University of Southern Queensland

Faculty of Engineering & Surveying

Formula SAE: Design Overview and Project Management

A dissertation submitted by

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Abstract

This project aimed to develop effective design management tools and practices to assist in the integration of all aspects of the design and construction of a race car. The race car was designed and manufactured by a team of university students.

Project and design management techniques were investigated and applied to the project team. This empowered the team to work effectively together. Successful integration of the vehicles' systems was achieved and the race car is now in the final stages of construction.

Management of the project team and the design process was found to be essential to the efficient completion of any complex engineering project.

University of Southern Queensland

Faculty of Engineering and Surveying

ENG4111/2 *Research Project*

Limitations of Use

Prof G Baker

Dean

Faculty of Engineering and Surveying

Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

John Armstrong

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Signature

Date

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To all the members of USQ Motorsport and the USQ Mech Club.

And to all our sponsors, without whom we would not have a car.

John Armstrong

University of Southern Queensland

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Chapter 1

Introduction

This project investigated the process of achieving effective design integration and project management within the University of Southern Queensland Formula SAE team.

Formula SAE involves the design and construction of a race car. This race car is evaluated in a competition which focusses on quality of design and good engineering practice.

Project management techniques were investigated and applied to USQ Formula SAE. The successful creation and implementation of this management scheme was critical in allowing the USQ team to compete in Formula SAE in 2004.

The engineering design process and design integration methods were researched and applied to the project. Design integration was achieved through establishing a quality design environment in which interaction within the team was encouraged. This enabled the successful and efficient design of the race car by the team members.

The achievement of this projects' objectives would enable the USQ Formula SAE team to be successful in designing and constructing a race car in 2004.

Chapter 2

Background

2.1 Chapter Overview

Design Overview and Project Management are crucial components of every successful modern engineering project, whether large or small, simple or complex. These processes help engineers reach a satisfactory conclusion in every endeavor.

Formula SAE is a competition in which a team of university students design, construct and compete with formula style racing cars. These cars are designed to a set specification, however the rules are designed to allow freedom of design while maintaining safety and fairness in the competition.

2.2 Competition Organiser

The competition is organised by the Society of Automotive Engineers(SAE). SAE is a worldwide organisation, originally founded in the United States of America in 1905. The Society's aim was to address a need for the free exchange of ideas and to develop common standards for those in the emerging automotive industry. This need was well recognised as demonstrated by the following editorial in *The Horseless Age* from 1902:

> "Now there is a noticeable tendency for automobile manufacturers to follow certain accepted lines of construction, technical questions constantly arise which seek solution from the cooperation of the technical men connected with the industry. These questions could best be dealt with by a technical society. The field of activity for this society would be the purely technical side of automobiles." — Peter Heldt
> (Society of Automotive Engineers current June 2004*b*)

SAE is now nearly 100 years old and has grown to over 83,000 members in 97 different countries. However its' function remains the same, as shown by the Society's purpose statement:

> SAE is a non-profit educational and scientific organization dedicated to advancing mobility technology to better serve humanity. Over 83,000 engineers and scientists, who are SAE members, develop technical information on all forms of self-propelled vehicles including automobiles, trucks and buses, off-highway equipment, aircraft, aerospace vehicles, marine, rail, and transit systems. SAE disseminates this information through its meetings, books, technical papers, magazines, standards, reports, professional development programs, and electronic databases.
> (Society of Automotive Engineers current June 2004*b*)

One of the ways SAE addresses these aims is by formulating and organising student competitions, of which Formula SAE is a part. Currently over 4,500 students from over 500 universities worldwide compete annually in SAE run competitions.

2.3 The Competition

Formula SAE was founded in 1981 as a sealed-road variant of SAE's established Mini-Baja competition. These competitions were aimed at giving universities the opportunity to participate in a regulated event that was interesting and appealing to students.

These events provided new opportunities to learn valuable engineering skills not necessarily acquired in formal engineering courses.

Formula SAE has grown worldwide and draws competitors from several countries. Two additional events are run annually; one in Australia, called Formula SAE-A, and one in the United Kingdom, called Formula Student. These events use the same rulebook, with some minor revisions included for Formula SAE-A and Formula Student. These rules have been included in Appendix B. University teams regularly travel around the world to participate in the competition. Figure 2.1 shows a typical Formula SAE race car.

Figure 2.1: The University of Southern Queensland Formula SAE car.

The objectives of Formula SAE have developed and been refined throughout the competition. Currently the background and aims of the competition as stated by SAE are as follows.

The team is to assume that they have been engaged by a manufacturing organisation to produce a prototype racing car to the given specifications for evaluation. The vehicle will be marketed as a non-professional weekend autocross race car. The car must:

- have very high performance in terms of handling, braking and acceleration.
- be low in cost.
- be easy to maintain.
- be reliable.
- look appealing.
- use common components.
- be comfortable.
- represent a manufacturing cost below $25,000 US.
- be able to be manufactured on a limited production run at a rate of four cars per day.

The competition and judging is designed to evaluate each teams' effectiveness at reaching these goals. Each race car is judged over eight events which cover performance, costing, design, presentation and economy.

The aims and benefits of the Formula SAE competition, as defined by the Society of Automotive Engineers are:

- Enhancing employment prospects
- Preparing students for the work force
- Contributing to the development of engineers -"project trained" - "hands-on" engineers
- Encouraging experience in cost effective innovation and creativity
- Emphasis on the importance of reliability
- Professional development
  - Team building
  - Meeting deadlines

- Project management
- Networking
- General and Financial management
- Sponsorship and communication skills
- Customer relations
- To be competitive

- Identifying high achieving potential employees

The objectives of Formula SAE assist in the fulfillment of the Society of Automotive Engineers overall goals.

2.4 The University of Southern Queensland

The University of Southern Queensland (USQ) competed in Formula SAE for the first time in 2004. University involvement in the competition began in 2003 when the Formula SAE rules were used as a basis for an assignment in the third year design subject, MEC3303: System Design. This served as a preliminary investigation into the competition.

In late 2003 Formula SAE was offered as a final year research project topic and received much interest from students and staff. Nine project topics were allocated in early 2004 and the decision was made to compete officially in Formula SAE-A. Figure 2.2 shows the 2004 USQ Formula SAE project team.

Figure 2.2: The 2004 USQ Formula SAE project team

University involvement in Formula SAE-A continued to develop over the course of the project. The engineering faculty, the engineering workshop, the USQ Mech Club and several staff and students actively participated in the project. The Student Guild and the USQ news services also lent their support to USQ Formula SAE-A.

2.5 Objectives

The overall aim for this project as stated in the Project Specification (refer Appendix A) was:

> **This project seeks to develop effective design management tools and practices to assist in the integration of all aspects of the design and construction of the Formula SAE-A vehicle**

This major aim was divided into several discrete objectives, each with a view to obtaining the overall goal. These objectives as stated in the Project Specification were:

1. Conduct literature review of the design, construction and testing of automobiles.

USQ Formula SAE-A could learn from others' experience through studying the methodologies that organisations involved in designing and constructing vehicles employ.

2. Research the specification of the Formula SAE vehicle.

The Formula SAE-A specification had to be strictly adhered to. The specification outlined factors for the design, construction and competition of the race car, and gave other requirements such as reporting to SAE-A that were required.

3. Provide and maintain general design overview of the Formula SAE vehicle.

This included developing overall design criteria, supervising the implementation of these criteria into the design, and ensuring that the design met all relevant specifications.

4. Coordinate the integration of each subsystem into the overall design.

The design of each subsystem needed to be completed with consideration to how it interacted and complimented every other subsystem on the vehicle.

5. Create and maintain the project information system.

The project information system ensured that all individuals involved in Formula SAE-A had access to critical information. It was also a source of information and advertising aimed at promoting USQ Formula SAE-A.

6. Document each step of the design process and provide justification for each design decision.

Design documentation provided part of the project information system. It was critical to keep all members of the team informed of decisions impacting the design of the vehicle. Each design decision had to be considered and appraised against the general design criteria and the Formula SAE-A specification.

7. Investigate and utilise human resource management skills.

This project involved the participation and skills of a number of individuals. Systems were developed to fully utilise each persons' contribution to the team.

8. Conduct cost analysis and assist in the allocation of funds to each section of the project.

The allocation and tracking of funds is a major part of every engineering project. Cost analysis and financial control were also part of this project.

9. Write project dissertation.

The dissertation was the primary method of documenting the work of the project.

Satisfying all of the projects' objectives enabled the attainment of the paramount goal: to develop effective design management tools and practices to assist in the integration of all aspects of the design and construction of the Formula SAE vehicle. This in combination with the rest of the team, enabled USQ Formula SAE to compete effectively in the Formula SAE-A competition in 2004.

2.6 Literature Review

This section lists literature sources that were reviewed and found to be satisfactory in their content.

Project Management: A Managerial Approach (Meredith & S. Mantel 1995)

This text provided good insight in to the background and development of project management, as referenced in §3. It was also a good source of project management methods and techniques. Some quotes are:

> "There is a tendency to think of a project solely in terms of its outcome - that is, its performance. But the time at which the outcome is available is itself a part of the outcome, as is the cost entailed in achieving the outcome."

And in reference to the role of the project manager:

> "(The project manager) will take responsibility for planning, implementing and completing the project, beginning with the process of getting things started."

Fundamentals of Machine Component Design (Juvinall & Marschek 2000)

This text offered insight into broad considerations for any engineering project and was also a good reference for technical information relating to design. A quote in reference to safety is:

> "The important first step in developing engineering competence in the safety area is cultivating an awareness of it's importance."

The Engineering Design Process (Ertas & Jones 1996)

This text provided information on the design process, management techniques, cost analysis, optimisation, safety and communications. In reference to the design process:

> ”It is at the beginning of the design process, during the conceptualisation phase, that it is most important to consider alternative solutions.”

Introduction to Work Study (Kanawaty 1992)

This text provided some limited information on safety considerations in the workplace.

Computing Essentials (O’Leary & O’Leary 2002) and **Internet in Easy Steps** (Preston 2002)

These provided advice on the effective design of websites. For example:

> ”Create a simple method of navigating that allows users to get the their desired information as quickly as possible. None of your content should be more than three clicks from the home page.”

Management: An Australasian Perspective (Davidson & Griffin 2003)

This text was a good source of basic management principles and of information relating to Human Resource Management(HRM). For example:

> ”... managers now realise that the effectiveness of their HRM function has a substantial impact on the bottom-line performance of their organisation.”

Research Methods for Postgraduates (Greenfield 2002)

This text provided information on research methods and on technical writing style and presentation.

Engineering Management Science Study Book (Morgan 2002)

This text provided information on Critical Path Analysis, timelines and Gantt charts.

2.7 Chapter Summary

Performing effective design overview, integration and project management were critical factors in the successful completion of 2004 USQ Formula SAE-A project. The following chapters are a study into the research and implementation of these factors as they were applied throughout the year.

Chapter 3

Project Management

3.1 Chapter Overview

This chapter gives a brief introduction to project management and its uses. The primary focus is on the purpose of project management rather than its' implementation. Management implementation can vary significantly between projects depending on the nature of the project and the environment in which it is completed. The implementation of project management techniques to USQ Formula SAE is discussed in the following chapter.

3.2 Introduction

Project management, at is most basic level, is defined as:

> The means, techniques, and concepts used to run a project and achieve its objectives.
> (Meredith & S. Mantel 1995)

Therefore, the primary purpose of project management is to achieve a projects' objectives.

The objectives of a project are often mistakenly only thought of in terms of the performance of the finished product. However, cost and time are equally important factors. As shown in Figure 3.1 (Meredith & S. Mantel 1995), only when performance, cost, and time objectives are satisfied is the project target reached.

