# Warwick Mobile Robotics Project

## Project definition

This project relates to the building of an Urban Search and Rescue Robot. “Warwick Mobile Robotics” (WMR) has been following this goal since 2007, leading to the design of multiple robot prototypes. This year’s project will concentrate on further development of the robot, ‘Atlas’, which was designed and manufactured as a re-launch of the WMR project during the academic year of 2016/17, with the aspiration of the robot being suitable for participation in the RoboCup competition in April 2017. Urban Search and Rescue Robots (USARRs) are of huge importance in accessing areas in disaster zones that are deemed too dangerous for human rescuers, a relevant example of this is the very recent application of a snake-like USARR in the aftermath of the earthquake in Mexico City in September 2017 [1].

At the point of project handover the robot ‘Atlas’ does not function. The mechanical composition consisted of a metal sheet body structure containing four electrical motors. The lack of other finished components from the 2016/17 team means that the instrumentation, motor controls, communication and power supply will be designed from scratch.

Furthermore, the robot shell currently has a weight of around 50kg, which is the maximum allowed at relevant competitions [2] and since there are several additional parts required, the current design will undergo extensive light weighting to make it viable for participation.

In addition, the team will design a robotic arm that is to be attached to the robot, capable of object manipulation according to the competition guidelines, [2].

WMR is looking back at a history that was very rich in success in the years following the project’s initiation, with the robots gaining wide recognition in 2008 when WMR won the competition and gained extensive sponsorship from outside the University and Warwick Manufacturing Group. In recent years, however, the groups have failed to reach a competitive standard with the designed robots, resulting in a loss of most of the external sponsoring, meaning the 2017/18 group will have just the basic budget available to all School of Engineering Fourth Year projects at the University of Warwick. Due to this, another goal for the project is to gain sponsorship, to cover costs for some of the more costly parts required for the design.

The key mechanical aims of the project can therefore be summarized as the optimization of the robot’s shell with extensive light weighting and the design of a robotic arm. The electrical aims being providing the robot with a suitable design for power supply and motor control, instrumentation and communications to allow remote access to the robot’s functionalities.

## Project justification

The economic, societal and human impact of natural and manmade disasters is clearly visible. According to the 2010 Red Cross World Disasters Report [3] in the 2000-2009 period approximately 1.1 million were killed in disasters, causing direct damages of $986 billion, not mentioning the opportunity cost due to lost production and growth [4]. A significant proportion of these disasters affected urbanized areas causing significant damage to buildings and infrastructure [4]. The consequences of this are twofold; firstly victims may be trapped in damaged/collapsed buildings, secondly rescue workers are impeded in delivering aid to trapped victims due to potentially dangerous rubble and hazardous materials [4], factors which USARRs may be of use due to their ability to withstand greater heat or ionizing radiation and it can also traverse structurally unsound debris without the risk of injuring the rescue worker, robots can navigate small openings. This is supported by Disaster Robotics [4] Robin Murphy, the director of the Centre for Robot-Assisted Search and Rescue (CRASAR) at Texas A&M University, in which these reasons are listed as the main tasks where USARRs may be of use, along with many others.

Robots have expanded sensing capabilities e.g. robots can 'see' heat, 'smell' metabolic by-products such as CO2 and 'hear' the electromagnetic radiation of heart beats [5], and can also be automated presenting the opportunity of a much faster and wider reaching USARRs response without the need for human intervention. Therefore, development a functioning USARR is highly relevant to society, where they are able to aid in the recovery of victims and in the investigation of damaged buildings [6] [7] [8].

Despite these potential benefits, USARRs have only been used only in a handful of cases; a total of 34 times up to April 2013, the majority of deployments were reconnaissance missions where the robot didn't usefully manipulate its environment [4]. The reasons for the slow adoption of USARRs can be attributed to several factors such as slow deployment time, mobility and dexterity constraints and social barriers, including the lack of certification programs [4]. The two most common modes of mission failure was human failure and mobility problems. Simple manipulation tasks, such as turning valves, have proven challenging [4].

