Manufacturing
Technology Centre

MTC UK

Robocup Rescue Team Description

PMO-004-F6

Foreword

This paper has been constructed to highlight:

- The contribution that the MTC apprentices can make to the competition

- Design iterations of our robot and the design solutions

- Signification contributions to the apprentice cohort skills and competencies

- Areas for enhancement include;

- Technical

Our design will be modified as problems occur and new solutions are found

- Commercial

We shall be endorsing our own company during the competition to showcase the capability the MTC has to train hard working and knowledgeable apprentices that can compete with some of the world's leading graduates.

- Interpersonal

The project has made the apprentices a much closer team and has also improved their communication skills by liaising with engineers or speaking to suppliers who have more knowledge and expertise in certain aspects of the project.

- Community awareness

This project will be showcased as an apprentice project, it will be used on the MTC stands at STEM events to show young people how interesting engineering really is.

The project will be sustained by a continuous budget if the team performs well enough. With this being our first year, the budget is smaller as the apprentices need to prove their worth on the project.

Table of Contents

1 Introduction

This year the MTC is designing and manufacturing an Urban Search and Rescue robot for competing in the 2016 Robocup Rescue competition.

This is a project that the MTC is looking to participate in on an annual basis, with the aim to develop our apprentice's technical ability and management skills.

The team is given the responsibility to manage a development budget, offering great experience for their future roles within the business. The project is structured in line with the MTC's project delivery process and the team is required to report the project progress in the same way they would if this were an industrial client project.

This responsibility includes planning the project expenditure and costs to completion.

Bi-weekly progress meeting with senior managements and regular team meetings support their development in understanding how to interact with stakeholders and other business units.

The technical development of the team will enable them to complete the manufacturing of the robot platform by utilising the advanced manufacturing equipment housed at the MTC. Complex machining of parts such as the gears which will be all be performed by the team as well as all the manufacturing planning and scheduling. The design sub-team must develop advanced skills in CAD systems and electronics to support their complex CAD model assembly.

During the project duration each member of the team will be given responsibilities within sub-teams to ensure the project continues to progress and has suitable focus on all the critical features of the robot design. These sub-teams include machining/manufacturing, design (chassis, drivetrain and arm), electronics systems (including sensory capability) and administration and events.

Manufacturing Technology Centre

The MTC has been established to prove innovative manufacturing processes and technologies in an agile environment in partnership with industry, academia and other institutions. The MTC houses some of the most advanced manufacturing equipment in the world, creating a high quality environment for the development and demonstration of new technologies on an industrial scale. This provides a unique opportunity for manufacturers to develop new and innovative processes and technologies.

The MTC is at the forefront of automation technology and the developing engineers and technicians deployed across the business are immersed in the development of automation solutions for the most challenging and testing business applications. The Robocup team is drawn almost exclusively from the MTC technical apprentice community. This competition provides the perfect opportunity to demonstrate their skills, commitment and emerging competence in the field of robotics and automation.

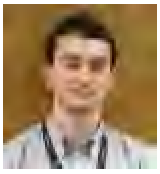
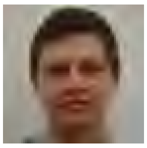
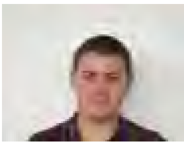
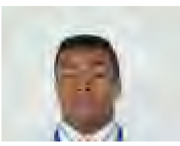
Presently, across the United Kingdom the profile and the contribution of the apprentice community has never been higher. This is the perfect opportunity for the MTC apprentices to highlight their contribution, enhance their technical skills and benchmark their abilities against teams from across the world.

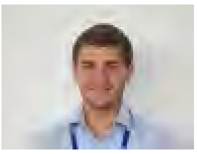
The competition will not only test the technical abilities of the trainees, the nature of the project will see their communication and interpersonal skills develop as they meet the challenges of a complicated and resource intensive competition.

The organisation invests heavily in the development of the engineering profession, this is demonstrated by the strategic imperative “to create and embed skills” being at the forefront of the MTC’s drive to enhance the capabilities of the manufacturing industry, and, importantly its people.

The competition has captured the imagination of Directors, Senior Managers and Members. Companies such as Makita have already donated equipment to support the build.