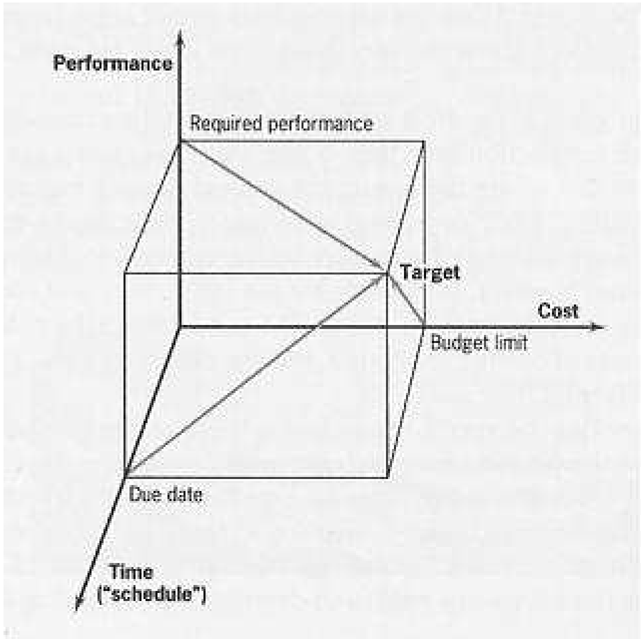


Figure 3.1: Performance, Cost and Time objectives need to be met to reach the project target.

Each of these categories are equally important to the satisfactory completion of the project. Failure to reach any of these objectives results in the failure of the entire project.

In addition to these categories, there can be a number of other objectives which the team must satisfy. An example of this would be achieving positive media exposure for the project.

3.3 The Origin of Project Management

Project management as a science is a direct response to the development of modern society. The three significant forces that have driven this response are:

- the exponential expansion of human knowledge.
- the growing demand for a broad range of complex, sophisticated, customized goods and services.
- the evolution of worldwide competitive markets for the production and consumption of goods and services.

Source: (Meredith & S. Mantel 1995)

Project Management was not invented or discovered, rather it was formed through the gradual change in management principles that were required given the changing form of society. Projects became more complex and involved increasing numbers of people and organisations. Development of new, rapid communication and transport systems have allowed organisations to grow and to undertake extremely large projects. Traditional management systems were not effective in dealing with this new degree of complexity. In response, new techniques were developed to effectively control and monitor these projects. These new methods collectively formed a new field of study: Project Management.

3.4 Project Management Scope

Project Management, as the definition suggests, covers all aspects of what is required to achieve a project's objectives. These aspects fall into two main categories:

Formal Management Tools and Techniques

These are skills which can be learnt through academic study and which generally exist to provide information and act as decision making tools. Examples are timelines, Gantt charts and Critical Path Analysis.

Informal Management Skills

These skills include good communication techniques, crisis management, conflict resolution, decision making, motivational and human interaction skills. These can be studied to a certain extent, however they depend more on the personality and attitude of the project manager, and on his past experience.

3.5 Project Management Fields

Project management is often divided into specific areas or fields which target and monitor specific objectives or which require a certain set of management skills. Fields common to all projects are:

- Project Organisation
- Project Planning
- Project Information Systems
- Task Scheduling
- Resource Management
- Cost Estimation and Financial Control
- Negotiation and Conflict Management
- Monitoring and Evaluation

Many other aspects may need to be considered depending on the nature of the project. Also, some fields may have a greater importance or may require more effort than others.

Only through the combined consideration of all of these fields can effective project management be performed.

A brief description of each of the standard fields follows:

3.5.1 Project Organisation

Project organisation involves defining and creating the basic structure within which the project is pursued. Factors that need to be investigated may be:

- The environment in which the project team operates. This includes the structure of the organisation in which the team works, and also the characteristics of the area in which the organisation is located. Depending on the scale or nature of the project, these considerations may range from local to global concerns.
- The structure of the project team itself. The size of the team and the structure of authority within it affect how the team will operate.
- The constraints and characteristics of the project. Some projects may require outside input or may need to be confidential. Other projects may be run in partnership with another organisation or may involve sub-contracting part of the work. Factors such as these will influence the structure of the management system.

3.5.2 Project Planning

The clarification of goals and project objectives, followed by the formulation and coordination of a plan that enables these objectives to be attained.

Each project should satisfy a need. Understanding this need is critical to a projects' success. Many projects fail because they either create a product which is not needed by the targeted demographic, or because the need was misunderstood and the product fails to satisfy it.

Once the need which the project aims to fulfill is understood, goals and objectives can be outlined to further clarify the direction of the project. These objectives should be made with consideration to the constraints within which the project is completed. Performance, time and cost factors should all be considered.

Goals are an important part of any project as they give focus and direction to each task. It is easy to lose perspective on a problem when looking only at the details. Goals are a standard to which decisions can be compared. Each decision made should bring the project closer to attaining its goal.

This is followed by generating a plan which enables the satisfaction of these goals.

3.5.3 Project Information Systems

The creation of an information system to allow the exchange of relevant data both within the project team and to outside parties. The nature of this system varies largely depending on the project and the environment. However, the aims of the system are always the same:

- To provide current relevant information to each member of the project team.
- To provide required information to other involved parties both within the organisation and without.
- To document each decision and section of the project for future reference.
- To attract interest and to promote the project. For example through media coverage. (Note: not relevant for all projects)

3.5.4 Task Scheduling

Task scheduling involves time management and is often completed in conjunction with resource management. Task scheduling divides a project into several discreet activities. The resources and time that are required for each activity are evaluated and a plan is formed to complete the project efficiently within the time constraint.

Task scheduling is generally performed throughout the project as situations arise which may make required resources unavailable at their required time. The schedule may therefore be fairly dynamic: the degree of this dynamism depends on the project and its' environment.

Task scheduling is generally a very important task in most projects as it is fundamental to determining a large part of the cost of a project. It can also be important where the consequences of not completing a project on time are significant. The construction of power station would be an example of this.

3.5.5 Resource Management

Resource management involve the planning and organisation of resources in conjunction with task scheduling in order to ensure that the required resources are available for each task at the required time.

Resources can be split into three main categories: Human, Material and Financial.

Human resources include the project team, industry experts and consultants, sub-contractors, workers and any other people involved in the project. Each individuals' contribution may be intellectual, physical or both.

Material resources are the raw materials required to manufacture the projects' product and the physical resources which are required during manufacture. Examples of these may be lathes and milling machines, concrete and temporary barrier fencing.

The organisation and utilisation of resources is one of the primary functions of a project manager. Effective use of resources results in a cheaper, more effective outcome in the shortest time possible.

3.5.6 Cost Estimation and Financial Control

Financial control is generally a specialised job in large engineering projects, however all engineers need to understand how cost affects a project.

Cost is a major influence in almost every engineering venture, and has a considerable affect on the methods and techniques employed in the design of a product. Projects with a generous budget can afford to use financial resources to research alternatives to find innovative solutions. Conversely, projects which involve a competitive tendering process are generally tightly controlled with little room for innovation. However, this is not always the case, as a tight budget can encourage the discovery of innovative cost-saving techniques in order to increase profit margin for the organisation.

Ultimately, all projects work to a budget, and it only responsible to ensure the each project makes efficient use of its' financial resources.

3.5.7 Negotiation and Conflict Management

Projects bring many individuals and organisations together that have differing priorities and aims. Conflict and disagreement can arise between any of the involved parties. Effective negotiation skills are important to minimise conflict and to reach satisfactory conclusions which consider all parties points of view.

The methods used to manage negotiation and conflict vary depending on the scope of the project, the concerned parties relationship to each other, and the seriousness of the disagreement. Methods range from simple conversation and meetings to formal arbitration in a court of law.

Depending on the seriousness of the conflict, outside parties may become involved in this process.

3.5.8 Monitoring and Evaluation

Monitoring and evaluation provides information and feedback on all aspects of the project. This process is done internally and, in most cases, externally as well.

Internal monitoring usually analyzes how well the project team met its' initial objectives. Quality documentation of the entire project is required for internal monitoring to be effective.

External monitoring can involve analysis of the product by an outside party, analysis of the design process by an outside party, or simply by product performance in the intended marketplace.

However monitoring is completed, it should be compared to the original goals and objectives of the project and evaluated on these criteria.

3.6 Chapter Summary

Project management is a continual learning experience. Each new project offers new challenges and obstacles for the manager and it is his ability to adapt and use his skills effectively that enable each project to be successfully completed.

The purpose of project management is to enable the achievement of a projects' goals. The following chapter discusses the application of project management and relevant tools to USQ Formula SAE.

Chapter 4

Project Management of USQ Formula SAE

4.1 Chapter Overview

USQ Formula SAE involved the completion of a complex engineering problem. It did, therefore, have need of effective management in order to reach its' goals. This chapter describes the methodology employed and the decisions made in the management of USQ Formula SAE.

4.2 Project Organisation

As stated in § 3.5.1: project organisation involves defining and creating the basic structure within which the project is pursued. This includes investigating the environment in which the project team operates, the internal structure of the project team, and the constraints and characteristics of the project. A description of these factors and the steps taken to create the USQ Formula SAE team follows.

USQ Formula SAE was pursued as a final year research project undertaken by a team of students. Final year research projects have access to university funds and facilities, and are supervised by lecturers.

In 2004, nine students undertook this project. The project was divided into nine fields of work, each under the responsibility of a single student. The students and their respective fields were:

1. Design Overview and Project Management: John Armstrong
2. Spaceframe Chassis Design: Chris Baker
3. Monocoque Chassis Design: Bruce Grassick
4. Engine Systems: Travis Mauger
5. Suspension Systems: Rex Parmenter
6. Steering Systems: Les Rayner
7. Drivetrain and Braking Systems: Jeremy Little
8. Bodywork and Aerodynamics: Ken Nelder
9. Instrumentation, Control Systems and Vehicle Testing: Brad Moody

The supervisors and associate supervisors involved in USQ Formula SAE in 2004 were Chris Snook, Selvan Pather, Bob Fulcher, Peter Penfold, Doug Baddeley and Ruth Mossad. Chris Snook was the primary organiser of the project, and was responsible for all communications with SAE-A.

Each final year engineering project had an allocation of approximately $200 of university funds, collectively giving an intial fund pool of $1800.

In May USQ Motorsport were successful in applying for the Formula SAE-A startup grant of $6000. This grant is available for teams competing for the first time in Formula SAE-A.

Early in 2004 the project team decided to encourage involvement in Formula SAE by all people who were interested in the project. To this end the USQ Motorsport club was formed. All individuals involved in the Formula SAE team were members of USQ Motorsport. This included students, staff, sponsors and supporters from the general community.

USQ Motorsport was created to generate a single identifiable team structure, of which all members could feel a part. The club has members from very different backgrounds, age groups and social circles. Therefore it was important to create a single cohesive group to encourage involvement and interaction between members.

Further discussion on the functions of USQ Motorsport are given in §4.6.

Henceforth the USQ Formula SAE team is referred to as USQ Motorsport, whilst the project team refers only to the nine final-year students.

4.3 Project Planning

Project planning involves the clarification of goals and project objectives, followed by the formulation and coordination of a plan that enables these objectives to be attained.

4.3.1 Identifying the Need

The first step in project planning is to identify the need which the project aims to fulfill. In this project the need is defined in §1 in the Formula SAE rulebook and was identified in §2.3.

4.3.2 Goal Formulation

The most significant goal set by USQ Motorsport was to actively enter and compete in Formula SAE in 2004. This goal was set in late March and needed to be determined before further planning was possible.

After making this decision, project objectives were discussed and identified. These objectives are outlined in the following sections and are divided into performance, cost, time and general objectives categories.

4.3.3 Performance Objectives

Performance objectives for Formula SAE-A were not only car performance parameters such as acceleration and handling, but also included objectives such as innovation in design and aesthetic qualities. The basic performance objectives as given in the Formula SAE rulebook were for the race car to:

- have very high performance in terms of handling, braking and acceleration.
- be easy to maintain.
- be reliable.
- look appealing.
- use common components.
- be comfortable.
- be able to be manufactured on a limited production run at a rate of four cars per day.

The competition judging and evaluation was based on meeting these performance categories. However, these objectives needed to be further focussed in order to create a plan specifically for USQ Formula SAE. USQ Motorsport decided to focus on the following objectives.

To have no major reliability problems at the competition

The race car (dubbed *Jettison 1*) was designed with high reliability as a major design criteria. A review of competition performance has revealed that reliability is often a problem and in previous years a number of competitors were unable to complete all events. This usually resulted in no score for that event.

This design objectives assisted in making design decisions where reliability was weighed against performance. Each component was designed to be 99.9% reliable for the span of the competition. This did not mean that performance was not a significant priority: all design decisions still considered performance strongly, however where there was some uncertainty, the component was designed with an emphasis on reliability.