The project will aim to meet its key learning outcomes, which are taken from the Project Webpage [9], in the following manner: There will be regular group meetings, currently there is one weekly meeting with the project supervisor scheduled, as well as another involving the project students. Everything covered in the meetings will be written down in the meeting minutes. Furthermore, there is a spreadsheet recording the weekly activities of each individual student is recorded.

A poster outlining the project will be designed and showcased alongside a presentation to summarise the final outcome at the end of the first academic term, and a formal technical report is due in week 31 of the academic year. Supplementary tasks to aid project completion will include the attempt to raise additional funds and extensive individual research, which will then hopefully lead to working designs, resulting in a functional robot. All of the above should result in fulfilment of all learning objectives [9].

The final step of the project will be dealing with project handover to the 2018/19 WMR team and thus emphasis will be placed on proper documentation of all designs, especially electronic ones, since documentation here has been a major issue in previous years, leading to problems on the electronics side of the project especially. Documentation of each project step is thus an essential part of this project, to ensure future competitiveness of WMR and should, for this reason, be considered one of the most crucial goals for the year to come.

## Project Aims

The Main aim of the WMR project is to produce a Robot capable of competing in the RoboCup Competition in Magdeburg. From this aim, a V model has been produced, Figure 2, to look at system overview, a Gantt chart for the timing and this was then broken into objectives below:

- Raise sponsorship, for finances or parts
- Complete the design for the robotic arm, wireless control system, power distribution board, sensors and motor controls.
- Implement design and optimization, in order to produce a versatile, robust and unique robot.
- Produce a working robot that will perform well during rigorous testing.
- Create extensive documentation for a smooth handover to the future years of the WMR project, which was defined in the project outline.

To achieve these project aims the Gantt chart in *Figure 1* was produced to measure ongoing performance and what has been achieved, estimating when sections are to be completed.

| | | | |
|---|---|---|---|
| Deadline | Red | Production and Assembly | Blue |
| Competition | Purple | Coding | Blue |
| Planning stage | Green | Testing stage | Yellow |

