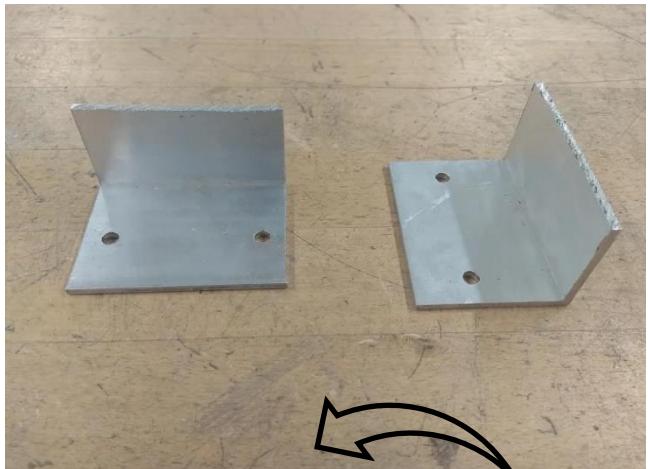
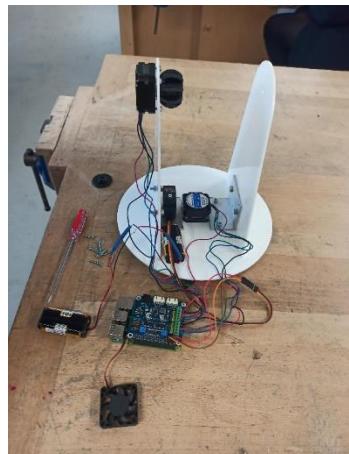
## Photo Diary

During the development phase, we initially incorporated smaller 90-degree metal brackets into our design, aiming to provide structural support and stability. However, as our project progressed, we encountered limitations with these brackets, realizing they were too weak to withstand the rigors of our intended application. Recognizing the need for a more robust solution, we sought alternatives that could offer greater strength and durability.

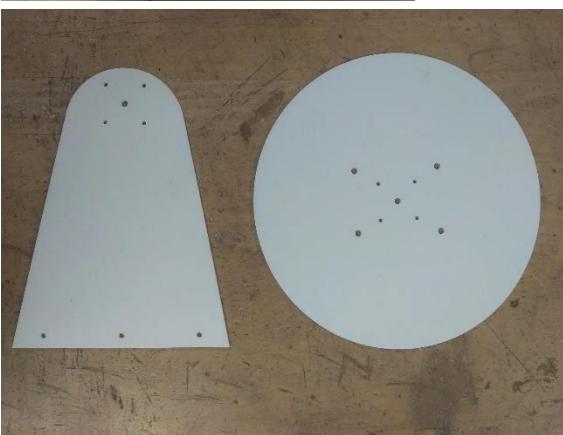
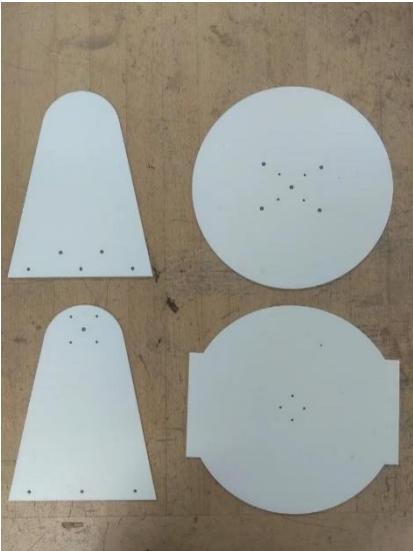
Upon careful consideration, we identified thick steel brackets as a suitable replacement, offering the necessary strength and resilience to meet our project requirements. To our advantage, we found an opportunity for upcycling these brackets from the tank treads of an old project, repurposing materials that would otherwise go to waste. Not only did this decision enhance the structural integrity of our project, but it also contributed to cost savings and environmental sustainability.

By repurposing existing materials, we not only reduced expenses associated with purchasing new components but also minimised our environmental footprint by diverting materials from landfills. This sustainable approach aligns with our commitment to eco-friendly practices and demonstrates our resourcefulness in finding innovative solutions to engineering challenges.

Ultimately, the transition to thick steel brackets upcycled from previous tank treads proved to be a beneficial decision, enhancing the strength and durability of our project while also promoting cost-effectiveness and environmental responsibility. This experience underscores the importance of adaptability and creativity in the development process, showcasing how simple yet thoughtful adjustments can lead to significant improvements in project outcomes.



In our project, we utilized the dimensions of the stepper motor to meticulously cut out accurately sized holes in acrylic using the laser cutter. This process involved a series of iterative design steps to ensure optimal fit and functionality. Initially, we carefully measured the dimensions of the stepper motor and incorporated these measurements into our 2D design files. We then proceeded to test the initial designs, cutting out prototype holes to verify their compatibility with the stepper motor.



Through iterative testing and refinement, we fine-tuned the dimensions of the holes to achieve a precise fit for the stepper motor. This iterative process involved making incremental adjustments to the design based on feedback from each test. We adjusted parameters such as hole diameter and spacing to ensure a snug fit without compromising the structural integrity of the acrylic components.

By continuously iterating and refining our designs, we were able to achieve a perfect alignment between the stepper motor and the acrylic components. This meticulous approach ensured that the stepper motor could be securely mounted in place, enabling smooth and reliable operation of our project. Overall, our iterative design process allowed us to leverage the dimensions of the stepper motor effectively, resulting in accurately cut holes that contributed to the success of our project.