2 Meet the team

Role in team	Team Member	Skills	Job role
Project lead	 James Cox	CAD design, producing engineering drawings, CNC machining	James is a 4th year apprentice who was nominated by the team to take the lead on the project, deciding the next steps in the project and ensuring everything falls into place.
Project support	 Adam Land  Matthew Foster	CAD design, producing engineering drawings, vast amount of CNC machining experience CAD design, CNC machining,	Adam is our Workshop Technical Manager at the MTC. He has a wealth of knowledge and experience in manufacturing engineering, which has crucially helped us with our design. He was also a previous member of the Warwick Mobile Robots (WMR) team back in 2011. Matthew is now a research technician after completing his advanced apprenticeship. He is now assisting the team by using his knowledge to influence the teams design ideas.
Robot head	 Elliot Brooks  Shaun Duncan	CAD design, 3D printing CAD design, metallurgy	Elliot and Shaun are both 3rd year apprentices who have very limited knowledge on cameras but have researched hard and found suitable camera ideas to use. They have also used their CAD design skills to design the robots head and gripper.
Robot arm	 Shaun Smith	CAD design 3D printing	Shaun and Dale are both 3rd year apprentices who have had no experience working with robotic arms but have researched and developed knowledge on how to make the arm twist and bend

	 Dale Stratford	CAD design Metrology	efficiently to reduce surface areas to make the robot more streamlined.
Chassis/tracks	 Dale Armson  Connor O'Dowd	CAD design 3D printing Wire EDM CAD design CNC machining	Dale is a 3rd year apprentice and Connor is a 4th year apprentice. Both of them have been tasked with designing the robot's tracks and making changes to the chassis to accommodate other components on the robot. They have met with the track supplier who were more than happy enough to support us in our goal to create our robot for search and rescue purposes and push the boundaries.
Drivetrain	 George Slater  David Earles  Rhys Scott	CAD design CNC machining CAD design Laser CAD design CNC machining Manual machining	George is a 4th year apprentice. David and Rhys are both 3rd year apprentices. David has had some experience working with motor technology whilst completing small side projects in his spare time. The trio felt they could step up to the tasks of deciding which motors would suit our robot and how they will be accommodated in our robot's design.
Electronics	 Jonathon Burcham	CAD design and assembly Electronics	Jonathon is a 3rd year apprentice. He's been using his skills on Siemens NX CAD software to design the robot and the joints needed to make the arm and gripper move efficiently. He has also been tasked with working out where all of the robots electronics will go and how they will work.

Logistics	 Michael Barrett	CAD design CNC machining Manual machining	Michael is a 3rd year apprentice. He took on the tasks of administration, from project plans and ordering materials to ensuring we are all kept up to date with the competition details.

We've also had some help and support from previous Robocup Rescue competitors who are working in our Intelligent Automation theme area at the MTC.

3 Our progress:

Below is a screenshot of our initial robot design:

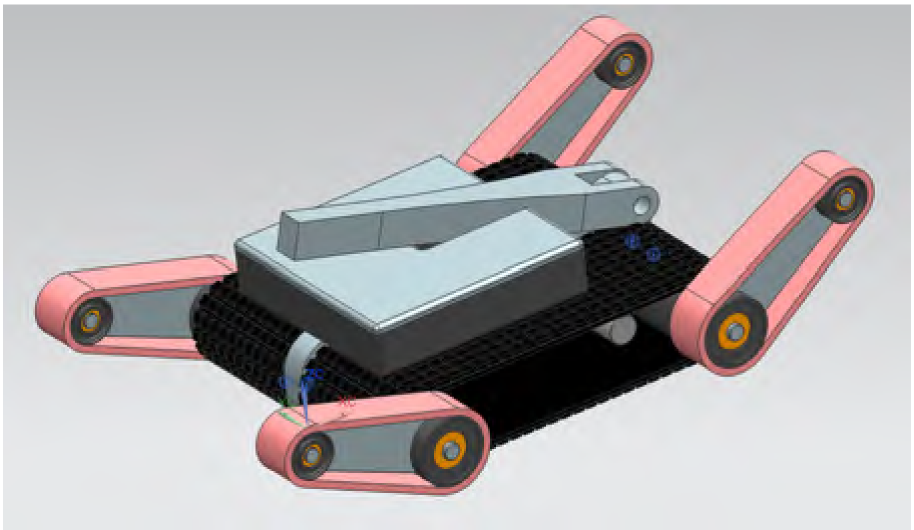


Fig 1

Below is a screenshot of our current robot design:

