Executive Report

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Figures, Tables and Equations

1. Team Introduction

Warwick Mobile Robotics (WMR) is a multidisciplinary team of fourth year engineers working within the School of Engineering at the University of Warwick. WMR consists of eight undergraduates ranging in skills from Mechanical and Manufacturing Engineering to Electronic and Systems Engineering.

An organisational structure was created to clarify individual team member's roles and responsibilities within the team. This structure was not used rigidly however, and functional working groups typically formed around particular subsystems or the delivery of a particular capability; see the Business, Publicity, Finance and Management Report Section 5.3.3 for a full description of the systems approach used for resource management.
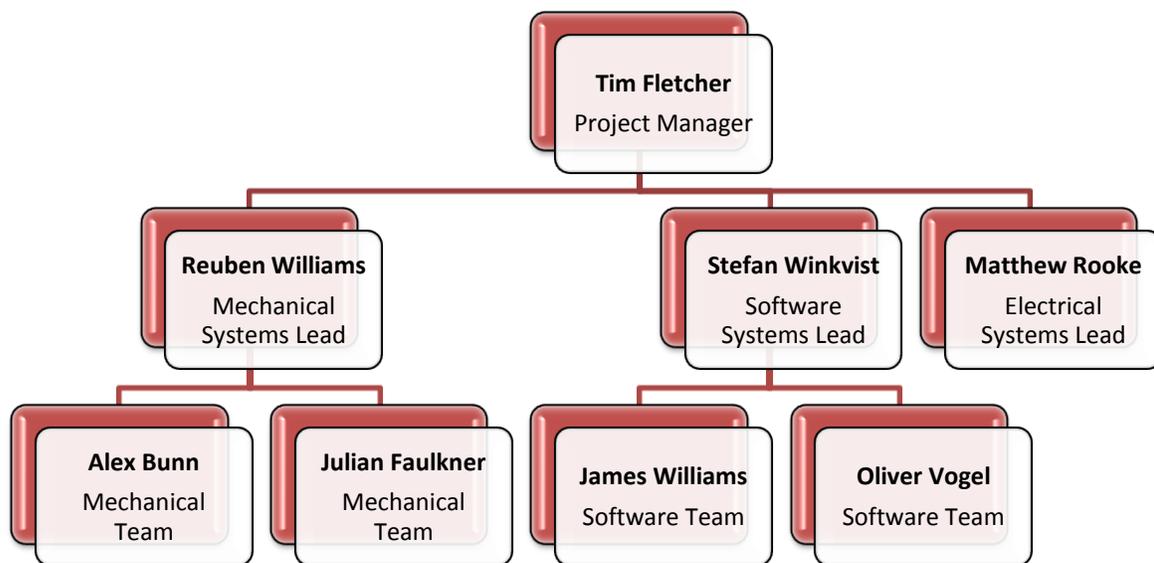
Figure 1-1: Organisational structure of the team

The project focus for the 2008/9 academic year is the development of a mobile search and rescue robot with autonomous capabilities for deployment in the RoboCup Rescue Competition arena. Formal aims and objectives for the project are stated in the following section.

2. Project Aims and Objectives

Aims and objectives were stated at the outset of the project to provide a guide as well as a benchmark for success.

2.1 Aims

- Build on the success of 2008
    - Optimise tele-operation
    - Implement mapping and autonomy
    - Investigate further victim identification
- Raise the profile of WMR and sponsors through continually developing marketing strategy
- Increase awareness of Engineering both at the University of Warwick and as a profession
- Showcase Warwick innovation to the world

2.2 Objectives

- Achieve Best in Class for Mobility at RoboCup Rescue German Open
- Qualify for the international final in Austria

3. Methods

3.1 Design Philosophy

A systems perspective is used for to guide all project work.