#### **List of Parts Laser Cut:**

- Left Upright (Holes for Stepper Motor Fixing)
- Right Upright (Hole for Axle to Rest)
- Top Circular Rotary Base (90 Degree Bracket Holder Holes)
- Bottom Circular Base (Holes for Stepper Motor Fixing)

Our project journey involved meticulous iterations of 2D designs and precise measurements, facilitating the accurate laser cutting of components from white acrylic. Through multiple iterations, we refined our designs to ensure optimal fit, functionality, and aesthetic appeal. Each iteration allowed us to address any design flaws or inefficiencies, ultimately enhancing the overall quality of our project. By embracing this iterative approach, we maximized the efficiency of our laser cutting process, resulting in precisely crafted components that met our project requirements with precision and accuracy.

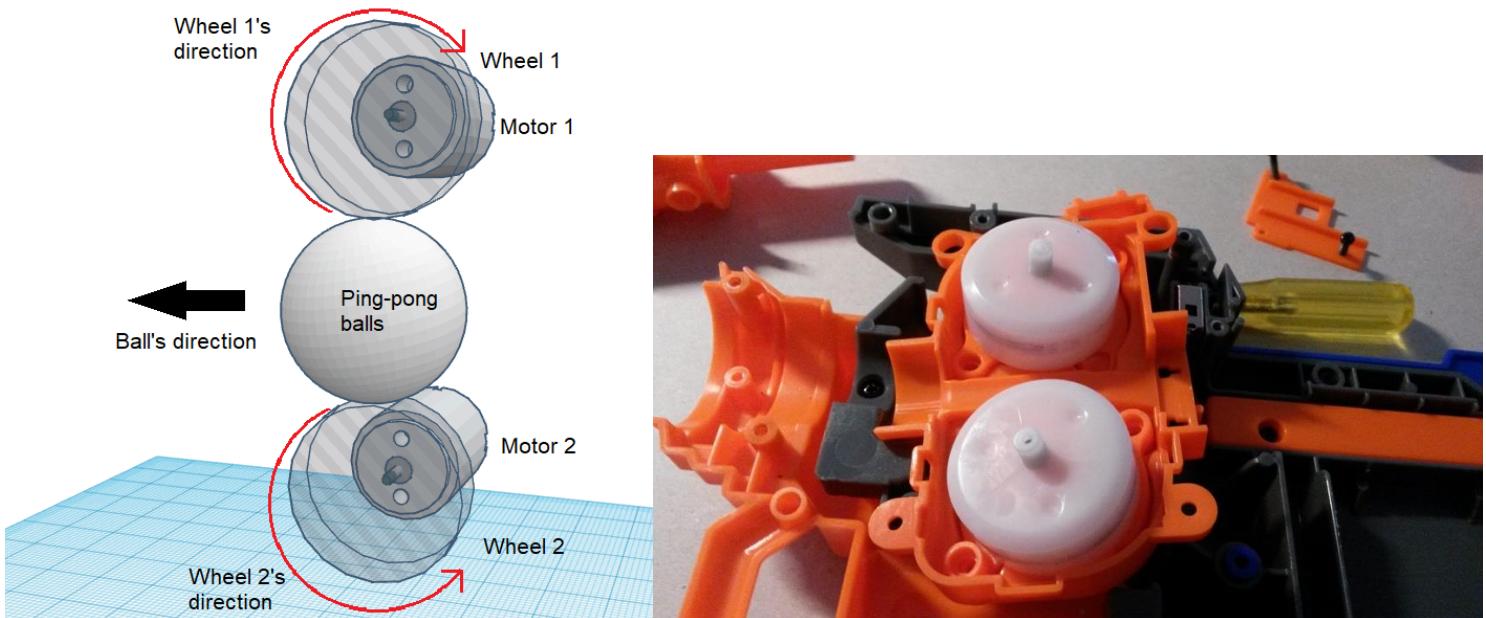
In the initial stages of our project, we explored the possibility of upcycling and repurposing a Nerf gun firing mechanism, which relied on stored elastic spring potential energy. This approach seemed promising as it offered a readily available and cost-effective solution for our project. However, upon closer examination, we realized that this mechanism had limitations that rendered it unsuitable for our purposes.



One major drawback we encountered was the limited firing capacity of the Nerf gun mechanism. Due to the nature of the stored elastic spring potential energy, the mechanism could only fire a single shot before requiring manual reloading. This limitation posed a significant challenge for our project, as it would restrict the effectiveness and efficiency of our reconnaissance robot, especially in dynamic and potentially dangerous situations.

Furthermore, we recognized that our project lacked the necessary facilities to produce enough torque to stretch the spring and store sufficient energy for multiple shots. Without the capability to overcome this technical hurdle, relying on the Nerf gun mechanism would ultimately compromise the functionality and reliability of our project.

As a result, we made the strategic decision to explore alternative solutions that could offer greater firing capacity and operational flexibility. While the Nerf gun mechanism initially seemed promising, its limitations highlighted the importance of thorough evaluation and consideration during the design phase of our project. Ultimately, this decision led us to pursue alternative mechanisms that better aligned with the objectives and requirements of our reconnaissance robot.