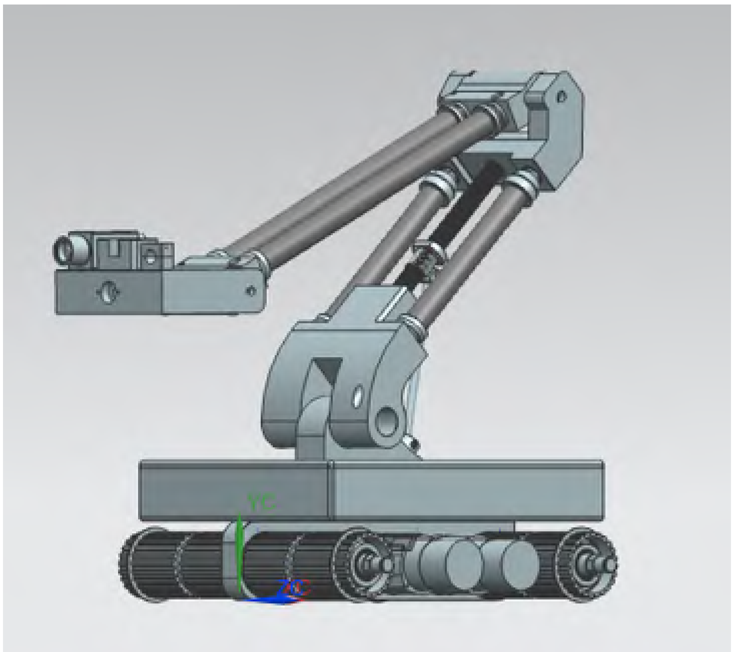


Fig 2

It is based around a 30mm wide central chassis plate upon which all the other components are based. This means the robot has very little chance of getting 'beached' on obstacles. This is why we believe our robot will be highly competitive in the mobility areas of the course.

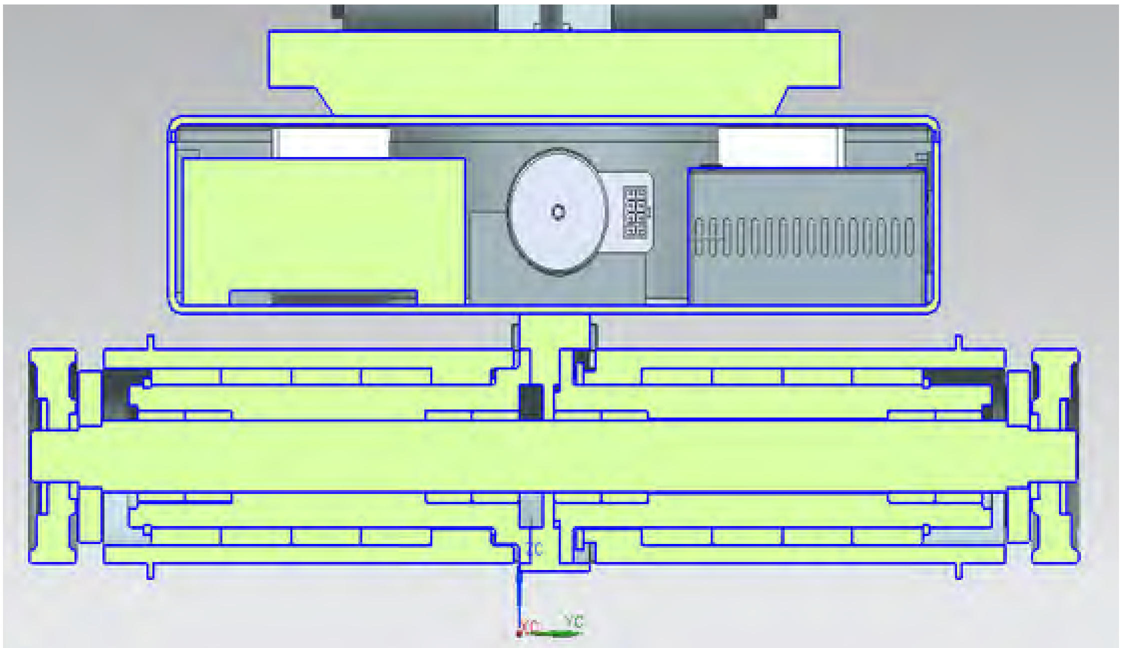


Fig 3

This section view shows how the robots various shafts all work. The flipper shaft is located on bearings that are housed in the stub shafts which are attached to the central chassis plate. There is another set of bearings between the stub shafts and the 75mm diameter 150mm wide track pulleys. This means all of the shafts will move very freely and we will have a reduced loss between the drive motors and the tracks.