A systems perspective is used for all design work in this project. Figure 3-1 illustrates the three high level stages to a systems engineering design project: design definition, equipment design and verification. By focusing on definition and verification of system capabilities, this process (described in detail in the Systems Design Report Section 1.2) ensures that all subsystems interact to deliver the required overall performance.
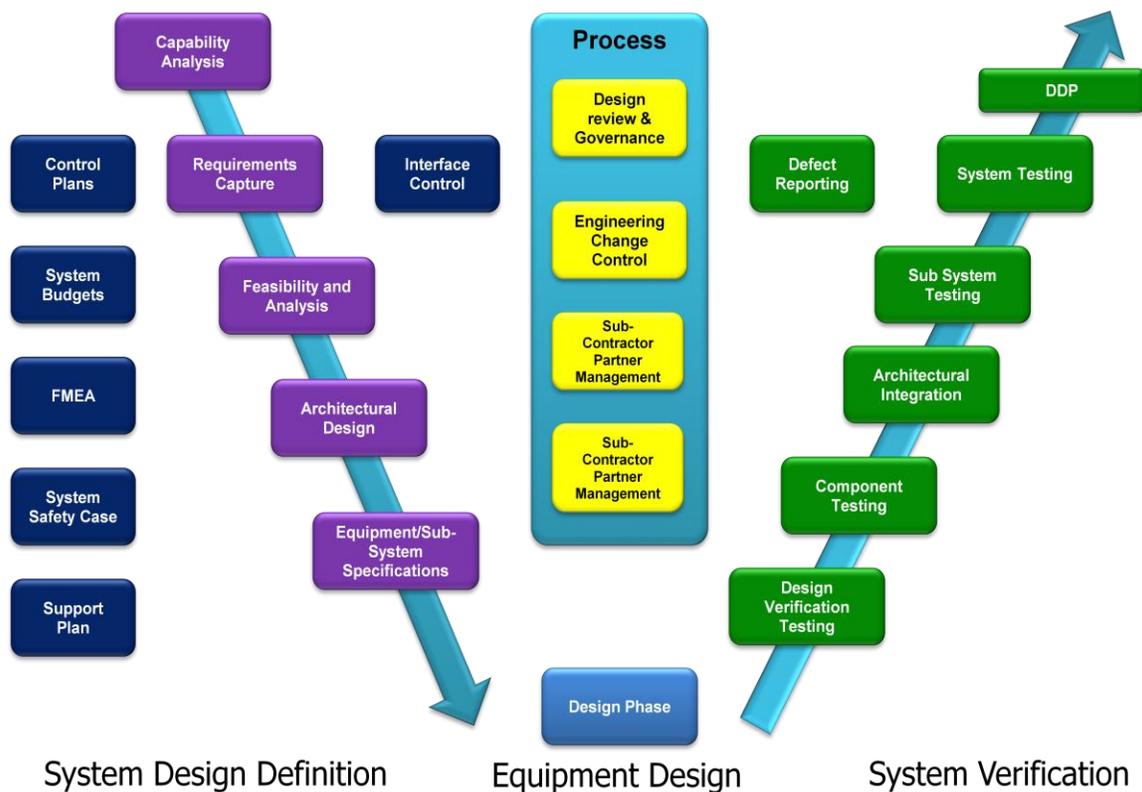

Figure 3-1: Systems V-Diagram (Northrop Grumman Remotec)