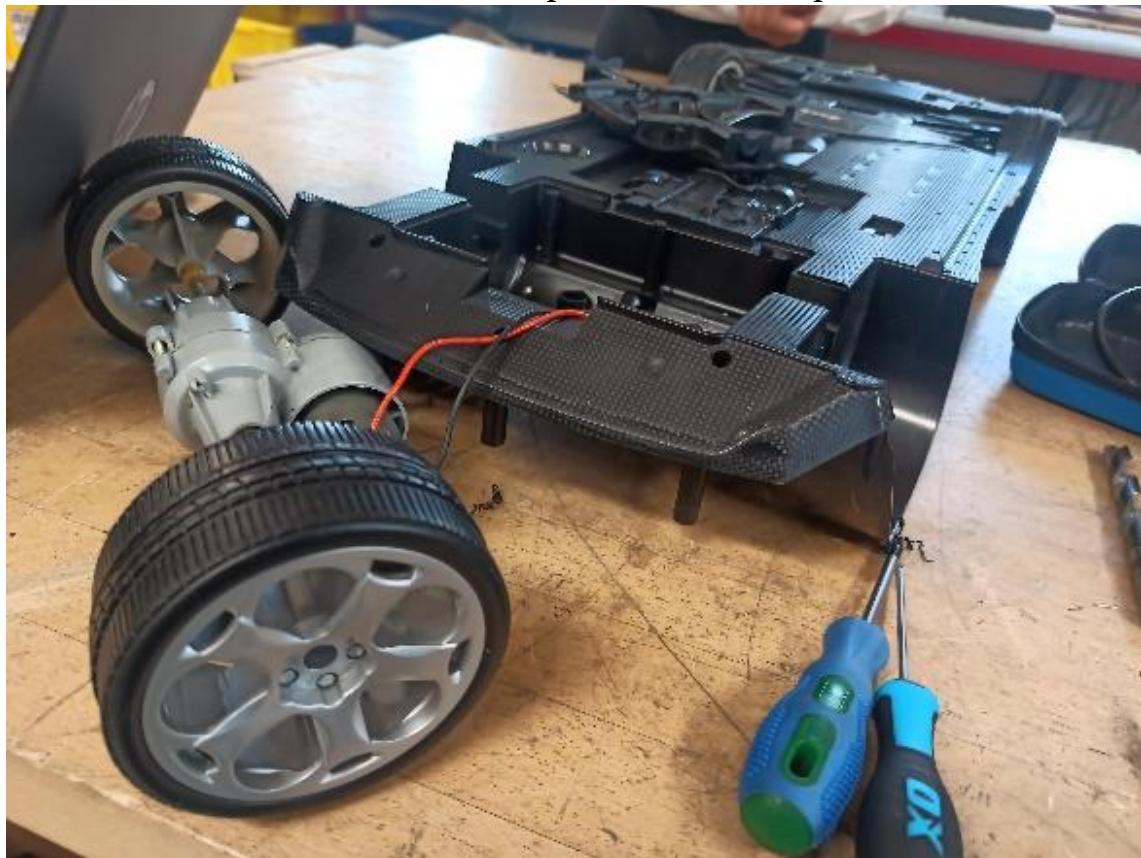


In response to the limitations of the Nerf gun firing mechanism, we opted for a different approach by implementing a flywheel mechanism coupled with a storage unit. This innovative solution allowed us to overcome the single-shot limitation of the Nerf gun mechanism and achieve the capability to shoot multiple Nerf darts.

The flywheel mechanism works by spinning rapidly, generating kinetic energy that can be transferred to the Nerf darts. We integrated a storage unit into the mechanism, which served to push the Nerf darts into the spinning flywheel. This setup enabled us to load multiple darts into the storage unit, effectively increasing the firing capacity of our reconnaissance robot.

By utilizing the flywheel mechanism in conjunction with the storage unit, we were able to achieve a rapid and continuous firing capability. This was a significant improvement over the single-shot limitation of the Nerf gun mechanism, allowing our robot to engage in sustained reconnaissance missions without the need for frequent manual reloading.

Overall, the decision to implement the flywheel mechanism with a storage unit proved to be a highly effective solution for our project. It not only addressed the limitations of the original Nerf gun mechanism but also provided us with a versatile and reliable firing mechanism capable of shooting multiple Nerf darts in rapid succession.



## Finalising Our Project

### Conclusion And Implications

In conclusion, our project has made significant advancements in the realm of movement, enhancing the rover's capabilities to navigate smoothly and efficiently. The incorporation of a new suspension system has played a pivotal role in ensuring that the rover moves seamlessly across various terrains, enabling it to overcome obstacles with ease and maintain stability even on uneven surfaces. This improvement has not only enhanced the rover's agility but also contributed to its overall reliability during reconnaissance missions.

Moreover, the inclusion of an antenna has greatly improved signal transmission, allowing for seamless communication between the rover and its controller. This enhanced connectivity has extended the range of remote usage, enabling operators to control the rover from considerable distances with minimal signal interference. This capability has proven invaluable in scenarios where remote operation is necessary, ensuring that the rover can be deployed effectively in a wide range of environments.

However, it is important to acknowledge that our project encountered a drawback related to the rover's turning capabilities. The limited space and turning radius of the front two wheels restricted the rover's ability to execute sharp turns, resulting in a smaller angle of turning than desired. While this limitation posed challenges in navigating tight spaces or executing precise maneuvers, it did not significantly impede the rover's overall functionality.