To aim for simplicity in design

Simplicity is always a good factor to design into a race car. It has a carry-down effect which benefits other objectives and does not necessarily result in a poorer performing car.

Simplicity in design has the following advantages:

- The car is cheaper to construct as there is less work in creating components.
- The car is able to be manufactured at a greater rate.
- Maintenance costs are lower and reliability is enhanced.

The challenge lies in not significantly degrading the performance of the car whilst retaining simplicity in design.

4.3.4 Cost Objectives

The cost objectives as defined in the Formula SAE rules were for the car to:

- be low in cost.
- represent a manufacturing cost below $25,000 US.

These objectives were basically the same: the first objective suggested that value for money was important, while the second gave a fixed upper limit.

The available funds for USQ Motorsport were largely uncertain at the commencement of the project. To this end the team set some of its' own cost objectives:

To construct and compete with the car effectively for the lowest possible financial outlay

After receiving the SAE startup grant USQ Motorsport had a guaranteed fund pool of approximately $7800. This was determined to be sufficient to construct the car, provided cost was strongly considered in the design and selection of components.

This was used to the team's advantage as manufacturing cost was a significant part of the judging criteria at the competition.

Designing for low cost does not necessarily result in poor vehicle performance. Many expensive components that most teams purchase could be manufactured with similar levels of performance. Purchased components were also carefully appraised regarding cost for performance benefit.

To raise additional funds through sponsorship and fundraising activities.

Additional funds were required to finance travel to Melbourne for the competition held in December. Also, a larger budget would give the team greater options in the design of the car as financial cost became a less significant factor.

Sponsorship fell into two main categories: financial support and services support. Sponsorship through supplying services represented a cost saving to USQ Motorsport, as the team was supplied a service for which they would normally have to pay.

Fundraising activities directly increased the fund pool of USQ Motorsport.

4.3.5 Time Objectives

Time objectives for Formula SAE are largely determined by the competition. Deadlines set by the Formula SAE rules were:

- 2nd August, 2004: Team registration
- 1st September, 2004: Safety Structure Equivalency form
- 1st October, 2004: Design Report and Design Specification Sheet
- 1st November, 2004: Cost Report
- 2nd - 5th December, 2004: Competition

The Safety Structure Equivalency form, Design Report, Design Specification Sheet and Cost Report are all reports that were required to be submitted to SAE-A for evaluation throughout the year. The dates for these reports did not have a significant effect on task scheduling as they were specified so that the required work for the reports was completed before the submission dates.

These deadlines were fixed and had to be met in order to successfully compete in the Formula SAE-A event. In addition to these the project team determined time objectives within this timeframe:

To complete major construction on Jettison 1 by October 1st

Defining this objective gave USQ Motorsport a timeframe within which task scheduling for the construction of Jettison 1 could be performed. Meeting this objective would allow sufficient time for vehicle testing and evaluation.

The creation of a task schedule within this timeframe is further discussed in §4.5.

4.3.6 General Objectives

There were several objectives determined by USQ Motorsport that did not fit into performance, cost and time categories. Generally these objectives were concerned with the administration and actions of USQ Motorsport outside of the design and construction of the car. They were important, however for the performance of the team.

To locate a suitable workspace

A quality workspace was required for the construction of Jettison 1 and as a secure location to store components. Ideally this location was determined to have the following qualities:

- Be easily accessible by the project team.
- Be secure.
- Have sufficient space for the storage of components and for the construction of the vehicle.
- Be located in proximity to the engineering faculty and the workshop.
- Have large access doors to allow the race car to be easily moved.
- Be located in a position where the creation of noise is not a significant issue.
- Be reserved for the sole use of the USQ Motorsport team.

To encourage participation in the project throughout the university

This was already addressed through the creation of the USQ Motorsport club.

The activities of USQ Motorsport were designed to encourage new members to become involved in the team.

To provide opportunity for third year engineering students to participate in project work.

This was primarily done through the formation of USQ Motorsport, however the project team determined that the teams' activities would be most beneficial to third year engineering students. It was decided that additional effort would be made wherever possible to encourage third year participation.

To raise awareness and interest in the Formula SAE competition and in USQ Motorsport

Meeting this goal would make the task of finding sponsorship and support for USQ Formula SAE-A easier. It would also serve to promote our sponsors and the university throughout the community.

To cultivate a good relationship with the faculty workshop

The faculty workshop would be the primary means of constructing many components for the car. The project team determined that this should be listed as a goal because of the close nature in which USQ Motorsport would work with the workshop. This would not only impact this years' competition, but would affect the following years as well.

4.3.7 Formulating the Plan

After determining the goals and objectives for USQ Motorsport, the team needed to formulate a plan which would enable them to achieve these objectives. Following is a description of the plan and of the actions taken to fulfil this plan during the year.

Performance Objectives

The performance objectives were:

- For Jettison 1 to:
  - to have very high performance in terms of handling, braking and acceleration.
  - be easy to maintain.
  - be reliable.
  - look appealing.
  - use common components.
  - be comfortable.
  - be able to be manufactured on a limited production run at a rate of four cars per day.
- To have no major reliability problems at the competition
- To aim for simplicity in design

These objectives were met through consideration during the design of Jettison 1. These aspects are fully discussed in Chapter 6.

Cost Objectives

The cost objectives were:

- For Jettison 1 to:
  - be low in cost.
  - represent a manufacturing cost below $25,000 US.
- To construct and compete with the car effectively for the lowest possible financial outlay.
- To raise additional funds through sponsorship and fundraising activities.

Satisfaction of USQ Motorsports' objective to complete the car with a low financial outlay satisfied the objectives given by SAE-A. As cost was a major factor in the design and selection of components for Jettison 1, this is discussed in Chapter 6.

In order to raise additional funds through sponsorship and fundraising, USQ Motorsport created a task group to specifically target this area. The members of this task group were Melinda Plank, Vivienne French, Richard Gurney, Rex Parmenter, Derek Mulder and myself.

The group was assigned to create and distribute a sponsorship package to selected organisations. Levels of sponsorship were determined which defined the responsibilities of the sponsor and the associated responsibilities of USQ Motorsport. Suitable organisations were found to target, and the package was distributed.

There was limited response to the sponsorship package, so some members of the task group made face-to-face contact with selected sponsors. This approach was successful and the group were able to secure a number of sponsors.

A list of sponsors and their respective contributions can be found in Appendix G.

Many of these sponsors elected to donate prizes for raffles. Therefore the majority of the fundraising activities were raffles. These were held frequently toward the end of the year and at special events such as open day.

The USQ Mech Club also held fundraising events such as barbecues in support of USQ Motorsport.

Time Objectives

The time objectives were:

- To meet the following SAE-A deadlines:
  - 2nd August, 2004: Team registration
  - 1st September, 2004: Safety Structure Equivalency form

  - 1st October, 2004: Design Report and Design Specification Sheet
  - 1st November, 2004: Cost Report
  - 2nd - 5th December, 2004: Competition

- To complete major construction on Jettison 1 by October 1st

Time objectives were met through management of the tasks involved in designing and constructing Jettison 1. This is discussed in §4.5.

General Objectives

The general objectives were:

- To locate a suitable workspace with the following properties:
  - Be easily accessible by the project team.
  - Be secure.
  - Have sufficient space for the storage of components and for the construction of the vehicle.
  - Be located in proximity to the engineering faculty and the workshop.
  - Have large access doors to allow the race car to be easily moved.
  - Be located in a position where the creation of noise is not a significant issue.
  - Be reserved for the sole use of the USQ Motorsport team.
- To encourage participation in the project throughout the university.
- To provide opportunity for third year engineering students to participate in project work.
- To raise awareness and interest in the Formula SAE competition and in USQ Motorsport.
- To cultivate a good relationship with the faculty workshop.

A suitable workspace was located and claimed in April. The only workspace that fit all of these criteria was the post-harvest lab in the engineering building. USQ Motorsport were able to secure this room for its' exclusive use.

Participation was encouraged in USQ Motorsport by holding frequent social events. These were run in conjunction with the USQ Mech Club. Barbecues and pizza days were held where the project team would display Jettison 1 and discuss their progress with those in attendance. Figure 4.1 shows the car being displayed at a Mech Club barbecue.

Figure 4.1: Jettison 1 displayed at a Mech Club barbecue

Articles were run on USQ Motorsport in USQ's internal news service, the "USQ News", to raise awareness of the project within the university community. This in turn encouraged more people to participate in USQ Motorsport.

USQ Motorsport fulfilled the role of providing opportunities for third year students to participate, however further efforts were also taken. Third year students were primarily targeted to actively participate in particular tasks. The best example of this was the Sponsorship and Fundraising team, of which three third year students were members. In addition, the third year subject "System Design" incorporated aspects of

USQ Motorsport and Formula SAE into its' assignments.

Awareness of USQ Motorsport and Formula SAE was raised through securing media coverage of the team and through holding an official car launch night. Media coverage included television coverage on WIN News, radio announcements on 4AK and 4WK and articles in print media. The Jettison 1 launch night was held as an Engineers Australia seminar for the local district. This included a display of the car, presentations given by the project team and discussions and social activities.

A good relationship was established with the university workshop through consideration of their requirements for work to be completed. USQ Motorsport were able to establish an excellent relationship and were granted an exclusive space in the workshop for Jettison 1's construction.

4.4 Project Information System

The objectives of USQ Motorsports' project information system were:

- To provide current relevant information to each member of the project team.
- To provide required information to other involved parties both within the organisation and without.
- To document each decision and section of the project for future reference.
- To attract interest and to promote the project. For example through media coverage.
- To fulfil all reporting requirements as specified by SAE.

The information system had to provide an effective means of communication between the following parties:

- Each individual in the USQ Formula SAE project team.

- The project supervisors.
- The USQ MotorSport Club.
- Sponsors.
- The university workshop.
- The general university population.
- The general community.

Where such communication involved decision making, work orders or other important data, it had to be easily recorded.

To address these communication needs the following methods were utilised:

Regular Meeting Schedule

This was the main form of communication within the project team. Meetings were generally held at least once a week. All key decisions were discussed at these meetings and issues that affected the entire team were resolved here. Figure 4.2 shows Rex participating in a team meeting.

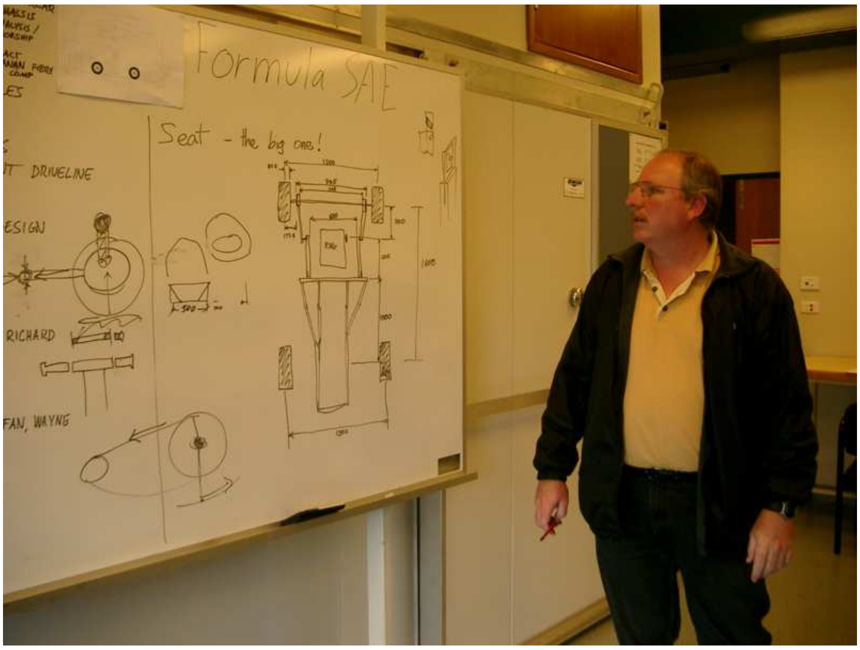


Figure 4.2: Regular team meetings were held to progress the design of the car

Supervisor Meetings

Meetings were held frequently between each project student and their supervisor. This was generally to ensure that the project was progressing satisfactorily and to suggest further work that might be done.