3.2 Design

All design work follows the systems approach illustrated in Figure 3-1. The structure of the Systems Design Report reflects this approach, flowing from capability to requirements analysis, then design and finally component and sub-system verification. As part of the capability analysis capabilities are separated into categories, for example mobility. The requirement capture process then identifies subsystems necessary to deliver individual capabilities, the interaction of these subsystems then defines the architecture of the overall system which can deliver the required capabilities.
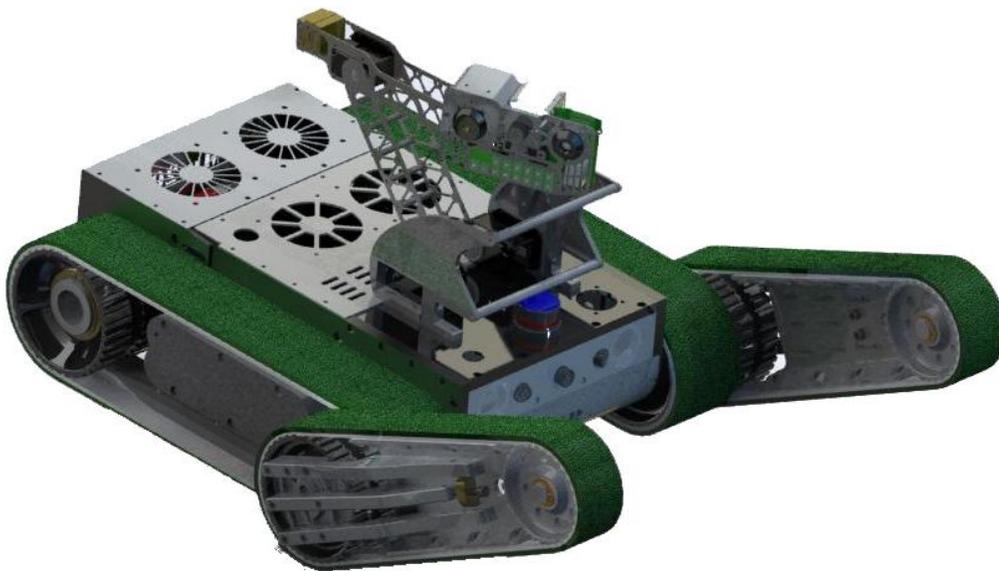
Figure 3-2: Initial 2008 Design

3.3 Publicity

Three of the aims for this project pertain to publicity, specifically:

- Raise the profile of WMR and sponsors through continually developing marketing strategy
- Increase awareness of Engineering both at the University of Warwick and as a profession
- Showcase Warwick innovation to the world

In order to achieve these aims a wide variety of promotional activates were undertaken; see the Business, Publicity, Finance and Management Report, Section 3 for a full

discussion of publicity. Notable promotional activities include a press release sent to mainstream media, a regular newsletter, presentations and demonstrations. Additionally the team maintained a strong brand identity though team polo shirts and branded posters.

3.4 Finance

Significant financing was required to deliver the teams stated objective of qualification to the RoboCup Rescue International final. This was achieved through sponsorship of the project by university research and development bodies and external partners. Table 3.1 summarises the capital inflows to the project.

Table 3-1: Summary of capital inflows to project

Source	Amount
WIMRC sponsorship	£4,989.00
WMG sponsorship	£4,700.00
ITCM sponsorship	£2,000.00
WIS sponsorship	£1,000.00
Sellafield grant	£3,000.00
School of Engineering	£1,200.00
Carried over from previous project	£1,147.64
Total:	**£18,036.64**

Financial control techniques such as budgeting and financial record keeping were used to ensure efficient use of budgetary resources. Section 4 of the Business, Publicity, Finance and Management Report contains a discussion of the financial tools and techniques used as part of the project.

3.5 Management

Managing a project of this scale requires detailed planning as well as effective team communication. Section 5 of the Business, Publicity, Finance and Management Report describes the tools and techniques used for planning as well as the team organisation and structure.