*Table 1 Colours*

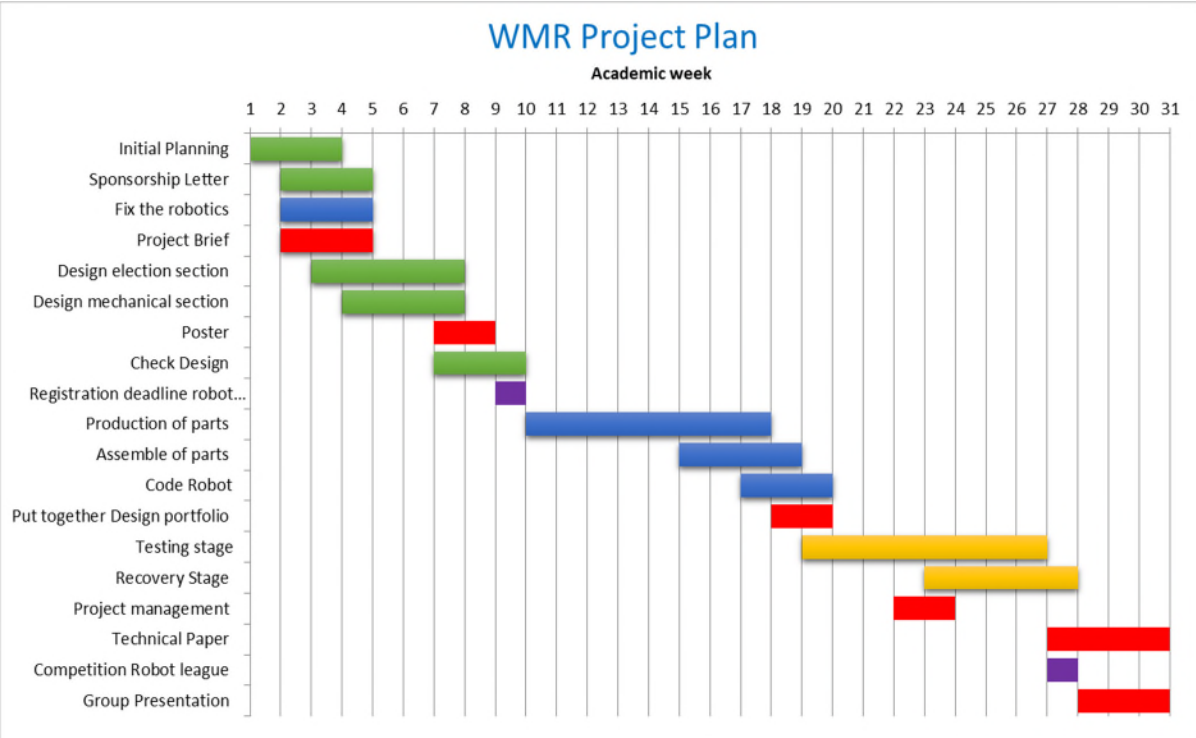


*Figure SEQ Figure * ARABIC 1 WMR Project Plan Gantt Chart Along With Colour Coding Legend.*

## Initial Project Evaluation

A key constraint for the project is to create a robot capable of competing at the RoboCup Robot Rescue League in April 2018, meaning following competition rules for the design. Tasks must be completed within strictly set timeframes, to leave sufficient time for an extensive testing phase, ensuring the robot is in satisfactory working condition. The management of the project requires all work completed to be compiled for use in a Portfolio upon completion.

It is essential that all members of the project group complete tasks assigned to them according to a set timetable, to ensure parts required for future stages of development are ready in time. Careful use of available resources is critical, so as not to waste project budget, which is fairly limited. Designs need to be as effective as possible, to minimise waste and to ensure quality. It was therefore important for the group to formulate a set of project goals, which any deadlines could be tied to, in order to ensure that the project is successful, [10] and the management tool chosen must reflect this as well as the team's ability to collaborate.

The main Project management technique chosen was the V-Model, as it allows the entire team to focus on their individual tasks within the framework of the entire system, allowing the team to implement sub-system constraints and requirements in order to successfully complete the project [11]. The V-Model designed for the project can be seen in *Figure 2*.