The Website

A website was created for the USQ Motorsport club. This site was one of the primary forms of communication between USQ Motorsport and the general community. It was designed as a resource that could be accessed by anyone who was interested or involved in Formula SAE. The website was be updated regularly to reflect the teams' activities and included discussion on each team members' progress. The website also functioned as an advertising medium and as a method of exposure for the teams' sponsors. The website can be viewed in Appendix F.

Email

Email was the preferred medium for all other significant communication. It is easily monitored and is rapid. Email was used to communicate between all parties involved in the project, both to keep them updated of current progress and to inform them of issues that needed to be addressed.

Drawings, Diagrams and 3D Modeling

As the design progressed, drawings and documentation needed to be produced to enable the manufacture and further design of Jettison 1. All work performed in the workshop was specified by CAD and hand drawings. These drawings were checked and appraised by Chris Snook and myself before being authorised for production.

3D modeling was used in many cases to generate production drawings and to assist with integration of design. Design integration of components is discussed in Chapter 6.

4.4.1 Communication Media

Effective communication depends upon having a common communication medium. As discussed, email was used for most important notifications and is by nature universal. However standards needed to be set for common software use, so that all team members could access each others' data. The software packages that the team elected to use were:

- LaTeX 2_ε for project appreciation and dissertation documents.
- Fluent for Computational Fluid Dynamics(CFD) calculations.
- ProEngineer for solid modeling and detail drawings.
- ANSYS for Finite Element Analysis(FEA) calculations.

All team members were expected to use these programs for all their work.

In addition to the formal communication methods utilised, due to the small nature of the project, much important communication was done informally at unplanned times. Care needed to be taken to inform everybody of any decisions made in these meetings. This was accomplished through weekly meetings or via email.

4.5 Task Scheduling

Effective task scheduling minimizes the time needed to complete a project and assists in the allocation of resources.

In 2004, USQ did not have the advantage of prior experience in Formula SAE-A. Therefore it was difficult to estimate standard times for activities. However, estimates were made and a timeline was created with an expected completion date. This timeline clarified the order in which tasks needed to be completed and was a useful tool for determining the percentage of completion at any time.

The initial timeline is shown in Figure 4.3.

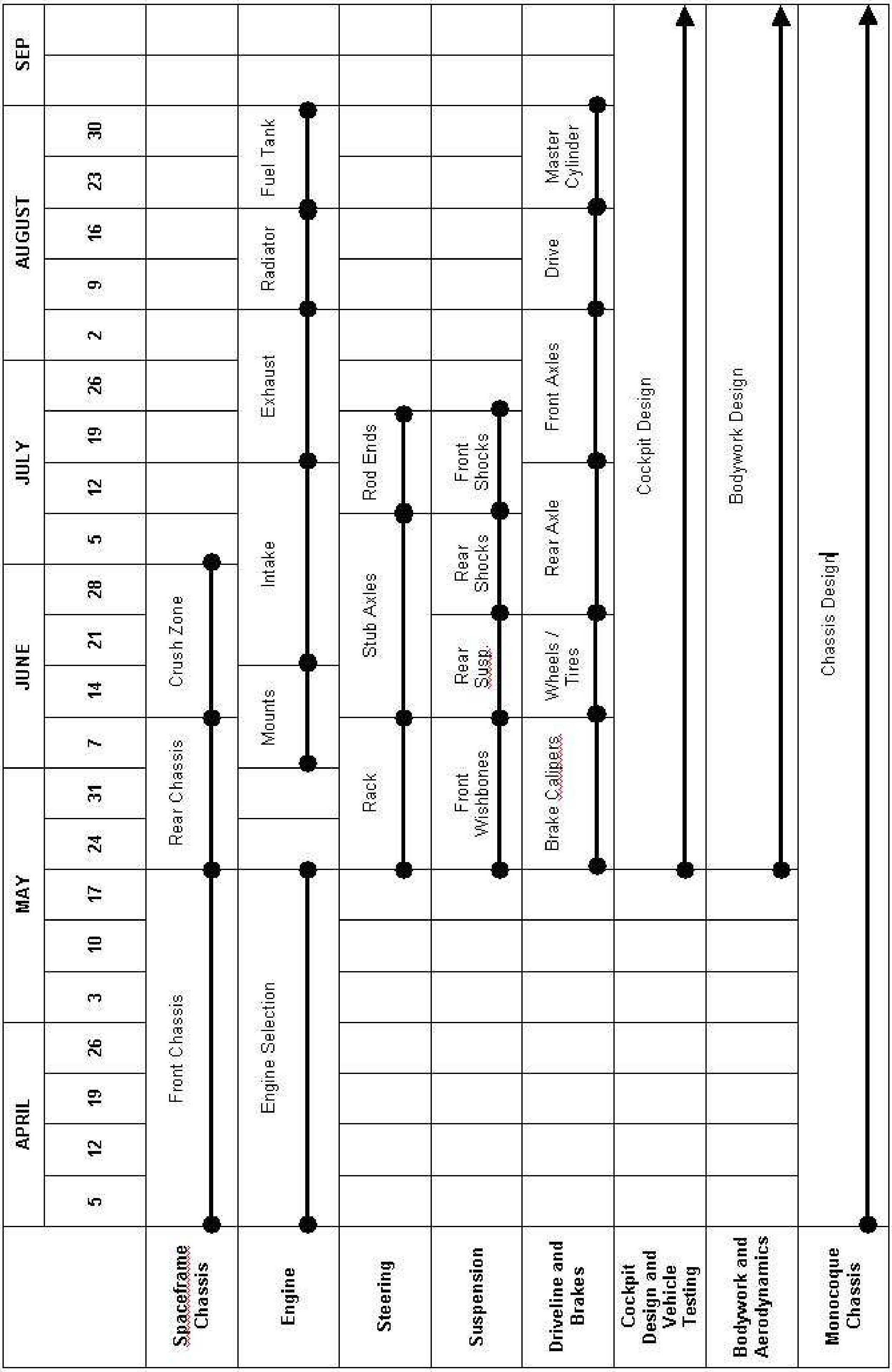


Figure 4.3: Initial Project Timeline

Certain tasks could not be completed until other tasks were fully complete. It was therefore important to complete the tasks in the order specified by the timeline.

USQ Motorsport were not successful in adhering to the initial timeline. However, the team gained valuable experience from which better time estimations could be made in following years.

4.6 Resource Management

Resource management involve the planning and organisation of resources in conjunction with task scheduling in order to ensure that the required resources are available for each task at the required time.

The following sections discuss the available resources and their use.

4.6.1 Physical Resources

Physical resources are the raw materials required to manufacture the projects' product and the resources which are required during manufacture.

Each project team member was expected to investigate and select suitable materials for their section of the design. These materials were acquired through the university purchasing system following approval by Chris Snook and myself.

Other physical resources that were used are:

USQ Workshop

The USQ Workshop was the primary source for the supply and manufacture of basic components for Jettison 1. Facilities available included:

- TIG, arc, oxy-acetylene and MIG welding facilities.

- CNC milling and turning centres.
- Conventional machining centres.
- Spray-painting facilities.
- Hand tools and equipment.
- Workspace for Jettison 1.

The workshop was also a source of basic raw materials such as steel.

Chris Hanifan

Chris was the main source of high tensile steel tubing used in the construction of the chassis, and of other miscellaneous materials such as body fasteners and aluminium scrap. Chris kindly donated these resources to USQ Motorsport.

Sponsors and Supporters

Several sponsors donated materials and components or supplied them for a reduced price. Significant support came from these organisations:

- Bandit Motor Gear: Donation of safety harness and restraints. Supply of numerous components at reduced price.
- Buchanan's Advanced Composites: Supply of all material and much physical work involved in the construction of the GRP fibre-composite bodywork.

4.6.2 Human Resources

Human resources include the project team, industry experts and consultants, subcontractors, workers and any other people involved in the project. Each individuals' contribution may be intellectual, physical or both.

Significant sources of human resources that were utilised in the USQ Formula SAE project were:

The USQ Formula SAE team

The project team was the most significant human resource since the successful completion of the Formula SAE racing car depended directly on each individual completing their respective section of the design work. The team also had significant responsibilities relating to all aspects of the construction of the vehicle.

Difficulties arose when team member Rex Parmenter was unavailable for an extended period of time due to illness. To address this situation I reassigned some of his work to other team members. Chris Baker was responsible for investigating and selecting the shock absorber system and Les Rayner was responsible for designing the rear suspension uprights. Fortunately Rex recovered from his illness and was able to continue with his work.

USQ Motorsport

The USQ Motorsport club was the primary resource outside of the project team. The significant uses of the club were:

- a source of intellectual knowledge and experience. Some of the members of USQ Motorsport had significant experience in automotive design and construction.
- a labour base which could be utilised to assist in the vehicle construction. Some of the members had specialised skill and experience, for example in welding and spray painting.
- a source of motivated individuals which could be used to form task groups. These groups assisted in finding sponsorship and running fundraising activities.

Project Supervisors

The project supervisors and assistant supervisors for USQ Formula SAE were Chris Snook, Bob Fulcher, Selvan Pather, Doug Baddeley, Ruth Mossad and Peter Penfold. The supervisors were the primary source for advice and direction in the project. They also collectively represented significant intellectual knowledge.

Industry Contacts

Some specialised knowledge was required during the design and construction of the racing car. Several sponsors contributed their time and expertise in race car design to the project.

4.6.3 Financial Resources

Financial resources for USQ Formula SAE came from four significant sources.

Faculty Project Funds

The university had funds available to assist in the completion of student projects. These funds can be accessed through the university purchasing system. The limit of these funds was approximately $200 per project student, or around $1,800 for the team.

Sponsorship

Several sponsors made cash donations to USQ Motorsport. These donations are detailed in Appendix G. In total $10 050 was donated to USQ Motorsport.

Fundraising

Fundraising activities had duel purpose of both raising funds and providing exposure for the team and sponsors. Several sponsors made donations of prizes that were used in raffles. Fundraising also involved activities such as Bash-a-Bomb and barbecues.

In total, approximately $500 was raised through these activities.

SAE Startup Grant

Teams competing for the first time in Formula SAE-A are entitled to a $6,000 startup grant. USQ Motorsport were successful in applying for this grant in 2004.

The organisation and utilisation of resources is one of the primary functions of a project manager. Effective use of resources results in a cheaper, more effective outcome in the shortest time possible.

In its first year of competition, the USQ Formula SAE team were successful in creating good relationships with all of its potential resource suppliers, and in establishing strong support for the coming years.

4.7 Cost Estimation and Financial Control

The control of funds was managed by Chris Snook and myself. Each team member priced components that were required for their section of the design. These prices were further investigated by myself and purchase approvals were completed by Chris Snook.

As discussed previously, it was USQ Motorsports' aim to manufacture a competitive race car in as cost-efficient manner as possible. Engineering judgement was used to determine whether a components price was justified. This is further discussed in Chapter 6.

4.8 Negotiation and Conflict Management

There were no serious needs for conflict management during the course of the project. Each student was assigned a supervisor who oversaw their project. Any negotiation done regarding their project was completed through discussion with the relevant supervisors.

Some negotiation occurred during the course of the project relating to the scope of each individuals' design. In particular the reassignment of responsibilities resulting from Rex's illness required some negotiation and acceptance.

4.9 Monitoring and Evaluation

The primary source of evaluation in Formula SAE is the competition itself. Further evaluation is completed through appraisal of the success of the team in meeting its' objectives and through the evaluation of each team members' dissertation and project work.

4.9.1 Formula SAE Competition

The formula SAE competition was designed to evaluate a teams' performance through written reports, verbal questioning, static testing of the car, and dynamic performance events. This process has not yet taken place and so can not be used for evaluation at this stage.

4.9.2 Internal Appraisal

Internal performance appraisal was done in regard to how well USQ Motorsport met its objectives. A discussion on each objective follows:

The performance objectives were:

- For Jettison 1 to:
  - to have very high performance in terms of handling, braking and acceleration.
  - be easy to maintain.
  - be reliable.
  - look appealing.
  - use common components.
  - be comfortable.
  - be able to be manufactured on a limited production run at a rate of four cars per day.
- To have no major reliability problems at the competition
- To aim for simplicity in design

Many of these performance objectives will be evaluated at the competition and can not yet be appraised.