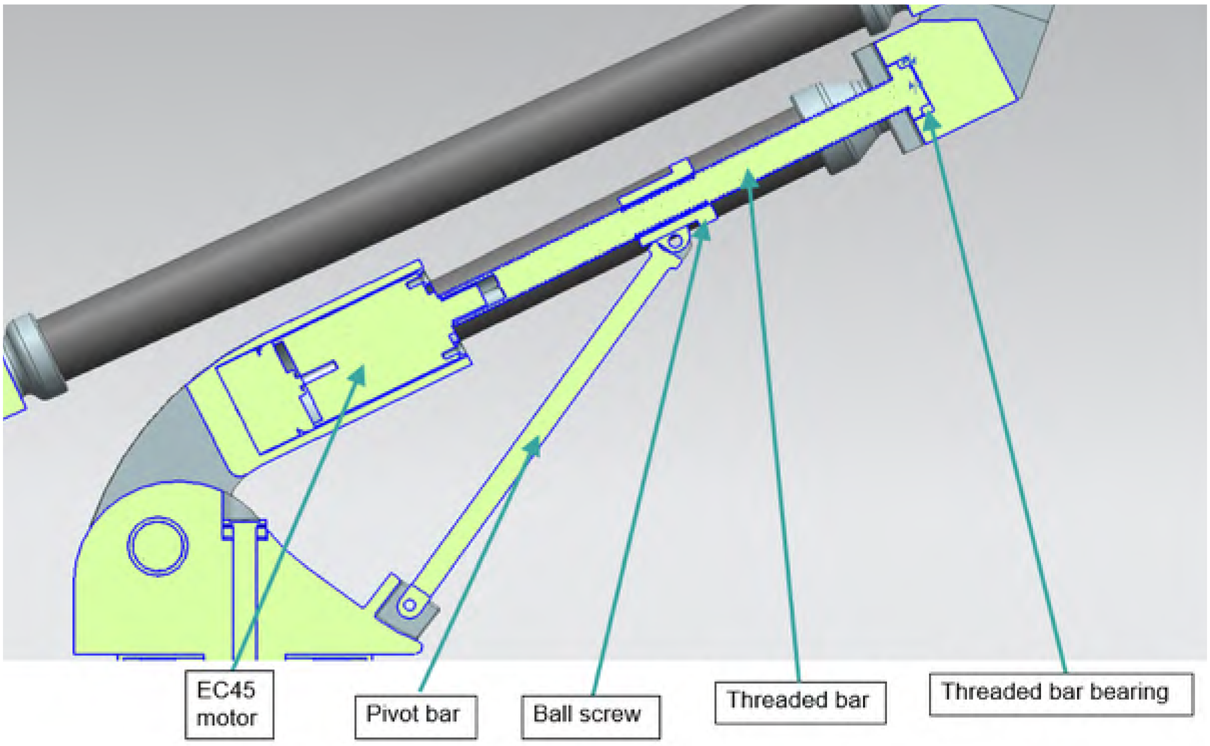


Fig 4

3.1 Technology to be used

We will be looking to utilise as much of the technology as we can at MTC to enable us to build a competitive robot using minimal off the shelf components. We will be using our CNC milling and turning machines to create components such as our flipper shafts and our central chassis plate. We are going to use our Wire Electrical Discharge Machines (Wire EDM's) to manufacture our flipper paddles and a vast amount of components will be made using our state of the art 3D printing machines.

3.2 Robot features

We've designed our robot to house lots of features to make it competitive in the competition.

3.2.1 Chassis

Chassis plate

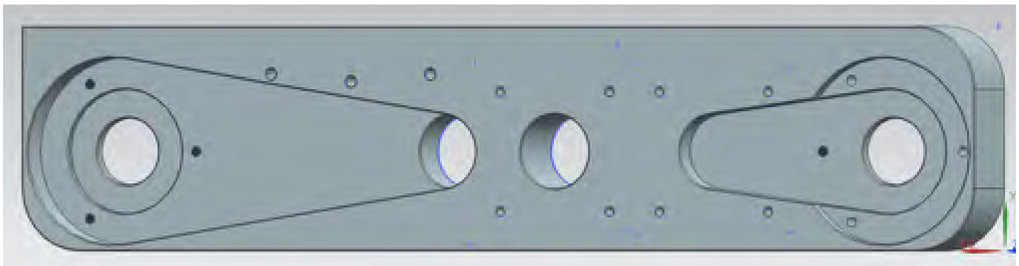


Fig 5

Our re-designed chassis plate incorporates our new rotary base robot design and allows our larger and more powerful Makita drill motors to be attached to the side of the chassis plate.

Below is a model of how the Chassis assembly will look once fully assembled and operational.