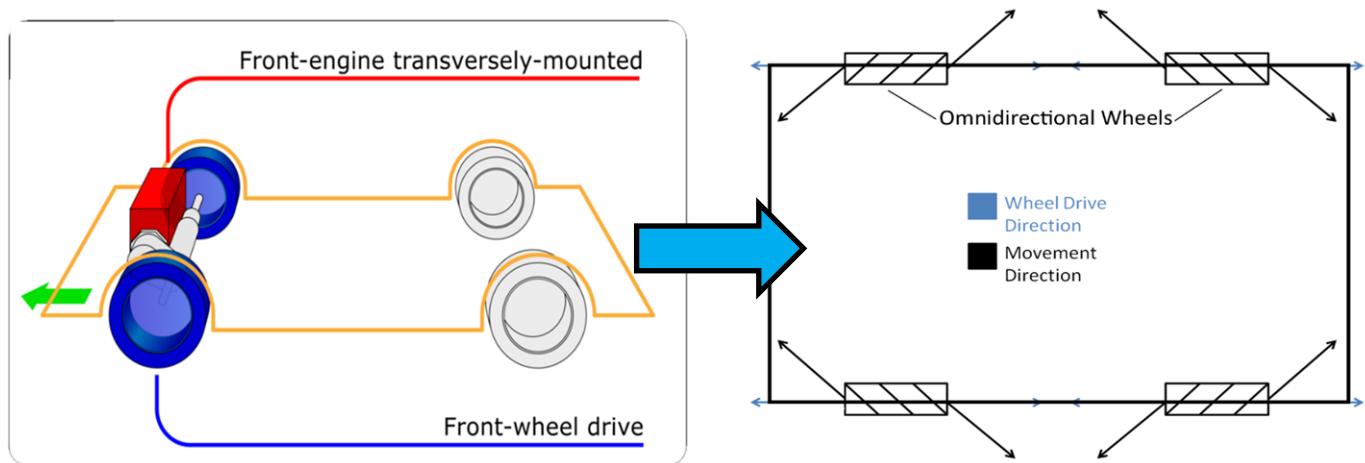
In conclusion, despite facing challenges, our project has succeeded in enhancing the rover's movement capabilities, ensuring smooth and efficient navigation across diverse terrain. While improvements can still be made, particularly in addressing the limitations of turning radius, the advancements achieved thus far represent a significant step forward in the development of our reconnaissance robot. With continued innovation and refinement, we are confident that our project will continue to make strides in improving movement capabilities and overall performance.

## Reflections

One of the most challenging aspects of our Sentry Rover project was attaching the camera module to the base of the turret's barrel. We encountered several obstacles during this process, including ensuring a stable and secure connection, maintaining a clear line of sight for the camera, and dealing with limited space constraints. At times, it felt like we were trying to force a square peg into a round hole, as the camera's mounting system didn't quite align with the turret's design. However, through persistence and creative problem-solving, we were eventually able to find a solution that worked for us. Looking back, I realize that this experience taught us the importance of flexibility and adaptability in engineering projects. It also highlighted the value of taking our time and thoroughly testing our designs before moving forward. By overcoming these challenges, we were able to develop a stronger and more resilient rover that can withstand the demands of real-world applications

## Potential Improvements

One improvement that can be considered for this rover is a change in the mobility mechanism i.e. how the rover moves itself. For a rover that currently uses 2-wheel front-drive, we can consider replacing this with omnidirectional wheels.



Omnidirectional wheels or poly wheels are wheels with small discs or rollers around the circumference which are inclined at an angle to the turning direction. These discs or rollers can rotate the entire body of the vehicle without changing the orientation of the wheel itself. The effect is that the wheel can be driven with full force, where many cylindrical rollers ensure that the wheel itself has a higher degree of freedom and manoeuvrability.

Omnidirectional wheels could prove advantageous over a 2-wheel front-drive mechanism with its flexibility in movement, as they can move in any direction (hence 'omnidirectional') without the need for steering mechanisms. An omnidirectional wheel mechanism offers a much smaller turning radius compared to 2-wheel front-drive wheels, making them far more manoeuvrable in the tighter spaces or environments.

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This can prove essential for missions where the target could be in unusually narrow spaces – the manoeuvrability of omnidirectional wheels would excel greatly in these scenarios.

Although omnidirectional wheels offer far superior mobility and traversal options than 2-wheel front-drive, there is the issue of stability and grip. Omnidirectional wheels have less surface contact and so, are more prone to slipping on angled or sub-optimal surfaces. In addition, omnidirectional wheels have far more moving parts which require regular maintenance, meaning this would be may only offer marginal benefit in dynamic, rough terrain. Concerning stability, omnidirectional wheel robots can achieve omnidirectional mobility with only three wheels – a save in cost and manufacturing time. This means that stability can be improved by increasing the number of wheels, which incidentally increases load-bearing capacity.

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Since stability and payload are essential in reconnaissance missions, it is important to consider omnidirectional wheels as a possible opportunity to greatly increase the manoeuvrability of the rover.

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## Project Wide Criteria

### Understanding Of the Science Behind the Project

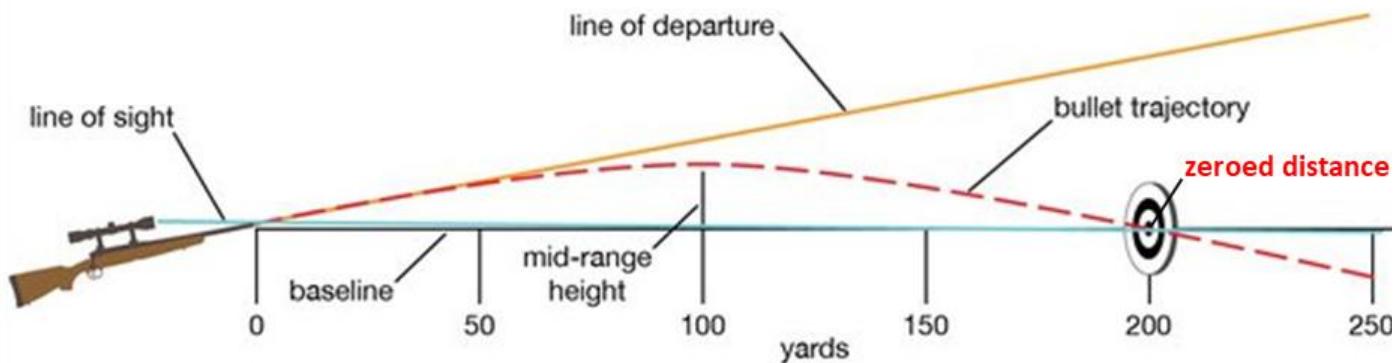
The turret on the rover utilises a spring-loaded firing mechanism inspired by Nerf toy guns to launch foam darts with precision. This system harnesses the potential energy stored in the spring to propel the projectile towards the target. The mechanism is designed to release the spring at the precise moment to achieve optimal velocity and accuracy in targeting. This simple yet effective system allows for reliable and consistent firing capabilities on the rover.