However, USQ Motorsport was successful in retaining simplicity in design. The impact upon performance of some of the design decisions resulting from this philosophy will also be evaluated at the competition and during vehicle testing.

The cost objectives were:

- For Jettison 1 to:
  - be low in cost.
  - represent a manufacturing cost below $25,000 US.
- To construct and compete with the car effectively for the lowest possible financial outlay.
- To raise additional funds through sponsorship and fundraising activities.

USQ Motorsport was successful in manufacturing Jettison 1 for a very small financial outlay. Total cost for the race car is discussed in Chapter 7.

The team was also successful in securing good sponsorship support and in raising money through fundraising activities.

The time objectives were:

- To meet the following SAE deadlines:
  - 2nd August, 2004: Team registration
  - 1st September, 2004: Safety Structure Equivalency form
  - 1st October, 2004: Design Report and Design Specification Sheet
  - 1st November, 2004: Cost Report
  - 2nd - 5th December, 2004: Competition
- To complete major construction on Jettison 1 by October 1st

USQ Motorsport was successful in submitting the required reports to SAE. However, the team was not successful in completing major construction of Jettison 1 by October 1st.

The general objectives were:

- To locate a suitable workspace with the following properties:
  - Be easily accessible by the project team.
  - Be secure.
  - Have sufficient space for the storage of components and for the construction of the vehicle.
  - Be located in proximity to the engineering faculty and the workshop.
  - Have large access doors to allow the race car to be easily moved.
  - Be located in a position where the creation of noise is not a significant issue.

    - Be reserved for the sole use of the USQ Motorsport team.

- To encourage participation in the project throughout the university.
- To provide opportunity for third year engineering students to participate in project work.
- To raise awareness and interest in the Formula SAE competition and in USQ Motorsport.
- To cultivate a good relationship with the faculty workshop.

USQ Motorsport was successful in all of these objectives.

4.9.3 Dissertation

The dissertation was the primary means of assessing each individuals' project performance.

4.10 Chapter Summary

The management of USQ Formula SAE was a complex and dynamic process. USQ Formula SAE differed from many engineering projects in many significant ways, however the application of basic management principals still held. The successful application of these principals enabled USQ Motorsport to attain its' primary goal of actively competing in the 2004 Formula SAE-A competition.

Chapter 5

Engineering Design Process

5.1 Chapter Overview

This chapter investigates modern engineering design theory and its' application to USQ Formula SAE. The general engineering design processes used commonly in complex engineering projects are described. An understanding of these processes was important in order to promote efficient and effective design practices. The application of these processes to the design, manufacture and evaluation of Jettison 1 is discussed.

5.2 Design Process

The design and manufacture of any complex engineering system is best completed by following a set design process. This process defines every step of the project and assists in its' overall management. The general design process is depicted in Figure 5.1.

Additional steps such as development research or board approval may be added to this process, depending on the nature of the project and the organisation completing it. However, the basic structure as shown suited the process of design for Jettison 1.

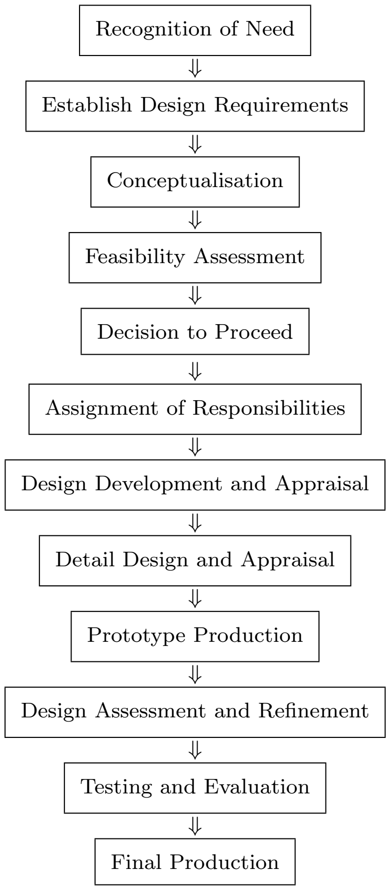


Figure 5.1: The Design Process[]

5.2.1 Recognition of Need

The recognition of need is defined as:

> The identification of a need for a product or system which can be satisfied through engineering effort.

The recognition of need was discussed in Chapter 4.

5.2.2 Establish Design Requirements

Before designs and concepts can be developed, further requirements must be established for the design. These requirements are a tool which enable concepts to be appraised and ensure that the design will meet the need defined in the first step.

The design requirements are generated from three main sources:

1. The need statement.
2. Specifications and rules to which the design must comply.
3. Further considerations dependent on the environment in which the design is created.

The need statement is the first source of design requirements. These factors are the most important as the success of a design is determined by how well it meets this need.

The specifications and rules were provided in the form of the 2004 Formula SAE rulebook and the Formula SAE-A Rulebook Addendum. These provided specifications to which the design had to comply to be able to run in the competition. Therefore, meeting these rules was of paramount importance.

Other considerations can be made which are unique to the environment in which the design is created, or which the team wishes to impose on the design. These requirements consider factors such as financial situation, experience of the team and resources available.

5.2.3 Conceptualisation

Conceptualisation is the process by which many potential solutions to the need are defined, discussed, developed and investigated. It is very important that many alternate designs are considered during this process.

Conceptualisation has two main purposes:

- to encourage innovation in design. It is easiest to conceive truly unique solutions at this stage before any one idea has become dominant in the minds of the engineers.
- to actively seek the best solution to the need while providing justification for the rejection of other designs, based purely upon the experience and instinct of the design team.

While this is not a true feasibility assessment, (that is the next stage), many solutions can be justifiably discarded through discussion in this stage. In addition, the designers are able to grasp an understanding of the advantages and shortcomings of their chosen solution, and establish a number of viable alternatives.

The main method which the Formula SAE team approached conceptualisation was through brainstorming at team meetings. Alternate designs were discussed within the team and all team members had the opportunity to develop these concepts. At this stage individual team members focussed on researching their section of the design so that they could provide good advice based on their knowledge of the advantages of particular concepts. It was also important to appraise the concepts against the basic design requirements.

Through conceptualisation the team was were able to create a basic design for Jettison 1 with some basic parameters. These parameters enabled the team to begin designing their section of the racecar individually.

5.2.4 Feasibility Assessment

The feasibility assessment is where the proposed design and parameters are closely examined against the design requirements.

For USQ Formula SAE this process was completed in conjunction with the conceptualisation phase. This enabled the team to quickly discard inferior or impractical concepts and to develop the design parameters rapidly.

However, as the team increased their knowledge through experience and research, they were able to make better judgement of the proposed design and suggest further alternatives and improvements. Through this process the basic design parameters developed throughout the entire course of the project, resulting in many changes to the design. This createed a complex and dynamic design environment which had to be carefully managed to ensure that the design continued to integrate effectively and met the basic design requirements. The conceptualisation and feasibility process, while existing as initial steps in the design process continued throughout the project.

5.2.5 Decision to Proceed

Most engineering projects are subject to approval from outside the design team. This can be through approval by the management of the organisation or through the winning of a contract.

In USQ Formula SAE the team had to make the decision to manufacture and compete with the racecar in 2004. This decision was made primarily by the student team, with some input from the project supervisors. The alternative was to complete a detailed design of the racecar in 2004 with a view to manufacture in 2005.

In March the USQ Formula SAE team made the decision to proceed with the manufacture and competition of the racecar in 2004.

5.2.6 Assignment of Responsibilities

The assignment of responsibilities in an engineering project is generally done through the creation of a work breakdown structure (WBS). The work breakdown structure divides the project into a number of elements, tasks or systems which are similar in size and complexity. These can be further divided into tasks within each element. The level of division of tasks required depends upon the complexity and nature of the project. An example of a WBS created for a space shuttle program is shown in figure 5.2. (Ertas & Jones 1996)

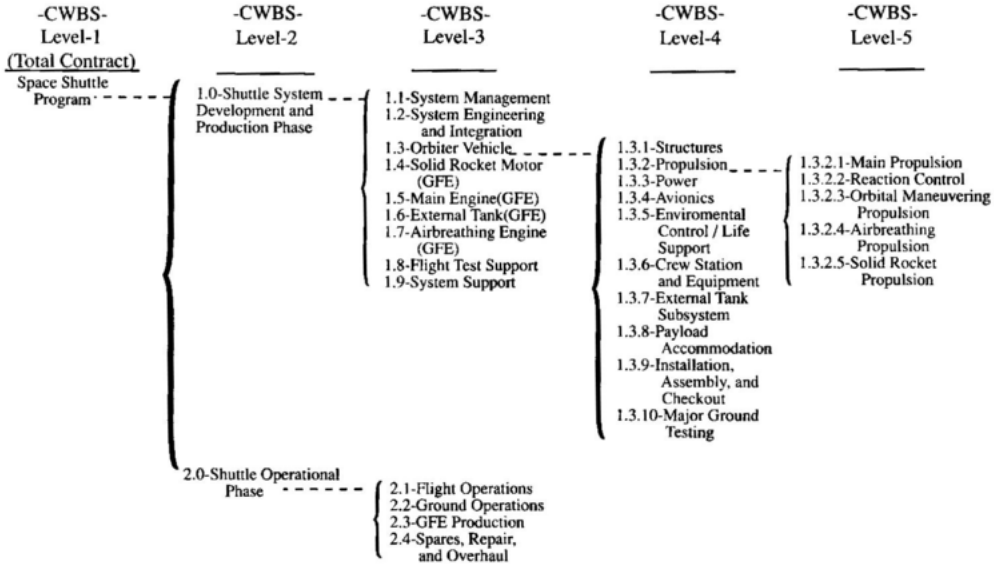


Figure 5.2: Work Breakdown Structure for a space shuttle program

The assignment of responsibilities for the Formula SAE project team was largely determined by each team members' project specification.

The division of the project was discussed in Chapter 4.

These divisions could then be separated into tasks and a work breakdown structure could be created. The work breakdown structure of each system is as follows:

Spaceframe Chassis -	Chassis
	Crush Zone
	Floor Pan
	Firewall
Monocoque Chassis -	Monocoque Chassis Design
Engine Systems	Engine Selection

	Intake and Fuel System	
	Exhaust System	
	Cooling System	
	Fuel Tank	
Suspension Systems -	Front Suspension -	Wishbones
		Suspension Mounts
		Shocks and Actuators
	Rear Suspension -	Wishbones
		Suspension Mounts
		Shocks and Actuators
Steering Systems -	Steering Rack	
	Uprights	
	Hubs	
Drivetrain and Brakes -	Drivetrain -	Drive System
		Rear Axle System
		Wheels and Tyres
	Brakes -	Brake Calipers and Rotors
		Hydraulic Actuation System
Bodywork and Aerodynamics -	Bodywork Design	

Instrumentation, Control Systems and Vehicle Testing -

	Vehicle Instrumentation	
	Pedal Box	
	Seat	

Driver Control System

Vehicle Testing

5.2.7 Design Development and Appraisal

In this stage the design is progressed by making general decisions on the layout and specification of systems in the design. No detail design is required, rather each system is investigated and alternative solutions for each system are proposed. The integration of each system into the design is strongly considered at this stage. (Design integration is discussed in §5.3.) These systems are then specified and detail design can commence.

In USQ Formula SAE-A, this design development was largely done during the weekly meetings. An example of a decision made at this stage was the selection of a solid rear axle system. Design development of Jettison 1 is discussed further in the following chapter.

5.2.8 Detail Design and Appraisal

Detail design involves the complete specification and design of a component to a production stage. Full investigation of all relevant parameters is required. The specification must include all of the requirements of the component. Factors which may need to be considered include:

- Likely failure methods and consequences
- Strength and fatigue requirements
- Operating parameters
- Environmental conditions
- Test requirements
- Critical dimensions

- Maintenance provisions
- Material requirements
- Reliability requirements
- Surface and material treatments
- Design life
- Packaging requirements
- External marking
- Cost of component

Many other factors may be important depending on the component or system.

After consideration of these factors the design can be completed using experience and good engineering judgement.

The design then needs to be fully documented for manufacture through relevant production drawings and documents. These may include detail drawings, assembly drawings, bills of materials and other relevant data.