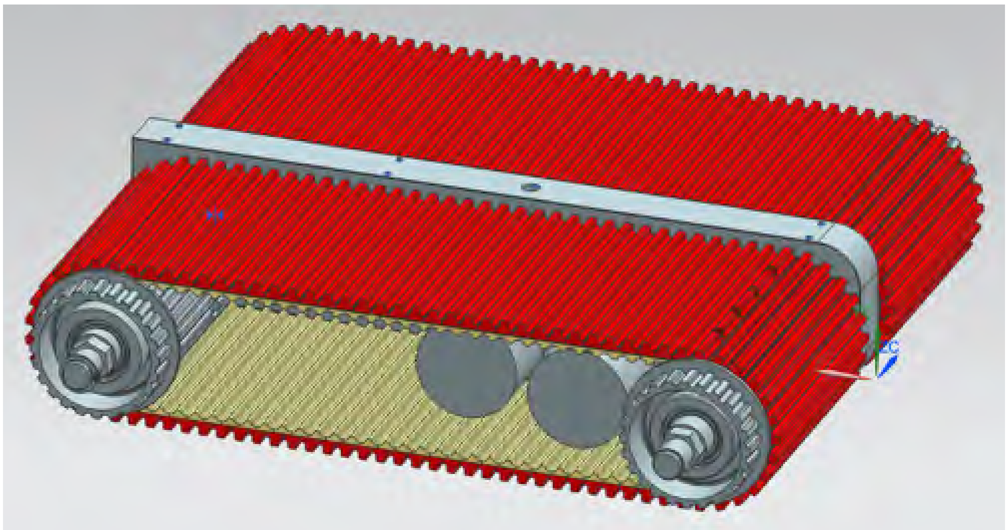


Fig 6

Electronics housing

We have a large electronics housing located on top of our chassis plate. The idea of this is to keep it away from the rotating tracks and also to keep all of the heavy items at the bottom of the robot to keep the centre of gravity as low as possible. The electronics box was adapted to fit around the rotary base of the robot.

3.2.2 Electronics

Thermal imaging

The robot will feature a Flir A35sc thermal imaging camera to enable us to locate any survivors or potential dangers through changes in heat signatures in the surrounding area. Different filters can be used with the camera to produce different images and highlight various changes in the environment. The camera can recognise thermal signatures from -25 ˚

C to +135 ˚ C and has a resolution is 320 x 256 pixels.

Fig 7

Fig 8 *[1]*

HD Cameras

The HD cameras that we are using on our robot are Axis F1004's which are capable of full

720p HD at 30 frames per second. They allow us to stream live images and also have a 102° viewing angle to give us a good field of view. We are planning to use multiple cameras which are a plugged into a camera main unit to create a better view of the surrounding environment for the operator.

Fig 9

On board computer

We are going to use an Intel NUC Kit BOXNUC5i5RYH using an Intel Core i5-5250U processor. The PC allows memory up to 16GB which should be more than capable of running the software and applications for our robot. The on board PC will be running a Linux operating system which we chose as it will work effectively with our LIDAR (Light Detection and Ranging) system.

Fig 10

3.2.3 Sensors

CO_2 sensor

The robot will also have a CO_2 sensor to assess any changes in the air to enable us to locate any survivors.

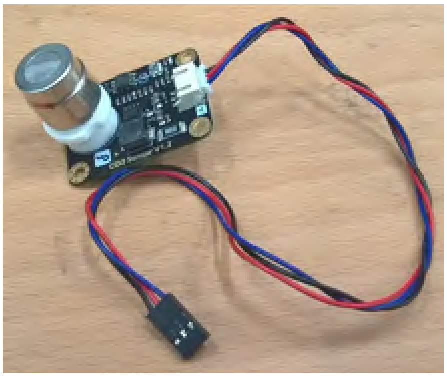


Fig 11

Speaker/microphone

We will also have a microphone and speaker on the robot to enable us to communicate with any survivors around the competition course.

Mapping

We've also got a LIDAR system on our robot which will enable us to create a map on the course and tag locations of victims. We are using a Hokuyo URG-04LX scanning laser rangefinder. It has a scanning range of 240° with angular resolution of 0.36°.

Fig 12

3.2.4 Motors

Drive Motors

Makita UK gave us 4 drills with brushless motors for us to use to power our tracks and the rotation of our flipper shafts. We are using chain and gears to transmit the drive from the motors to the tracks.

Makita also sent us some of their lithium ion batteries to power the robot itself.

Arm motors

We are going to use the EC45 flat 397172 motors from Maxon UK, teamed with their GP42C 203127 using a 126:1 ratio. This will give us 15Nm of torque which is more than enough for the arms manipulations and enough to pick up small objects using our gripper.

Fig 13

Gripper

We are going to use a two-finger style gripper on our robot located at the end of the arm, by the robots head joint. We are going to manufacture the gripper at MTC using our various 3D printers and different materials.

3.2.5 Drivetrain

Gears and chain

The gears for our robot are going to be made in house using our CNC machines, this is purely because of the custom nature of our robot and we require different tooth combinations and thickness to those that are widely available. We decided to use a 1:3.6 ratio (10t:36t) as this combination allows us to keep chain tension as well as ensure enough torque is transferred to the flipper arms/tracks to move the robot to the desired position. The gears and chain are 04B specification meaning they have a 6mm pitch and the gear teeth are 2.8mm wide. We decided to use ‘off the shelf chains’ as they enable us to replace any damaged links in the competition and the fact they would be much cheaper to purchase than manufacture an alternative.

Ball screw and nut

The bottom arm joint has a pivot bar which is attached to a ball screw nut which remains stationary. A motor is attached to a ball screw which is housed within the bottom arm joint. We chose the ball screw design idea as its self-supporting and less torque is required from the motor to enable it to move the joint when compared to joints that use the motors direct torque to create movement.