4. Outcomes

4.1 Final Design

In order to analyse the performance of the 2009 robot, a comparison should be made between the 2008 and 2009 (Figure 4-1) based on a gap analysis of the 2008 robot.
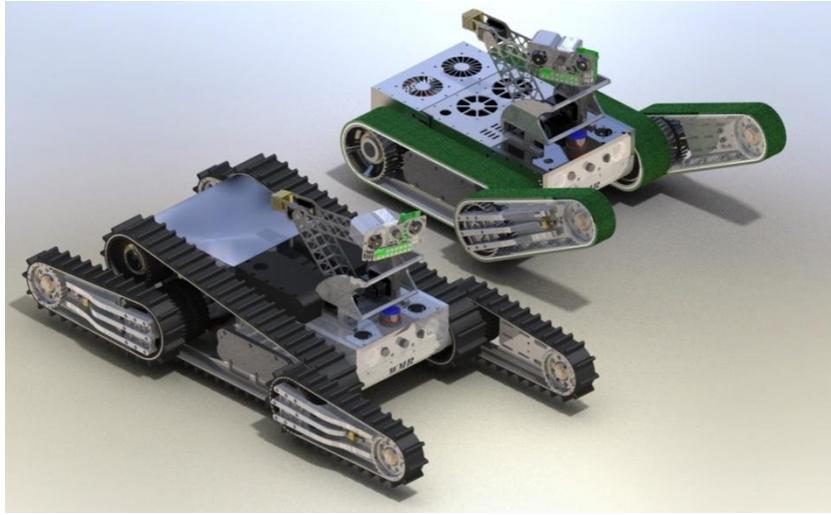
Figure 4-1: Comparison of 2008 and 2009 robots

The final robot (Figure 4-2) developed during the project aims to successfully achieve all requirements specified in section 2.4 of the Systems Report.
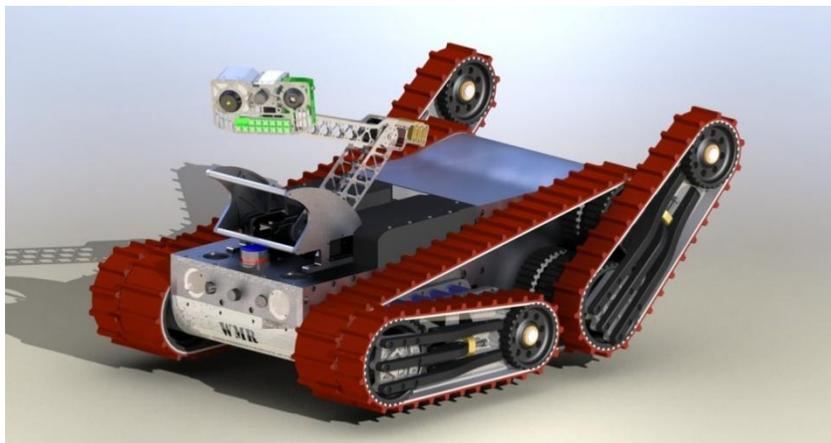
Figure 4-2: Final 2009 Robot Design

Major mechanical design features include profiled tracks and rear flipper arms. These directly relate to improving the mobility capabilities.
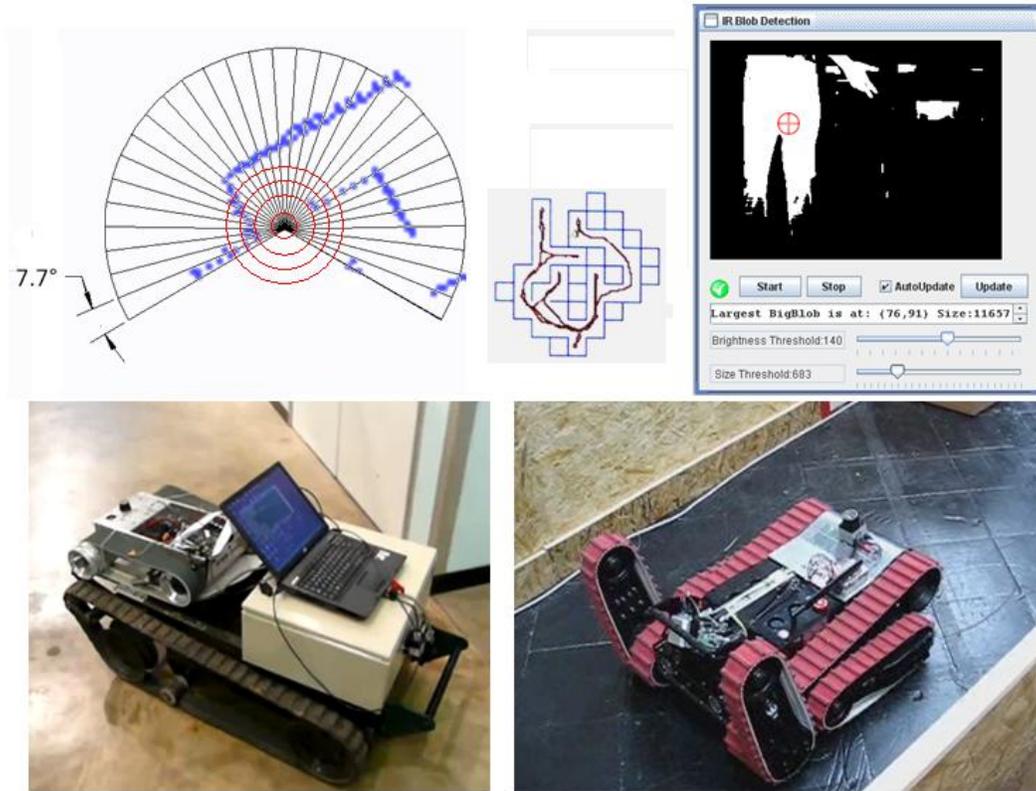
Figure 4-3: clockwise a) visualisation of PieEye framework, b) AI strategy simulation output, c) screenshot of blob detection GUI, d) full autonomous systems verification, e) sensor, control and AI sub-systems testing using test chassis