In the Formula SAE project team, each team member was responsible for researching and considering the relevant factors for their section of design. The project supervisors were able to provide advice and guidance in this area. This research and design work was the major focus of the students' research projects.

Once designs were completed, Chris Snook and I performed a design review to check for quality of design, integration with other systems, compliance with the Formula SAE rules and suitability in relation to the defined objectives of Jettison 1. If required improvements were made and the design was approved for manufacture.

5.2.9 Prototype Production

Once the design has been completed and approved, the product can enter the prototype production phase. The methods of production depend on the type of product created, however in all cases it is important that the design team coordinates with the production team. Product improvement efforts can be made with consultation between the teams and any problems that arise can be addressed immediately. A quality control system is also a part of most engineering production systems.

Jettison 1 was manufactured using services available at the university and through support provided by sponsors and supporters.

The majority of components were produced in the engineering workshop by Chris Galligan and Brian Aston. The workshop has a full range of machining centres, including CNC turning and milling machines, and welding and spry painting facilities. Constant consultation with Chris and Brian enabled product improvement to be made prior to construction. They were able to suggest alternate methods of construction and assisted with design simplification for production.

The university workshop was also available for student use for the production and assembly of Jettison 1. Members of USQ Motorsport were permitted to use hand tools and some basic equipment. Work days were organised where all members were invited to assist in the cars' production.

Major work that was performed outside of the university system included manufacture of the majority of the chassis and the production of the GRP bodywork.

The chassis was constructed with the assistance of Chris Hanifan. Chris is experienced in building chassis' for professional drag racing and he was able to provide advice on the design and construction methods employed. Chris also donated the high-carbon steel tube used in the chassis. Much of the chassis was constructed at Chris' workshop located in Willowbank.

Buchanan Fibre Composites (BAC) were largely responsible for the production of the fibre-composite bodywork. All work was done at their workshop in Toowoomba with the assistance of members of USQ Motorsport. BAC provided all materials required, assisted in the construction of the plugs and produced the actual bodywork sections.

5.2.10 Design Assessment and Refinement

Design assessment involves analysing the design and identifying faults and potential improvements. Design faults generally mean the product will not perform as expected and a redesign and production of a revised component is required. Potential improvements are changes which improve the products' performance, simplify the production process or reduce costs incurred.

Some improvements which may be made to products are identified as follows: (Source: (Ertas & Jones 1996))

- Simplify the design
- Eliminate operations that require skill
- Minimise the total number of parts
- Use modular design
- Minimise part variations
- Use a multifunctional design
- Design parts for multiuse
- Design to simplify fabrication
- Use of fasteners
- Minimise assembly directions
- Maximise compliance
- Minimise handling
- Eliminate or simplify adjustments

- Avoid flexible components
- Minimize testing

Each of these factors should be considered with regard to effects on other factors such as performance. Some examples of product improvement are shown in figure 5.3. (Source: (Ertas & Jones 1996))

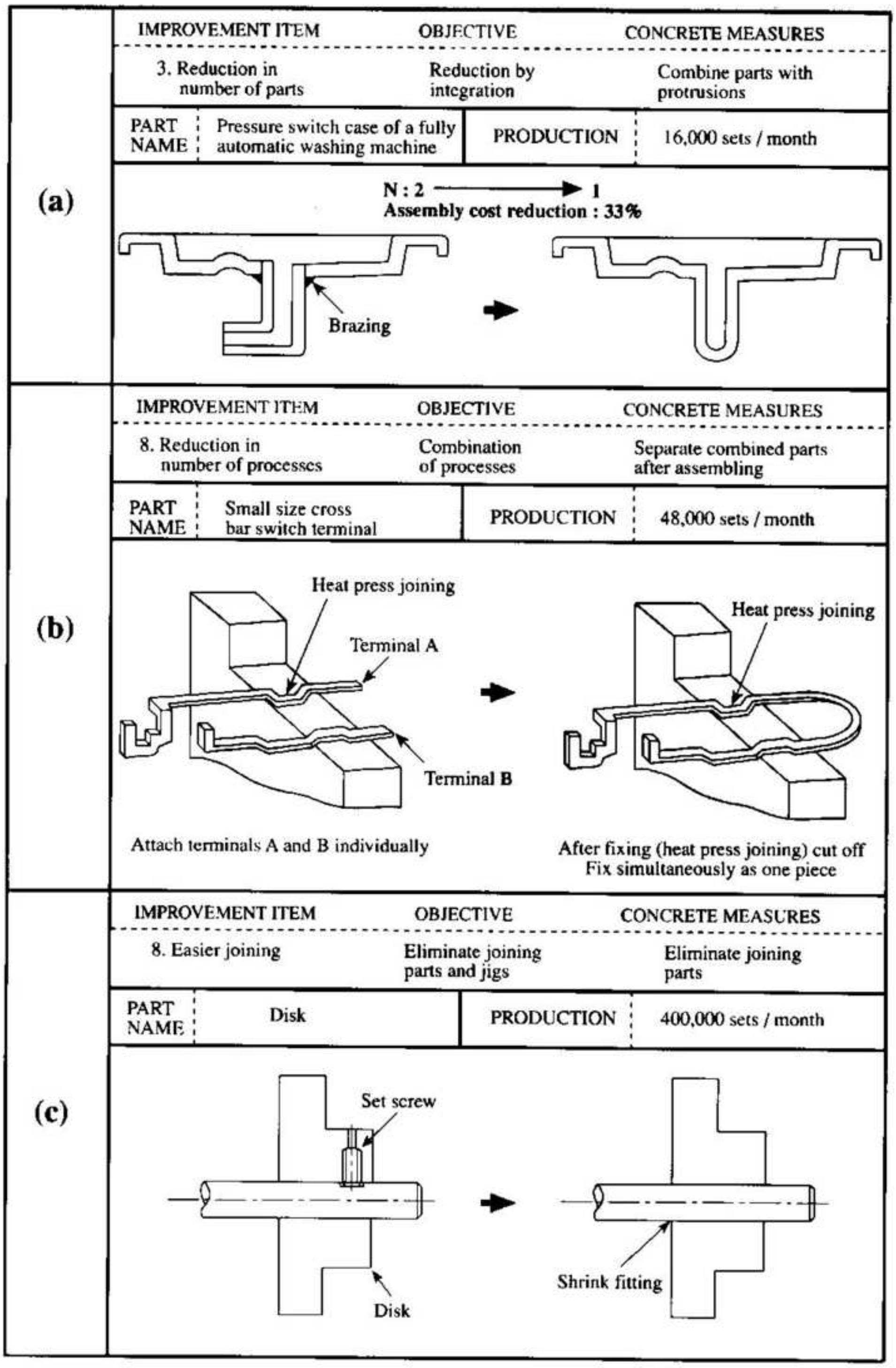


Figure 5.3: Examples of product improvement.

The Formula SAE project team encountered a number of faults in aspects of Jettison 1's design, and were required to make some improvements through redesign and respecification. The faults encountered and the improvements made are discussed in detail in Chapter 6.

5.2.11 Testing and Evaluation

The testing and evaluation stage is the final check of the performance of a product and is completed when the product is consumer ready. Evaluation of a product depends on its' nature and intended use. Some of the evaluation procedures that may be employed are:

- Destructive testing of prototypes. Example: Car crash-worthyness tests.
- Non-destructive testing.
- Evaluation by an external organisation.
- Accelerated life testing procedures.
- Consumer group testing. Example: Software beta testing.

The nature of the product determines the suitable methods of evaluation.

If problems arise during evaluation, the cause of the fault need to be found and the product must be respecified to address the fault.

Following successful completion of the evaluation process the product can be approved for final production.

Testing and evaluation for Jettison 1 was largely the concern of the Formula SAE competition held in December. This is where the design will be analysed and evaluated against set criteria by industry experts.

USQ Motorsport will be able to perform some limited testing before the competition once Jettison 1's manufacture is complete. This testing will mimic the tests performed at the competition.

5.2.12 Final Production

The final production stage is where the product is produced for the consumer. The production process should now be fully specified and all faults should have been identified. However, it is important that continuous quality assessment is carried out during this process.

Because Jettison 1 was designed as a prototype race car it will never enter this stage. However, as a prototype it had to be suitable for production and this was considered throughout the design process.

5.3 Design Integration

Design integration involves managing the relationship of every system and subsystem to each other within an engineering product. Each system must work effectively and in harmony with every other system.

Any engineering product can be broken down into systems and subsystems. As discussed in §5.2.6, engineering problems are generally divided into elements in the work breakdown structure. Usually different teams or individuals work on different tasks within the WBS. Problems can arise when systems are designed that work correctly in isolation, but are incompatible and can not work together. It is the purpose of design integration to overcome these problems.

Design integration is usually performed by a project engineer. This engineer oversees the overall design of the product and ensures that each component is designed to interact with every other. This requires an understanding of every system, good communication and documentation skills, and the ability to visualise the completed product. Learning to be effective at design integration is primarily a function of experience and guidance.

I was responsible for the design integration of the systems on Jettison 1. The considerations and decisions that were made during this process are discussed in Chapter

6.

5.4 Chapter Summary

The engineering design process can be applied to every complex engineering project. An understanding of this process and of the importance of design integration enabled the Formula SAE project team to effectively complete the design and construction of Jettison 1.

Further discussion on the design of components and their integration is discussed in the following chapter.

Chapter 6

Vehicle Design

6.1 Chapter Overview

This chapter deals with the design and integration of every component and system on Jettison 1. It begins with the investigation of design criteria, progresses through conceptualisation and development of design, and then describes the design process and parameters considered for each component.

6.2 Overall Design

This section discusses the processes and decisions made by the USQ Formula SAE project team in progressing the design of Jettison 1 up to the detail design stage. The conceptualisation, identification of objectives and the development and appraisal of the cars design was performed by the team as a group. I was primarily responsible for directing this stage of the design process.

6.2.1 Recognition of Need and Establishing Design Requirements

The recognition of need and the establishment of design requirements has been discussed in §4.3.

The key objectives determined by the team relating to Jettison 1 are reproduced as follows:

The performance objectives were:

- For Jettison 1 to:
  - to have very high performance in terms of handling, braking and acceleration.
  - be easy to maintain.
  - be reliable.
  - look appealing.
  - use common components.
  - be comfortable.
  - be able to be manufactured on a limited production run at a rate of four cars per day.
- To have no major reliability problems at the competition
- To aim for simplicity in design

The cost objectives were:

- For Jettison 1 to:
  - be low in cost.
  - represent a manufacturing cost below $25,000 US.
- To construct and compete with the car effectively for the lowest possible financial outlay.

- To raise additional funds through sponsorship and fundraising activities.

The time objectives were:

- To complete major construction on Jettison 1 by October 1st

6.2.2 System Design Decisions

From these objectives the team progressed through the conceptualisation and initial design development phase. From this process some basic design parameters were determined.

The establishment of these parameters was critical for the progression of design. These decisions were made with consideration to USQ Motorsports' overall objectives and to system integration.

The initial basic design parameters for *Jettison 1* were:

- Steel tube spaceframe chassis.
- Independent double-wishbone front suspension with inboard spring and shock assembly.
- Swing arm rear suspension.
- Solid rear axle (no differential) with chain and sprocket drive.
- 250kg target weight.
- 80mm ride height.
- 1300mm front wheel track.
- 1200mm rear wheel track.
- 1800mm wheelbase.
- 600cc 4-stroke naturally aspirated 4 cylinder motorbike engine.

- Carbureted fuel system.
- Cockpit designed with adjustable controls.

Steel tube spaceframe chassis

An initial design decision made by the project supervisors was to use a spaceframe chassis design for the debut car. The spaceframe represented the simplest design, and was easily constructed within the rules of FSAE. Chris Baker was assigned the to spaceframe design.

Independent double-wishbone front suspension with inboard spring and shock assembly

Independent front suspension was justified by being the only competitive suspension system. Alternate systems such as beam suspension were not seriously considered as they represented a significant performance disadvantage, both in handling characteristics and weight.

An inboard strut design with a pushrod actuation system was justified by the following advantages:

- The pushrod system allowed easy adjustment of vehicle ride height.
- The system had aerodynamic advantages over an external strut system.
- The system had greater adjustability through changing the pivot ratio.
- The system had good aesthetic qualities and enhanced the desirability of Jettison 1 through the use of current technology.