Tracks

The tracks and the flipper arm pulleys are going to be supplied by Transmission Developments. They are able to provide which tracks of various specification and can also machine custom profiles into them. We are going to use T10 specification pulleys and tracks, meaning the pulleys have a pitch of 10mm between each tooth.

3.2.6 Communications

Router

The robot is going to be controlled using a Wi-Fi connection. The robot has a TP-LINK TL-WDR3600 N600 router on board, this creates the wireless network that the robot will communicate over once it is turned on.

Fig 14

4 Developments

During the process of designing the robot, there have been many changes in terms of design and team structure. We decided working in smaller teams for each area worked better, with two to three people researching components or software in detail, rather than the entire team. This vastly improved the efficiency of the team as well as the robot design.

The main robot design changes have been the camera head, the rotary base for the robot arm and the robot arm joints. These were all changed to increase the capability of the robot when it comes to competition and allow the robots arm to extend further and rotate 360 degrees so in tricky terrain it can still capture the images of a certain location needed to score points.

5 Current state

We are currently in the manufacturing phase of the project. We began 3D printing of the arm joints which means the arm can start to be developed and assembled. We have started CNC machining of some of our components, for example the stub / stub slave shafts. We've also ordered material for any components to be machined and have started to look at our methods of controlling the arm joints and streaming video from our cameras to the operators PC.

Videos will soon be uploaded to a new MTC Robocup YouTube channel.

The purpose of the videos will be to show other teams what we are capable of at a relatively inexperienced level of robotics knowledge. It will also show how the apprentices will be making a robot from scratch, allowing the apprentices to take pride and possibly allow other teams to view the tactics and design ideas the MTC team will be using.

The expected date of a completed and moving robot is the end of April, this may seem a long time but it gives the apprentices nearly 2 months to test and make the Robot ready to compete in Leipzig.

5.1 Components manufactured:

Battery holder

Below are some photos of our 3D printed battery holder which will be mounted to the chassis plate.

Fig 15 *Fig 16*

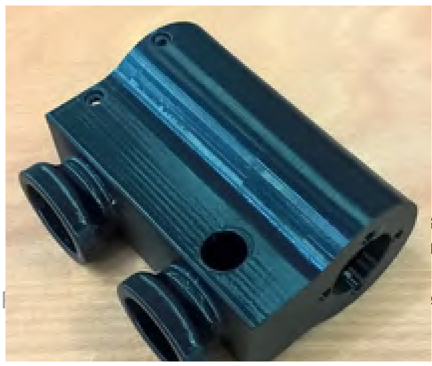
Motor casings

Below are our motor casings for our Makita drill motors that will power our tracks and rotate our flipper arms.

Fig 17

Arm joints

The images below show some of the arm joints for our robot that have been 3D printed.



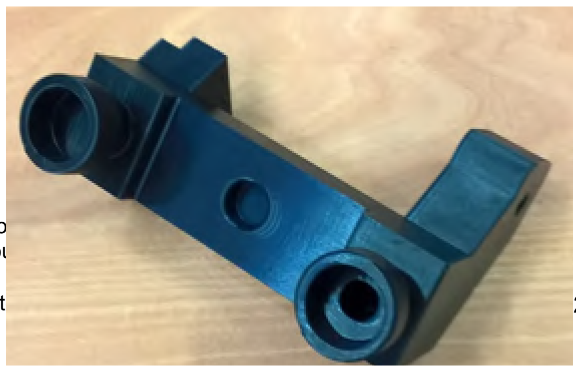


Fig 18 *Fig 19*

Gripper

We've purchased a linear actuator to enable our gripper fingers to open and close together and pick up items.

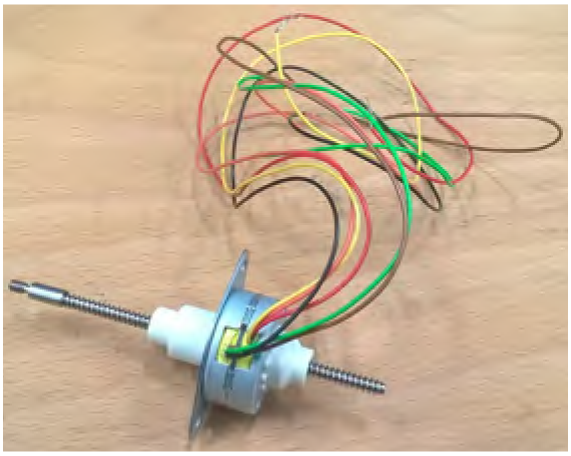


Fig 20

Pulleys

The below left image shows the pulleys that have been supplied to us by transmission developments. The below right image shows a test pulley we 3D printed to ensure that the pitch of the pulley on our CAD model was correct before producing a technical drawing for manufacture and machining our larger pulleys.