Significant progress has been made in advancing software functionality of the robot. Existing systems have been expanded and improved, while autonomous navigation and victim identification capabilities have been created, developed and successfully tested.

4.2 Evaluation against Requirements

The 2009 robot performed to the mobility requirement, although an area for development would be to introduce more powerful drive motors capable of full load application for sustained periods. The robot is capable of autonomously navigating through a 1.2 m x 1.2 m maze without collisions and code has been implemented to autonomously locate victims although this has not yet been fully validated in the competition environment.

4.3 Evaluation against Capabilities

Overall the 2009 design performed well in relation to the capability analysis. Mobility capabilities were demonstrated by successful navigation over all levels of the competition terrain. The robot also demonstrated autonomous capability; however, this was not fully verified in a competition scenario due to tight time constraints. Manipulation was not implemented in the current design and therefore remains a major area of development for further work.

Although manipulation represents a large area for future research, there remain a number of potential modifications and developments to the more mature technologies already present in the design.

4.4 Evaluation against Objectives
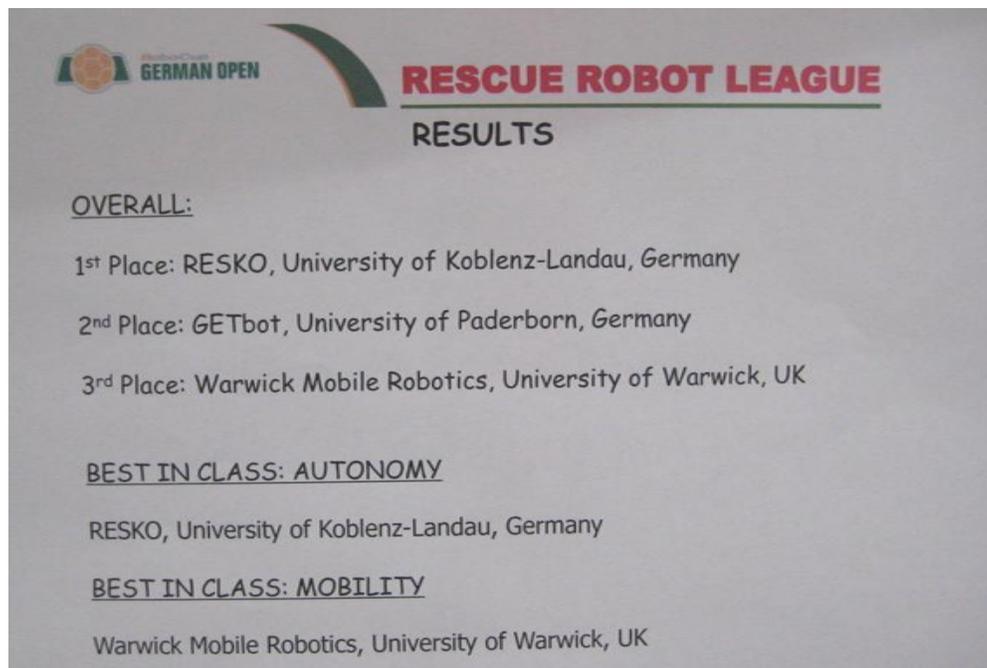
Figure 4-4: RoboCup Rescue Germen Open Results