This system had the disadvantage of being slightly heavier and more complex than a outboard strut system.

Swing arm rear suspension

Initially the decision was made to use a beam axle with swing arm rear suspension. This system was not independent and functioned like a motorcycle swing arm. The advantages of this system were:

- Potential weight advantage over independent systems.
- Simplification of the system and hence potentially greater reliability and lower cost.

However, in June this decision was overruled and an independent rear suspension system was selected. It was discovered that the swing arm suspension design would have too great an effect on the handling characteristics of the race car. The independent system utilised an inboard strut assembly similar to the front.

Solid rear axle (no differential) with chain and sprocket drive

The solid rear axle was determined to have to following advantages:

- Achieved simplification of design.
- Enhanced performance in straight-line acceleration, especially over open-centre differentials.
- Was lighter than a differential system and had less rotational inertia, providing an increase in responsiveness.
- Represented a significant cost saving of approximately $1000.
- Reduced maintenance requirements.

With careful design and suspension tuning, it was determined that any handling disadvantage from using this system could be minimised. The team decided that the advantages of this system, especially in relation to cost, were sufficient to justify this choice.

Chain and sprocket drive was selected because the engine had a sprocket drive output and the system could be manufactured using common components for minimal cost.

Alternative systems were investigated but rejected. A propeller shaft drive did not suit the orientation of the engine and would require the use of a differential. Belt drive systems have been used by some teams in Formula SAE but were generally found to be unreliable.

250kg target weight

The specification of a target weight gave the team a clear objective for which to aim. As the weight of the engine, wheels, tyres and many other components could be easily estimated, this target weight functioned as a target for the chassis, suspension and driveline systems.

80mm ride height, 1300mm front wheel track, 1200mm rear wheel track and 1800mm wheelbase

These parameters needed to be specified to facilitate the design of the chassis, suspension and steering systems. They were determined through the estimation of required space for components and systems, and through creating a basic design layout. The centre of gravity of the car was predicted and the location of the wheels was determined.

The 80mm ride height was later reduced to 60mm. The Formula SAE rules state that the underside of the car cannot contact the road surface during the competition. Lacking information on the quality of the surface, the team made a conservative decision for 80mm ride height. This resulted in a minimum clearance of 55mm at full suspension compression with the minimum amount of bump suspension travel required by the Formula SAE rules. The competition surface was later determined to be of high quality and this static ride height was reduced to 60mm resulting in 35mm clearance at maximum compression. To enable the car to be driven on a variety of surfaces or to allow greater suspension travel, this ride height was designed to be adjustable.

600cc 4-stroke naturally aspirated 4 cylinder motorbike engine

Initial investigation into engine selection revealed two viable alternatives: a single cylinder enduro style motorbike engine, or a 4 cylinder sports bike engine. Through research into the power characteristics of these engines it was discovered that a 4 cylinder sports bike engine was most suitable. These engines produced superior torque and provided a significant performance advantage over a single cylinder engine.

Maintenance costs for these engines was also investigated and found to be comparable. The single cylinder engine was cheaper to repair, but required more frequent maintenance; the 4 cylinder engine was more reliable, but was also expensive and complex to repair.

Carbureted fuel system.

A carbureted system had the following advantages over fuel injection:

- Represented significant cost saving.
- Had greater simplicity.
- Did not require special equipment for tuning.

A fuel injected system did have the potential for greater control over fuel metering and hence could benefit fuel economy and performance. However, a well tuned carbureted system could offer very similar performance. Most sports bikes used carburetors until 1998, and many of the first injected systems were found to be inferior to the carbureted system they replaced.

Cockpit designed with adjustable controls

Jettison 1 was designed as a prototype car for production and sale, hence it had to be able to accommodate a large percentage of the population. It was therefore determined that some adjustment of the controls was required, either by adjusting the position of the seat and/or pedals.

6.2.3 Progression to Component Design

Once these design parameters had been determined, work could begin on the design and specification of the individual systems and components. This process highlighted further parameters that needed to be discussed in order to achieve design integration. These processes are discussed in the follow section.

6.3 Component Design

The management of the component design process required the consideration of the following aspects:

- The oversight of the design and integration of each component and system on Jettison 1 within USQ Motorsports' design objectives.
- The acquisition of materials.
- The manufacturing processes used.
- The cost of the component.

As project manager, I was responsible for this process.

The following sections discuss these factors and highlight the experiences gained through this process. Each section is defined by each team members' scope of design.

A summary of component costs can be found in Chapter 7.

6.3.1 Chassis

Chris Baker was primarily responsible for the spaceframe chassis design. Bruce Grassick researched Monocoque design, however this was not incorporated into the 2004 car and so will not be discussed in this dissertation.

Spaceframe

Jettison 1's chassis design utilised a tubular steel spaceframe. The material was a high-tensile steel intended specifically for motorsport applications. This steel is cold drawn and electric resistance welded with a yield strength of 250MPa. The chassis was constructed using Gas Tungsten Arc Welding (GTAW or TIG).

Design

The spaceframe was designed using ProEngineer solid modeling software and simple timber models. A solid model of the chassis is shown in Figure 6.1. The timber models enabled the evaluation of ergonomic relations and of space requirements.

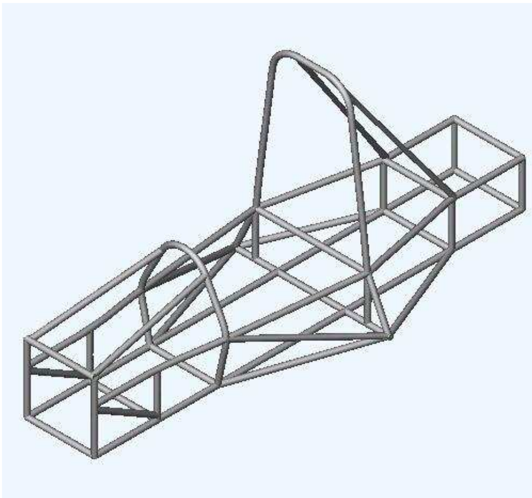


Figure 6.1: Solid model of the chassis

The material used was a larger diameter, thinner walled tube section than is commonly found in these vehicles. This tube was 31.75mm diameter x 2.1mm nominal wall thickness. These dimensions gave a large increase in buckling strength with a small increase in weight. This enabled the design of a strong and stiff chassis which was very simple to construct and was reasonably light.

The timber model highlighted some required changes to the design as system integration had not been fully considered. I specified that the front of the chassis be lengthened to provide adequate space for the brake master cylinders and pedals.

Throughout the chassis design I consulted between Chris Baker and the other team members regarding space requirements for components and load points and forces on the chassis. The most significant factors considered were:

- Space for and mounting of the engine.
- Suspension and driveline load points.
- Provision of space for the steering rack and inboard shock absorbers.
- Seat position.
- Compliance to the Formula SAE rules.

The relevant Formula SAE rules are detailed in §3.2 and §3.3 of the Formula SAE rulebook. (Refer Appendix B).

The chassis design was analysed using non-destructive testing and Finite Element Amalysis (FEA) using the ANSYS package. The non destructive testing consisted of torsional and bending tests. These results were used to confirm that the simplified FEA model was returning a reasonable approximation of the true stresses in the chassis. Chris Baker can be seen setting up the non-destructive test in Figure 6.2.

Figure 6.2: Chris preparing to test the chassis

The material selected for Jettison 1 did not meet the general standards provided by SAE in §3.3.3 for the front and main roll hoops. This standard specified 25.4mm x 2.4mm wall thickness. However, alternative material geometry could be used under certain provisions. The applicable provisions were:

1. The material must have equivalent (or greater) Buckling Modulus.

2. A minimum wall thickness of 2.1mm was maintained.

Proof of these requirements was required by SAE through the completion of a Safety Structure Equivalency form. The relevant calculations were as follows:

Material is 31.75mm x 2.1mm high carbon alloy steel tube. This material has a buckling modulus

$$EI = 4.321 \times 10^9 Nmm^2$$

This satisfied the requirements of minimum wall thickness for all members specified in section 3.3.3.2.2 of the rulebook, and the minimum buckling modulus

$$EI = 2.318 \times 10^9 Nmm^2$$

Material Source

The steel tube was donated by Chris Hanifan. Some mild steel material was sourced from the university workshop for the construction of brackets and other small parts as required.

Manufacture

The chassis was TIG welded by Chris Hanifan using the university welding equipment.

All bends were made by Botchers using a mandrel pipe bender. Standard pipe benders were found to be inadequate, and resulted in wrinkling of the inside radius of the bend. Defects such as these were unacceptable under the FSAE rules.

Cost

As discussed, all material for the chassis was donated by Chris Hanifan or supplied by the university workshop. Chris Hanifan also organised an funded the bending of the roll hoops.

Total Cost $ 0.00

Crush Zone

The crush zone is a deformable area in front of the major chassis structure which is designed to absorb energy in the event of a frontal collision. This was a safety requirement and had to be designed in accordance with the FSAE rules.

Design

The minimum size of the crush material as defined by Section 3.3.6.2 of the rulebook was a rectangular prism 200mm high, 100mm wide and 150mm deep. The crush zone had to be attached directly to the bulkhead and must be capable of decelerating the car within an acceptable limit.

Chris Baker proposed to construct the crush zone using a 2mm aluminium body filled with expanding foam. He found that this design would provide the necessary deceleration rate.

I approved Chris' proposal and encouraged the manufacture of a trial body from steel sheet to check geometry. This trial body was successful and I approved construction of the aluminium body.

Currently the aluminium body is under construction.

Material Source

The required aluminium sheet and expander foam were purchased by USQ Motorsport.

Manufacture

The manufacture of the crush zone is being completed using the facilities in the university workshop.

Cost

Aluminium sheet $ 114.29

Total Cost $ 114.29

6.3.2 Firewall

The firewall is designed to protect the driver in the event of a fire on Jettison 1. The driver had to be isolated from all components of the fuel supply, engine oil and the cooling systems. The requirements for the firewall are detailed in §3.4.10.1 of the Formula SAE rulebook.

Design

The design of this component has not yet been finalised. The proposed design requires a double firewall: one to isolate the driver from the engine compartment, the other to isolate the fuel tank. The fuel tank will be mounted underneath the drivers seat and requires additional protection from exhaust components.

The proposed design uses panels constructed from aluminium sheet which are bolted to the chassis. The use of fibreglass for this component was investigated but rejected because of greater manufacturing costs.

Material Source

The aluminium sheet will be purchased by USQ Motorsport.

Manufacture

The manufacture of the firewall can be completed using the facilities in the university workshop.

6.3.3 Floorpan

The floorpan protects the driver from the pavement and track debris. The requirements are detailed in §3.4.5 of the rulebook.

Design

The floorpan consisted of flat panels attached to the underside of the chassis extending from the bulkhead to the main roll hoop.

Chris Baker and I discussed using either aluminium or steel sheet for the structure. Steel was cheaper but significantly heavier and so aluminium was chosen.

To minimise weight Chris proposed to use 1.2mm aluminium, however I expressed concerns that this thickness would not be sufficient to support the weight of the driver as he stepped into the car. To address this concern the floorpan was made in two sections: a 2mm section at the front of the compartment extending to the seat where the driver could step, and a 1.2mm section for the remaining rear section. This gave the required strength in the areas that required it while minimising weight.

Material Source

The 2mm section was available as scrap form the purchased sheet used for the nosecone. The 1.2mm section was donated by the university workshop.

Manufacture

The floorpan was manufactured using the facilities in the university workshop.

Cost

Total Cost $ 0.00

6.3.4 Brackets

Brackets were required on the chassis to provide mounts for components. The brackets required for critical components such as suspension and driveline were designed by the team members responsible for these areas. All other brackets were designed by Chris Baker and myself.

The weight of components and the effect they had on the centre of gravity of Jettison 1 was a primary concern in determining each components location. Options were investigated before the best location was determined and the design and manufacture of the required brackets were completed.

6.3.5 Engine

Travis Mauger was primarily responsible for the engine system design. This included engine selection, the intake and fuel system, exhaust system, cooling system and fuel tank.

All specifications and restrictions relating to the engine and powertrain design can be found in §3.5 of the Formula SAE rulebook

Engine Selection

As previously discussed, the project team had decided to use a four cylinder sports bike engine.