Fig 21

Fig 22

Chassis plate

Below is an image of our prototype chassis plate which was CNC machined from a block of aluminium stock.

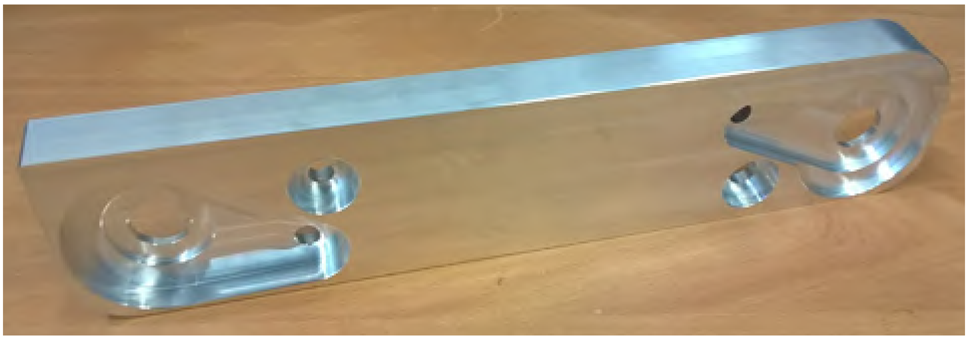


Fig 23

Stub/slave shafts

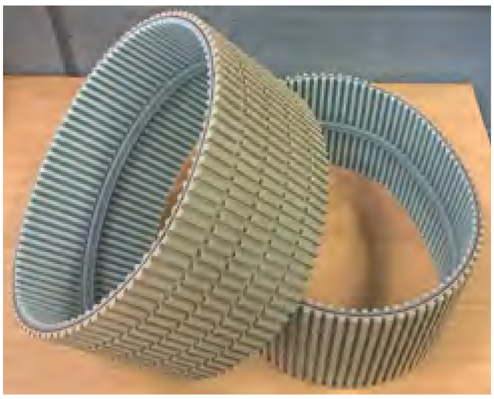
Here is a picture of the stub / stub slave shafts that will attach to our chassis plate. They

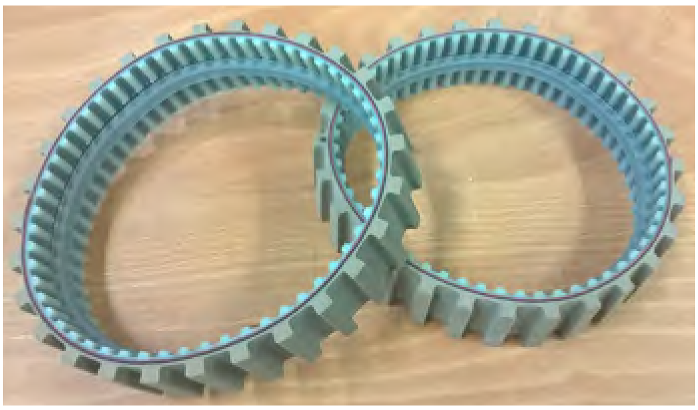
have been machined using one of our CNC lathes.

Fig 24

Tracks

The below images show the tracks that have been supplied by Transmission Developments





for our robot.

Fig 25

Fig 26

Gears

The images below show some of the gears for the robot that have been made using our CNC lathes.

Fig 27

Fig 28

Fig 29

5.2 Robot power distribution

Below is a diagram showing how we are planning to power all of our components on the robot.