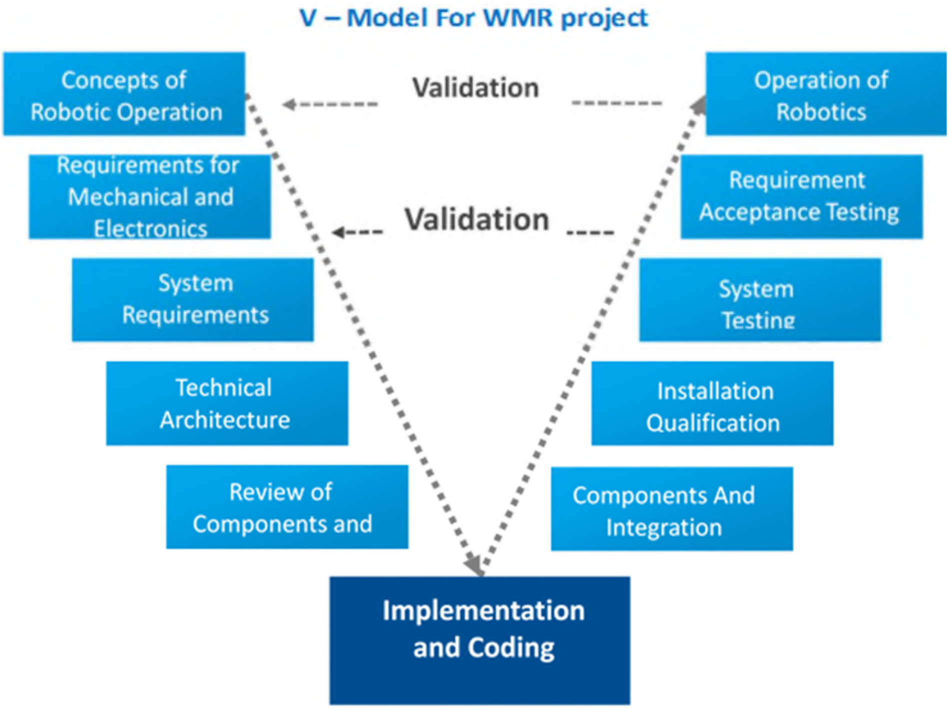


*Figure  SEQ Figure * ARABIC 2 V Model [13]*

A number of methods were suggested to track the progress of the project and how this is to be monitored to ensure that all tasks are completed in a timely manner. It was suggested to use Microsoft Project as an integrated software to track all information on progress deadlines and other important information in one location, and ability to keep a track of resources as well as time [12]. Due to the need to keep in depth records of meetings and actions to be carried out, it was chosen to set up a group Google Drive. This drive contains a number of documents including minutes of meetings and actions as well as a Gantt chart and a set of project deadlines, shown previously in *Table 1*, to allow the group to monitor deadlines in weekly meetings, as well as containing all work completed, such as any CAD or calculations.

The Gantt chart seen in *Figure 1*, along with this V-Model [13] have been placed on the wall of the workshop area so that technicians have a reference to check when the production of parts needs to be completed, ensuring fewer delays in the production process. The correct use of these tools should ensure that the work can be completed within the set time frame and up to the quality required to compete at the RoboCup competition.

## Sponsorship and Finance

Warwick Mobile Robotics (WMR) began exploring USARR projects in 2008. There onwards teams of Master level students have been entering the RoboCup annual competition and by 2013 three titles had been won with the USARR 'Champion'. Following this success, the development of small USARRs was explored. Unfortunately, this lead to teams from the year 2013 onwards being unsuccessful in producing an operational robot. Furthermore, due to the use and wear of 'Champion', the robot has now been decommissioned. This leaves the team with the challenge of overcoming the lack of sponsor confidence. Taking this into consideration suitable time, weeks 2-5, was allocated, seen in *Figure 1*, to develop sponsorship packs in order to re-generate interest from new and previous sponsors. Cross-referencing with the spreadsheet made of essential components; the team is aiming for large and essential components to be sponsored.

A spreadsheet has been made to collate potential and precedent sponsors along with contact details and a record of the sponsorship given. This detail and method of organisation will improve transparency and the tracking of finances, in turn reducing the risks of exceeding the budget.

Currently the funding available is the money provided by WMG. This equates to a total budget of £1400; likely not enough to complete the envisioned work. To keep within these financial constraints a spreadsheet has been made containing a list of components that are essential to be purchased to make the robot functional. Extra components are also listed that would add further functionality, making the robot more technologically advanced. These are not essential if funding does not allow it.

The sponsorship gained would preferably be the provision of parts as opposed to money. This is preferable for both the team and sponsor as this will cost less for the company, and the team can forego VAT charges that come with receiving money contributions. The aim is therefore to receive parts from sponsors and to use the WMG budget to purchase other essential parts that cannot be gained from sponsorship.

Another factor to be considered regarding the budget is the cost involved in attending the Rescue Robot League competition in Magdeburg, Germany. The initial cost to enter a team is €300, with an additional fee of €100 per person participating in the team on top of the entry fee. It has been estimated that for travel, accommodation and living expenses it would cost a further £500 for each member of the team to attend the event. This is a sizable cost that would require extensive sponsorship to become a reality.