Also, it's important to aim above the target to compensate for the vertical height lost whilst the projectile is travelling some distance. This is due to the effects of the gravitational pull of the Earth - any projectile weapon we use is going to be affected by gravity. Even a fast-moving bullet is still pulled down in an arc as it travels.

For genuine firearms, when the bullet leaves the barrel of the rifle, it also follows a parabolic path. Though, in order to hit a target at some distance, the scope or the sights are calibrated in such a way that when the rifleman directly aims at the target and takes a shot, the bullet will hit the target. The calibration of the sight is called zeroing. The scope points below the barrel axis, i.e. the line of departure. Gravity bends the bullet's path downwards. A rifleman adjusts the scope to aim correctly at one specific range - zeroing at specific distance. At other ranges, you must aim above or below your target.

For example, if the sight is zeroed to 200 yards, it means if you aim directly at a target 200 yards away, the bullet will precisely hit the target without any vertical compensation:

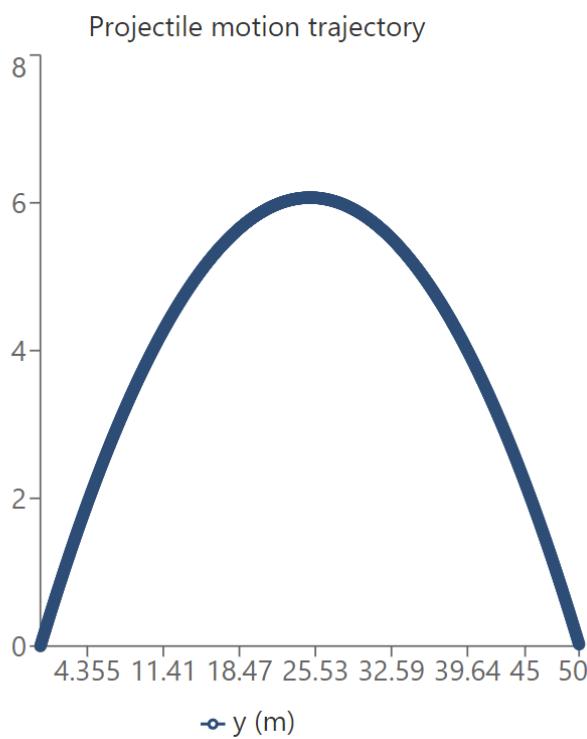
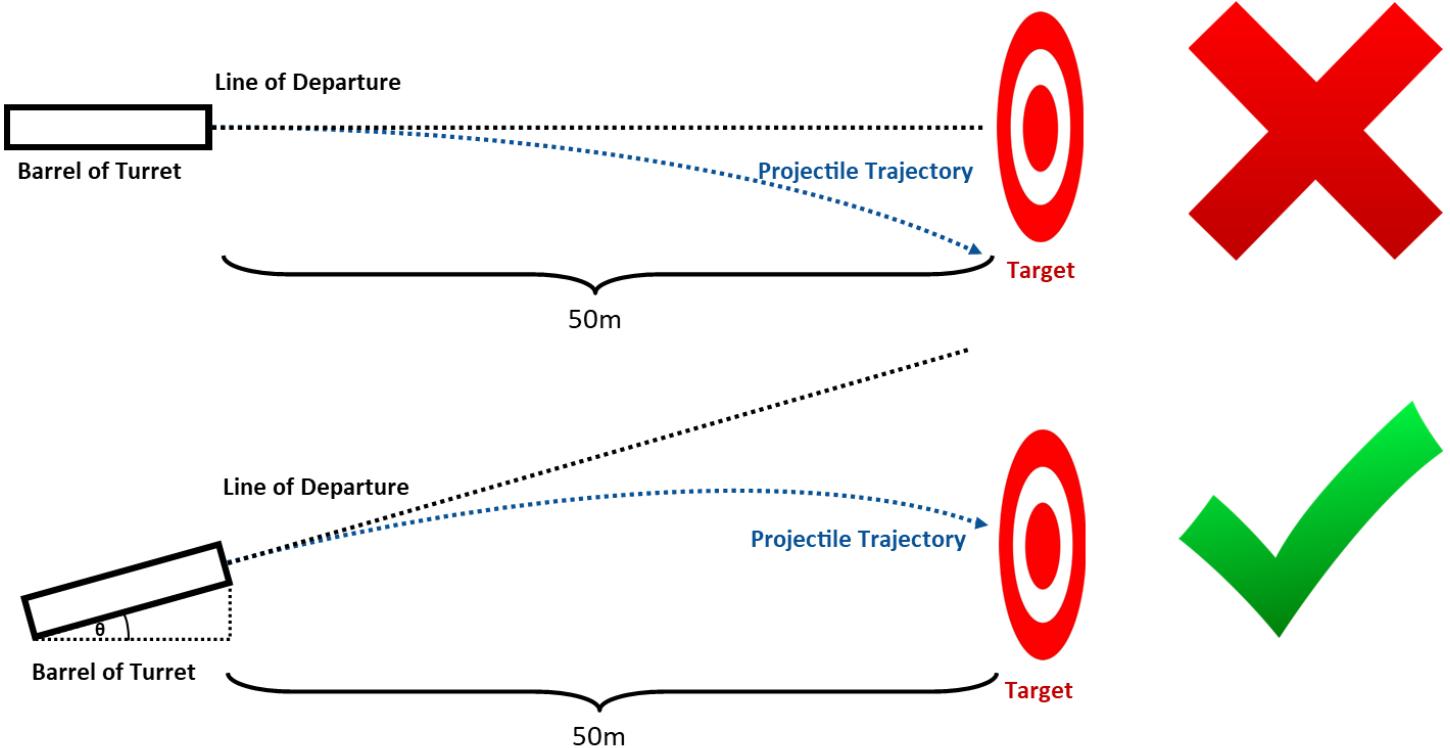
#### Elements of a trajectory