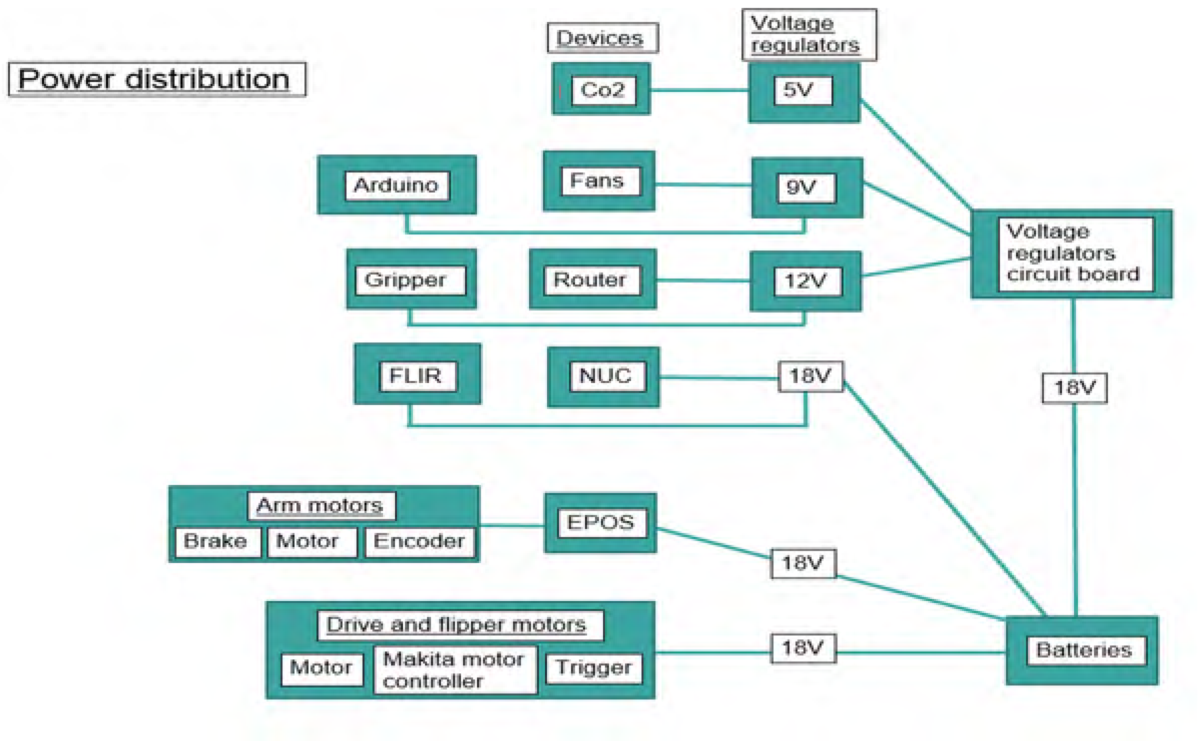
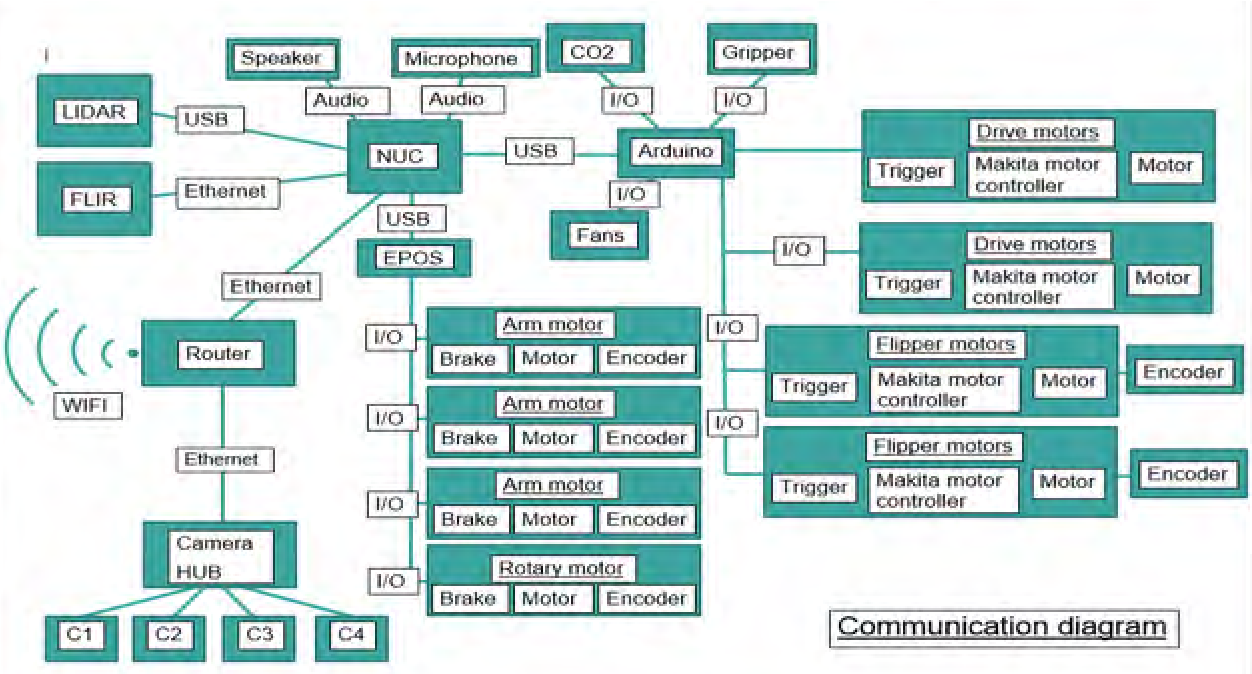


Fig 30

5.3 Robot electronics communication

Below is an electronic communication diagram that maps out how we plan to link our



electronics components together.

Fig 31

6 Appendix:

http://www.the-mtc.org/ - The MTC website will confirm the introduction shown above.

(Page 4)

7 Bibliography:

[1] – Flir thermal imaging camera examples – (Fig 8, page 13), N.D.
http://store.flir.com/product/a35-9mm-60hz-infrared-camera/a-series-infrared-cameras