## Project Plan

This following section will be looking into the management of the project in terms of time management, delegation of roles, recording of actions and the potential risks that have been considered. The star represents that these three components are averaged to give on 10% contribution.

## Project Deadlines

| **Assessment Submissions** | **%** | **Date** | **Week** | **Time** | **Type** |
|---|---|---|---|---|---|
| Project Brief | 10% | 02/11 | 5 | 14:00 | Hard Copy |

| | | | | | |
|---|---|---|---|---|---|
| Poster | 10% | 30/11 | 9 | 23:59 | Electronic |
| Poster presentation evening | - | 7/12 | 10 | 16:00-20:00 | Presentation |
| Registration deadline RoboCup Major teams | - | 15/12 | - | - | Electronic |
| Peer Assessment 1 | *10% | 8/12 | 10 | 23:59 | Electronic |
| Design Portfolio | 15% | 15/02 | 20 | 14:00 | Hard Copy |
| Project management | 10% | 24/03 | 24 | 14:00 | Hard Copy |
| Registration fee due | - | 15/04 | | - | |
| Competition Robot league | | 25-28/04 | | - | Competition |
| Technical Paper | 25% | 3/05 | 31 | 23:59 | Electronic |
| Project Completion Report | 10% | 03/05 | 31 | 14:00 | Electronic |
| Group Presentation | 10% | 14-18/05 | 32 | Unknown | Presentation |
| Individual | *10% | 10/05 | 32 | 23:59 | Electronic |
| Peer Assessment 2 | *10% | 10/05 | 32 | 23:59 | Electronic |

*Table 2 Project Deadlines (Black) and RoboCup Deadlines (Blue)*

## Project Management

The team consists of seven fourth year MEng students. The team is multidisciplinary, consisting of three mechanical, one automotive, one electrical, one systems and one electrical engineer. Therefore, it was decided that to increase productivity and allow members to develop a deeper understanding of concepts, sub teams were created. These were namely a mechanical and electrical team. Within each sub-team, members were then assigned a part of the robot development to focus on. Alongside engineering roles, each team member has taken on a secondary management role encompassing other key aspects of the development of the project this is summarised in *Table 3*.

| Name | Sub-Team | Engineering Role | Management role |
|---|---|---|---|
| Charles Perera | Electrical Team | Base Computer | Project Leader |
| Jan Specht | | FPGA and Power System | Co-ordinator |
| Bálint Vidos | | Pico computer and Sensors | Sponsorship |
| Mark Safford | Mechanical Team | Light weighting and design optimisation | Finance |
| Emily Carman | | Light weighting and design optimisation | Outreach and Health and Safety Officer |
| Tom de Oliveira | | Robot Arm and Powertrain | Procurement |
| Eashana Chotai | | Robot Arm and Powertrain | Secretary |

*Table 3 Sub team information*

It was decided early on that although members were specialising and given roles it would be essential for everyone to understand what all other team members were doing. This ensures that every member of the team is informed on how the project is developing but also that important project decisions will involve every member of the team.

Each week, two group meetings are held for all team members. The first aims to keep all members informed of the progress of each aspect (electrical and mechanical) of the project and allows for everyone's opinions, ideas or concerns to be raised and discussed.

The second meeting includes the attendance of Supervisor Dr. Emma Rushforth and on occasion technicians Jacob Gates and Dave Cooper. This ensures that the team is on track and receives the necessary guidance. *Table 4* shows the structure of the week.

| Monday | Tuesday | Wednesday | Thursday | Friday | Weekend |
|---|---|---|---|---|---|
| Release of Agenda for Tuesday | Weekly Team Meeting | Workshop Time | Release of Agenda for Friday | Weekly Project meeting | All member Catch up on work. |
| Project leader | Students | Students | Project Leader | Student's, Supervisor and Technicians | |

*Table 4 Timings of Team Meetings and Actions, with the Members Responsible Below.*

## Project Ethics and Health and Safety

Both the Delegated Ethical Review Form and Ethical Review Flow Chart have been considered and understood. The project being undertaken does not require the collection of any data from living participants.