Therefore, we must compensate for the bullet drop by aiming a little higher. When zeroed, the line of departure (the direction of the barrel) must aim higher than the line of sight (the sight through the scope) in order to hit a target at a specified range.

However, our rover turret does not have nor need a scope. This is because our rover turret is required to detect, aim and fire at targets at variable ranges. Therefore, this means we need to calculate the angle between the plane of the level ground and the line of departure from the barrel of the firing mechanism.

For example, if the target is 50 metres away from the barrel of the firing mechanism, you need to find the angle  $\theta$ , to aim up by.



By understanding and compensating for factors that influence the projectile's trajectory, the turret can enhance its targeting capabilities and increase the likelihood of hitting the intended mark.

## Safety And Ethical Issues and How They Were Resolved

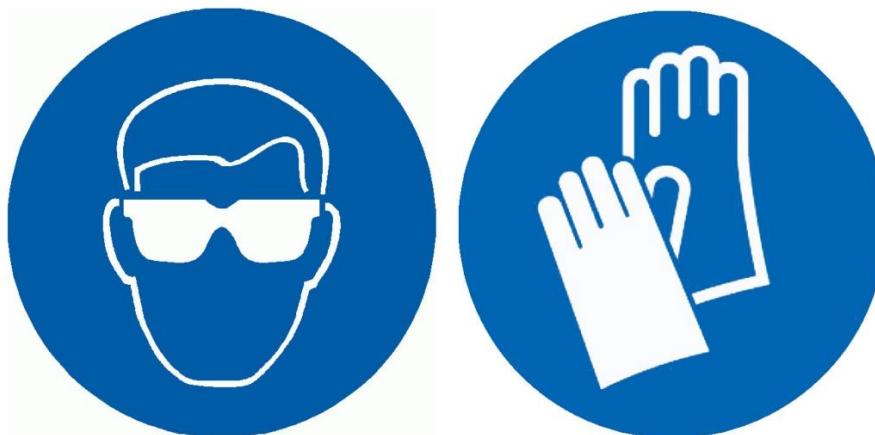
Throughout the manufacturing process of our project, safety considerations were paramount to ensure the well-being of our team members and mitigate potential hazards. When utilising heavy

machinery such as the laser for laser cutting components, stringent safety protocols were implemented. Trained professionals always supervised the operation, and machinery was never left unattended. We were acutely aware of the risks associated with interacting with the laser, including exposure to infrared radiation if the interlock mechanism of the door failed. To mitigate this risk, we refrained from lifting the cover while the laser was running, ensuring direct eye contact with the laser was avoided. Additionally, machinery was only activated when the cover was securely in place, and we refrained from lifting it until the cutting process was completed, as indicated by a 'READY' light on the control panel. Furthermore, we allowed the acrylic material used for laser cutting to cool down for a few minutes to minimise the risk of burns to our hands and fingers due to the high temperatures involved.

In addressing safety concerns related to 3D printing, we were attentive to the risks associated with hot equipment. We implemented protocols to handle hot surfaces and components with care, including the use of protective gloves and proper ventilation to mitigate the risk of burns and exposure to fumes. Additionally, when working with a LiPo battery, we adhered to safety guidelines to prevent potential hazards such as overheating, short-circuiting, or battery swelling, which could lead to fires or explosions.

Furthermore, the design of our reconnaissance robot incorporated moving parts, which posed potential risks of entrapment or injury if not properly managed. To address this, we conducted thorough risk assessments and implemented safety features such as protective enclosures, emergency stop mechanisms, and clear warning labels to mitigate the risk of accidents or injuries.

From an ethical standpoint, we carefully considered the implications of equipping our robot with a high-powered turret, acknowledging the potential for harm if misused. As a responsible and ethical decision, we opted to repurpose the turret for data collection purposes, utilising it as a platform for a camera instead of a weapon. This choice aligned with our commitment to ethical design practices and responsible use of technology, ensuring that our project prioritised safety, accountability, and positive societal impact.