WMR has realised its stated objective of achieving best in class for mobility at the RoboCup Rescue German Open as illustrated by Figure 4-4. Additionally the team's third placing has secured an invitation to the World Final in Graz, Austria thus achieving the team's second stated objective.

4.5   Evaluation against Aims

4.5.1   Optimise Tele-operation

Many improvements to the tele-operation interface were implemented during the project.   Many features have been added to the client GUI including a visual representation of flipper position, CPU temperature and a window displaying the output of the thermal image sensor post processing. See Systems Design Report Section 4.11.1 for a detailed discussion of these improvements.

Software was written to control the robot arm remotely to allow more flexible tele-operation and precise positioning of arm-mounted sensors. Inverse kinematics is used to translate from Cartesian space to joint space to allow intuitive control. Presets were stored to enable quick movement to popular arm positions.

One area for improvement is the visual sensor output – the field of view of the current webcam does not provide enough information on the robot position within its environment.

4.5.2   Implement mapping and autonomy

WMR has integrated sensor data and decision making software to enable autonomous navigation through unknown environments. This sensor data, namely LiDAR scans, are used to implement mapping functionality. A simple correlation algorithm is used to superimpose successive scans thus building a map.

This aim has been satisfied to some extent; however the approach has many limitations. The LiDAR sensors scan in a fixed plane and thus the map generated will be corrupted by changes in robot orientations along lateral and longitudinal axes (pitch and yaw). Additionally objects not in the scan plane are not detected.

4.5.3   Investigate further victim identification

Auditory sensing was investigated and implemented successfully at a component and subsystem level; however it was not integrated into the complete system. The team researched CO_2 sensing and purchased a sensor however due to supplier error there was insufficient time to test at either component or subsystem level.

Improvements were made to the thermal imaging sensor system in terms of post processing. Software was written to extract areas within the human temperature range for easy identification. A blob growing algorithm was also implemented to find the size

and location of all such areas to enable autonomous identification, and provide an aid to the tele-operator.

4.5.4   Publicity Aims

Three of the project aims pertain to publicity; these are listed in section 5-2.

The ongoing promotional campaign, described in the Business, Publicity, Finance and Management Report, Section 5, was highly successful in achieving these aims. The profile of WMR and sponsors were raised through mainstream media attention including an article in the Professional Engineer. Presentations at engineering events such as the Imagineering Fair have helped to promote interest in engineering while the RoboCup Rescue competition provided an international platform from which to demonstrate innovative research at the University of Warwick.

Figure 4-4: Photograph from Imagineering fair 07/11/08

5. Conclusion

The WMR team has succeeded in delivering the main focus of the project, specifically to achieve the two objectives laid out in the early stages of the project. In order to carry out these objectives the robot design necessarily met the majority of the capabilities and requirements specified in the requirements capture.

At the outset of the project the robot's strength lay in mobility, while other areas such as autonomous navigation were non-existent. The 2009 team has continued development of mobility as a major design principle, for example a second flipper set and profiled tracks have been added. Consideration has also been given to developing new capabilities, for example software has been written to provide a competent framework for autonomous navigation and victim identification strategies.

Application of systems principles to other areas of the project, such as planning and financial management have further ensured successful delivery of the project on time and in budget.

To conclude, the systems approach to design was successfully employed throughout the project. Following these principles allowed for systematic identification and management of capabilities ensuring their delivery in the final system.