## Risk

Before any work has been done all health and safety training allowing the team into the WMG workshops. Team members have completed all the relevant training and all of the Safe Systems of Work (SSOW), Risk Assessment, Chemical Management and Control of Substances Hazardous to Health (COSHH) forms have been completed for the work on the robot and handling of chemicals.

The risks to the project have been thought through and various management solutions have been initiated. The most suitable plans were selected and put in place to mitigate the impact of these, these are shown in *Table 6* below, using the risk matrix system shown in *Table 5.*

| Likelihood → | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| ↓ Risk consequences/impact | | Rare | Unlikely | Possible | Likely | Very Likely |
| 5 | Severe | 5 | 10 | 15 | 20 | 25 |
| 4 | Significant | 4 | 8 | 12 | 16 | 20 |
| 3 | Moderate | 3 | 6 | 9 | 12 | 15 |
| 2 | Minor | 2 | 4 | 6 | 8 | 10 |
| 1 | Negligible | 1 | 2 | 3 | 4 | 5 |

*Table SEQ Table * ARABIC 5. Risk Matrix*

| Category | Risk Factor | Probability | Impact | Score | Strategy | Management | Response |
|---|---|---|---|---|---|---|---|
| Resource/ Financial | Budget overspend/ lack of sponsorship funding | Possible | Severe | 15 | Avoid | Start sponsorship pack early to secure as much sponsorship as is possible in the form of parts and cash | Try and reuse and repair as much of the robot as possible, limit the scope of planned work |
| Legal | Health and Safety Disputes | Unlikely | Moderate | 6 | Avoid | Complete suitable H&S training | Respond quickly in proper manner with help of WMG H&S |
| Time | Delays in design | Possible | Moderate | 9 | Reduce | Advance design work to get all designs completed before week 8 | Time allowed in Gantt chart for recovery |
| Production | Delays in manufacturing | Possible | Significant | 12 | Reduce | Get all designs to manufacturers before the Christmas vacation | Time allowed in Gantt chart for recovery |
| Method | Equipment Damage/loss of documentation | Possible | Moderate | 9 | Avoid | Follow all procedures correctly, back up all documentation | Report, repair and replace |
| Deadline | Failure to be ready for RoboCup | Very Likely | Minor | 10 | Fallback | Follow Gantt chart to have everything completed within timescale | Time allowed in Gantt chart for recovery |
| Deadline | Failure to meet project deadlines | Rare | Severe | 5 | Avoid | Stick to Gantt chart timings | Time allowed in Gantt chart for recovery |
| People | Effect of Robocup attendance on exams | Unlikely | Moderate | 6 | Accept | Early preparation for exams as competition attendance will be confirmed well in advance | Attendees will be aware of the clash early on and allowed time to prepare |
| People | Team Member becomes unavailable | Possible | Severe | 15 | Reduce | Ensure proper documentation and keep all members updated | Adjust project scope to remaining members |

*Table 6 Risk Management Table*

As shown in the matrix the main risk to this project is budget constraints. The current budget is £1,400 and having already identified critical items up to the value of £1,000 that need to be purchased before other improvement works can be done, the project could be left severely underfunded without securing sponsorship. This risk has been passed down from previous years as a lessons learnt as they struggled with gaining enough capital and resources.

Another significant risk to this project is the time constraint, having learned from previous years that the tendency is to spend too long on the planning stage and not actually get anything done. This year WMR are carrying on the project legacy and so the planning stage should be succinct, meaning this risk is reduced. With the help of the Gantt Chart this risk should be able to be avoided completely as the timings have been planned out. To reduce this risk there is time set aside for recovery as a response. The team will also self-evaluate after each deadline to make sure any risks that arise from assignment completion will not reoccur.

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