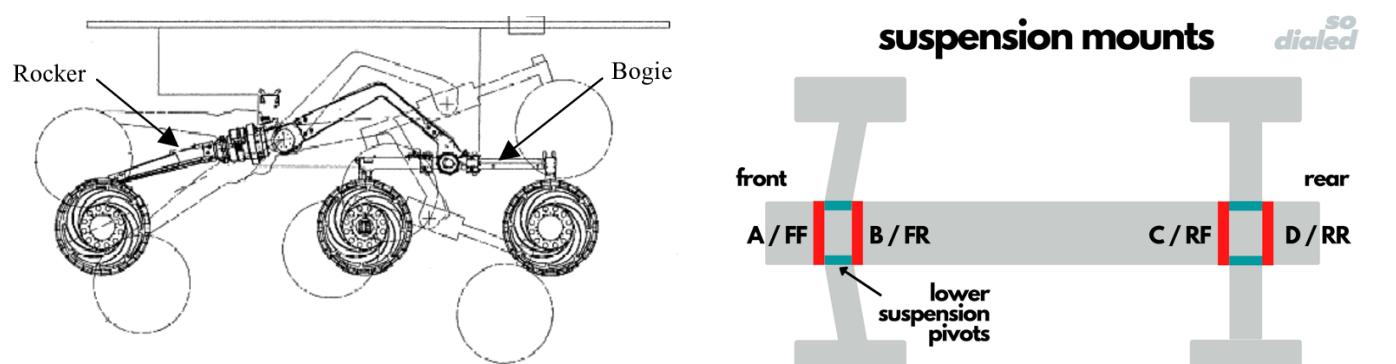
## Creative Thinking

Much of our creative thinking has stemmed from our initial prototyping and ideas process. For example, with inspiration from the typical mechanism of a Nerf gun. We took this idea and modified the firing mechanism of the trigger. For example, we simplified the mechanism such that the gun would fire using a snail CAM shaft instead. This process is referred to as iteration or refinement: we made incremental changes to improve upon the initial idea of the Nerf firing mechanism to simplify into the snail CAM shaft mechanism instead, which made engineering and producing this idea far easier due to its high feasibility.

Regarding sensor technology, we chose to opt for camera vision with a Raspberry Pi camera as opposed to other ultrasonic sensors, infrared sensors, cameras, or LIDAR. We chose a camera over general sensors because we realised the key advantage that computer vision grants: the capacity for intelligent decision making (such as object recognition). This feature easily enhances the versatility and applicability of our rover to be able to achieve our main goal: to target specific objects in a dynamic, changeable setting.

Furthermore, the incorporation of wheels inspired by the rocker-bogie mechanism used in NASA Mars rovers increases our rover's mobility across all terrains - terrains which are not constant. High mobility is imperative to be able to traverse any setting with mitigated risk of damage or getting stuck. The rocker-bogie suspension system allows for improved stability and traction on uneven surfaces.

However, it is important to evaluate this specific design choice over a typical 4-wheeled suspension, as a rocker-bogie mechanism for the sake of high mobility compromises simplicity and our budgeting, not to mention its susceptibility to easily suffering damage whilst out traversing dynamic terrains.



## Identifying and overcoming problems successfully

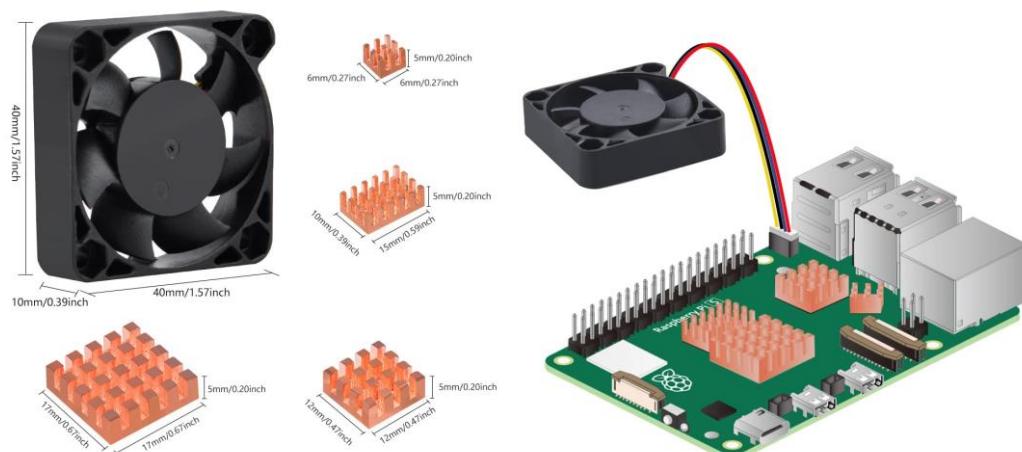
Throughout our project journey, we encountered numerous challenges with the Raspberry Pi, ranging from unexpected overheating issues to hardware failures. The situation exacerbated when the Raspberry Pi suddenly overheated and malfunctioned, leaving us without a fully operational device. This setback was compounded by the failure of the Raspberry Pi camera, as well as the unsuitability of an alternative web camera due to its low quality and blurry output. Undeterred by these obstacles, we resolved to overcome them by procuring a new Raspberry Pi 5, optimistic that this replacement would help us address our issues and propel our project forward.

In addition to hardware challenges, we grappled with uncertainties in the AI software, particularly regarding object recognition accuracy. To address this, we implemented a counter to measure the level of uncertainty in the AI predictions, allowing us to gauge the reliability of the system's outputs and make informed decisions based on confidence levels.

Furthermore, iterative refinement was crucial in optimising the design and functionality of our turret assembly. We experimented with various configurations and materials for the uprights of the turret, aiming to achieve the optimal balance of stability, range of motion, and weight distribution. This iterative process allowed us to fine-tune the design iteratively, ensuring optimal performance and reliability in the field.

To mitigate overheating issues with the Raspberry Pi, we incorporated a heat sink into the system to dissipate excess heat and maintain stable operating temperatures. This proactive measure helped alleviate thermal stress on the Raspberry Pi, ensuring uninterrupted operation and prolonging the lifespan of the device.

Moreover, we recognised redundancy in allowing both the turret and the car to rotate independently. To streamline functionality and optimise efficiency, we reconfigured the system so that only the car could rotate, simplifying the mechanism and reducing unnecessary complexity. This strategic adjustment enhanced the overall performance and usability of the reconnaissance robot, aligning with our goal of maximising functionality while minimising resource expenditure.



## Project Summary

We designed and built a Sentry Rover that utilises object recognition and remote control to detect and target specific objects. The rover is equipped with a camera module that uses TensorFlow's object recognition capabilities to identify objects within its line of sight. Once an object is recognized, the rover can be controlled remotely to move towards it and use its 'eyes' (camera) to track the object. The rover's advanced computer vision capabilities enable it to lock onto the object and adjust its trajectory, accordingly, allowing for precise targeting. The rover's ability to recognize objects and adapt to its surroundings demonstrates the potential for automation and precision in various fields such as surveillance, search, and rescue, and even space exploration. Through this project, we learned about the applications of computer vision and machine learning in robotics and gained hands-on experience with programming and building a complex robotics system.

## Personal Reflections

### **Alexander Eklund:**

Before the Gold CREST I had very little knowledge of the design and construction process of making a physical project. But I can say now that I will leave with a much greater knowledge of how the whole process works. This has been not just a project but an educational experience. I first learnt how to use 2D design and used this new skill in the construction of many parts of the project. I used my previous knowledge of physics and maths with my newfound knowledge of 2D design in order to make the stand that holds the weapon system. I also managed to construct a suspension that was previously non-existent. Additionally, I learnt the basics of line bending and 3D model which was pivotal in creating the initial prototypes. Overall, this has been a stressful yet very enjoyable process in testing and creating the final model.

### **Isabel Ogabeide-Ihama:**

One of the Primary areas I focused on was the electronics of the rover turret. Utilising my prior coding experience and electronics skills, I made significant contributions to the team, bridging the gap between hardware and software. This allowed me to participate in both the physical build and computational aspects of the project. Throughout this experience, I developed industry-specific skills and project management abilities. Working with a Raspberry Pi was a new challenge, but with team collaboration, we successfully applied existing knowledge to create a trained model for object recognition using OpenCV. I'm excited to apply these skills in future engineering projects, further developing my abilities in image processing and analysis. This project reinforced my passion for electronics and gave me a clearer vision of my future career.

### **Mahfuzur Rahman:**

Having leveraged my previous coding skills developed through personal projects, coupled with my electronics skills from GCSE studies, I have been able to greatly contribute to the electronics and programming side of the team. This has enabled me to have a role in both the physical manifestation of the project and the behind-the-scenes computation. The CREST Gold project has helped me to develop industry-specific skills in addition to project management skills. I believe this. Having not used a Raspberry Pi before, this was a new experience for me. However, with the help of other team members, we were able to tackle this feat and apply existing knowledge to what seemed to be a new concept. Regarding the coding side, I learnt about machine learning and creating a trained model for object recognition with the use of TensorFlow and OpenCV. I hope to utilise this knowledge and the skills gained from the project in future engineering endeavours.

### **Orianne Otchere:**

Completing the Gold CREST EDT project has been a transformative experience for me. It has given me an excellent platform to apply and develop my skills in electronics and coding to real-world application. Initially I found it difficult to work with the electronics, as it was my first time, however as the weeks went by through my own research of circuit design principles, I was able to get a stronger grasp of the techniques and skills needed. This taught me the importance of thorough planning and testing in electronics. In my opinion, coding on the Raspberry Pi was the most enjoyable part of my tasks, given that I plan to be a software engineer. Developing the software to control the turrets movement and additional features like human detection required a more in-depth understanding of Python than what I have been taught during my school years, but I thoroughly enjoyed the challenge!

### **Zain Kramutally:**

Throughout this project, I had the opportunity to delve into the world of 3D printing and 2D design, where I gained hands-on experience with software such as SOLIDWORKS. I learned the basics of design principles, including line bending and shaping acrylic pieces, which allowed me to create a functional prototype for the project. However, I was also exposed to more advanced concepts, such as machine learning and computer vision, specifically TensorFlow and object recognition. Although I didn't have the chance to fully explore these topics, I was fascinated by their potential applications and would have liked to contribute more to the software to further develop my understanding of these cutting-edge technologies. Despite this, my experience with design and 3D printing allowed me to appreciate the complexity and versatility of modern manufacturing techniques, and I look forward to further exploring the intersection of technology and design in future projects.

### **Aman Varshney:**

I joined this Gold CREST Awards scheme with very little experience and yet I'm proud to say that I'm leaving with applicable real-world engineering, budgeting and planning expertise as well as the management of intricate technological equipment. Some of the things I constructed was the modelling of the turret shooting mechanism, multiple 3D sketches of designs and detailed plans of the electronic circuitry involved. During my time I was faced with numerous, unexpected challenges testing my decisiveness, critical thinking and leadership ability allowing me to recognise the day-to-day struggles engineers face. I look back on these difficulties and am grateful that they have enhanced my social skills as a manager of this project, and I look forward to utilising this wonderful experience to better manufacture my future projects and further develop my engineering prospects.

### **Daniyal Amir:**

To reflect, I am proud of the result and the skills I developed throughout the process. One of the most enjoyable aspects of the project was designing and building the car's sentry uprights and base, as it required me to think creatively and troubleshoot problems. I also learned a great deal about CAD (computer-aided design), such as learning how to use the 3D modelling software SOLIDWORKS and 2D software like 2D Design V2. Using that modelling software, I feel like I have learnt a valuable skill that, on the condition that I pursue further engineering-based projects, I may use in potential future design and technology projects to come.