The engine selected was a four-cylinder, double overhead cam engine that is normally supplied in a 1993 Yamaha FZR600 motorcycle. This engine was available at low cost and offered many advantages over later model designs. The engine has a longer stroke and milder camshaft profiles, giving more torque at lower engine speeds. This means that the 20mm intake restrictor had less of an effect on the power output. The engine is depicted in Figure 6.3.

Figure 6.3: Jettison 1's engine

The major factor in this engines' selection was cost. The project team discovered that the cheapest way to acquire a complete engine was to purchase a wrecked motorbike. Fowles Aution Group were identified as a potential source for this bike. I attended a Fowles auction and was successful in obtaining a damaged FZR.

Due to cost constraints, the engine was not modified internally and retained the standard ignition system.

Component Source

The complete motorcycle was sourced from Fowles Auction Group in Brisbane through Armstrong Automotive.

Cost

The bike was purchased for $500. As many other components are sourced from the bike, for simplification the engine is assumed to have cost $500: all other components used from the bike are assumed to have no cost.

Total Cost: $ 500

Intake and Fuel System

The intake and fuel system controls the metering of the fuel and its' distribution to the cylinders of the engine. It also incorporates the intake restrictor.

Design

This system comprises three main components: the carburettor, intake restrictor and the intake manifold.

As discussed previously, the team decided to use a carbureted fuel metering system. Travis and I decided that a single 34mm Mikuni carburettor from the bike would be suitable. This carburettor had the following advantages:

- Constant Velocity (CV) design.
- No cost.

The CV design maintains constant air velocity through the carburettor throat by moving a sliding piston which changes the throat area. The movement of the piston is proportional to the amount of air flowing through the carburettor. The piston is attached to a mixture needle which controls the amount of fuel flowing into the air stream.

This design provides the correct mixture for any engine at any speed within the limits of the airflow through the carburettor. Travis determined that a 34mm carburettor provided sufficient airflow for this engine.

The intake restrictor was designed as a removable section in the intake manifold. The restrictor has tapers similar to a converging/diverging nozzle to maximise flow through the required 20mm diameter section. Two restrictors were manufactured and each was flow tested to evaluate performance. The restrictor with the highest flow rate was selected.

The design of the intake manifold is still under development. Travis designed a log type manifold and a trial version was produced. This trial manifold was constructed with an adjustable plenum volume and length, which was used to evaluate the effect of these parameters on engine performance.

Travis and I conducted preliminary tuning of the intake system. This has highlighted that the log type manifold is an unsuitable design for this engine. Further development of this system is required.

Material and Component Source

All material required for the intake manifold and restrictor was provided by the university workshop.

The carburettor was sourced from the purchased FZR motorbuke.

Manufacture

The trial intake manifold and restrictor were manufactured using the facilities in the university workshop.

Cost

Total Cost: $0

Exhaust System

The exhaust system must incorporate a muffler and must reduce the noise of the engine to an acceptable level. These restrictions are detailed in §3.5.5 of the rulebook.

Design

The design of the exhaust system has been completed by myself.

Because the engine was not modified, the standard exhaust design would be ideal. However, the standard exhaust ran below the engine casing. Retaining the standard exhaust would have required the engine to be mounted high in the chassis. This would result in raising the centre of gravity of Jettison 1. The centre of gravity has significant effect on the handling performance and safety of a race car. A low centre of gravity increases the stability of the vehicle and reduces the chance of overturning.

I decided to manufacture a new exhaust system which allowed the engine to be mounted low in the chassis. Once this decision was made, Chris Baker was able to progress with the design of the rear section of the chassis.

The exhaust system is a twin 2 into 1 design. This design was specified with equal length primary pipes and equal bends in each pipe which provided equal back-pressure to all cylinders.

The header pipes run either side of the engine and join in a collector near the rear of the gearbox. These pipes were constructed from 1 1/4 inch mild steel mandrel bends. The length of each pipe is identical and the distance from the cylinder head to the collector is the same as the standard headers.

The replication of the standard exhaust header design characteristics guaranteed an optimised design for this engine.

The mufflers were designed with removable baffle tubes to allow the back-pressure and noise level of the system to be optimised. This can be done by changing the number of holes in the tubes and by changing the amount of fibreglass packing in the muffler.

The mufflers feature an aluminium body with mild steel end caps.

The routing of the exhaust system required consideration of the position of chassis, driveline and suspension components.

The exhaust system during construction is shown in Figure 6.4.

Figure 6.4: The exhaust system mounted to the engine

Material Source

The exhaust tube and bends were purchased from Armstrong Automotive. Other materials used were sourced from the university workshop.

Manufacture

The manufacture of the pipes and mufflers was completed using the workshop facilities.

Cost

Exhaust pipe and collectors $ 141.40

Cooling System

Design

The standard FZR600 cooling system consisted of a single aluminium radiator and electric fan. This system was retained for Jettison 1. This required the relocation of the radiator and the manufacture of connecting pipes and hoses.

For the radiator to function efficiently it had to be mounted so that it received adequate air flow. It was determined that mounting the radiator behind the engine would require ducting to provide cool air to the system. Mounting the radiator in a side pod was then investigated.

Two options for side mounting the radiator were investigated:

1. In a side pod close to the ground on one side of the drivers compartment.
2. On the side of the main roll hoop at driver shoulder height.

Mounting the radiator low had the following disadvantages:

- This system would require an additional header tank in the cooling system. This is because the radiator would be mounted lower than the engine resulting in air being trapped in the cylinder head, possibly resulting in engine failure.
- Additional bodywork would be required to duct the air through the radiator.
- An additional firewall would be required to isolate the driver compartment from the cooling system.
- Longer hoses would be required which increase the pumping losses of the system. An additional water pump may therefore be required.
- The airflow to the radiator may be affected by the front wheel and suspension components, reducing the efficiency of the system.

Mounting the radiator on the side of the roll hoop overcame these disadvantages.

The positioning of the radiator in this location did affect the centre of gravity of the car. Because there is only one radiator mounted on the left side, weight was added to the right side to counteract this. The battery was mounted on the outside edge of the drivers compartment to achieve this.

The relocation of the radiator required the rerouting of pipes and hoses. New pipes were made from aluminium tube. These were designed with consideration to the location of the exhaust system and chassis.

Material and Component Source

The radiator and fan were sourced from the purchased motorbike. The aluminium pipe was provided by the workshop. Hoses and clamps were donated by Armstrong Automotive.

Manufacture

The manufacture of the pipes was completed using the workshop facilities.

Cost

Total Cost $ 0

6.3.6 Steering System

Les Rayner was responsible for the design of the steering system for Jettison 1. This included the design of the steering rack, uprights and hubs.

Steering Rack

Initially USQ Motorsport intended to purchase a suitable steering rack for the race car. After investigation it was found that a rack would cost over $ 1000 and Les decided to design a modified rack and pinion system.

Design

A suitable second-hand steering rack was donated to the team and Les designed his rack using the pinion and modified rack gears. The manufactured rack is shown during construction in Figure 6.5.

Figure 6.5: The modified steering rack during construction

Design integration of the steering system was very important. Factors that were considered are:

- Correct location of rack and tie rod pivots to provide good steering geometry and minimise bump steer.
- Location of the rack within the chassis for human factor design.
- Specification of steering ratio to provide optimal control of Jettison 1.

Initially Les designed the rack to be mounted low in the chassis. I identified the problem that this location interfered with the position of the drivers legs and increased the complexity of the design of the steering column. After discussion with Les the steering rack was relocated high in the chassis above the drivers legs. In this position Les was still able to achieve good steering geometry.

I organised the discussion of human factors in the control of the steering system between Brad and Les. It was determined that 320 degrees of steering wheel rotation from steering lock to lock was ideal for this system.

Material Source

The second hand steering rack was donated by Peugeot Renault Parts and Service. The materials used for the housing were supplied by the workshop.

Manufacture

The manufacture and modification of the steering rack was completed using the workshop facilities.

Cost

Total Cost = $ 0

Note - The cost of rose joints has been included in the suspension system.

Uprights

The uprights are equally a part of the suspension system and the steering system. To provide Les and Rex with a roughly equal amount of design work I defined the uprights as part of the steering system.

Design

The design of the uprights required the interaction of Rex, Les and Jeremy. The location of the top and bottom rose joint pivots affected the steering and suspension geometry. Provision for brake caliper mounts were also required on the front uprights. I organised and led the discussion between these team members and supervised the design of these related systems.

Les completed his initial design of the front uprights and the workshop manufactured them. These uprights featured a 5 degree king-pin inclination to reduce scrub radius and steering effort required. An assembly of the front upright, hub and brake rotor is shown in Figure 6.6.

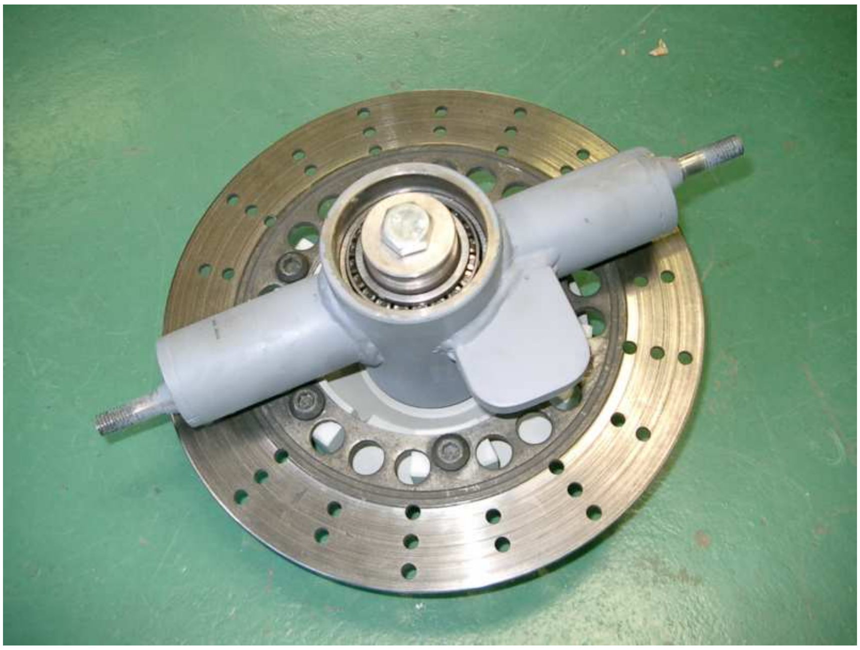


Figure 6.6: Front upright, hub and rotor assembly prior to modification

This design was found to have two faults:

1. The protruding studs for the top and bottom rose joints did not meet the standards for suspension fasteners given in section 3.7.2 of the Formula SAE rulebook.
2. The location of the bottom rose joint interfered with the brake rotor.

I conducted meetings with Les, Rex and Chris Snook to discuss solutions to these problems. It was decided to replace the machined studs with tapped holes and to offset the location of the bottom joint to provide clearance. These measures were successful in overcoming these problems, however this did result in a small change in the king-pin inclination. This was deemed to be acceptable.

The rear uprights were designed after the faults with the front uprights had been resolved. These were designed to be similar to the modified front uprights.

Material Source

The uprights were manufactured from mild steel which was provided by the workshop.

Manufacture

The manufacture and modifications to the uprights were completed by the university workshop.

Cost

Total Cost $ 0

Hubs

Design

Jettison 1's hubs were manufactured from steel. The front hubs and axles were machined from one piece of steel to simplify the machining process. They featured the use of common bearings and seals. The wheel studs are screwed into the hub and retained using a thread-locking compound.

The thread in the hubs for the wheels studs was incorrectly specified. To resolve this the team decided to manufacture special studs with a different thread on each end.

Material Source

The university workshop supplied the steel for the hubs. The wheel bearings, seals and studs were purchased by USQ Motorsport.

Manufacture

The hubs were machined by the university workshop.

Cost

Wheels bearings and seals $ 72.29

6.3.7 Suspension

Rex Parmenter was responsible for the design of Jettison 1's suspension systems. This included the design of the wishbones, suspension mounts and strut systems for the front and rear of the car.

As discussed in §6.2.2, the project team decided to use a double wishbone independent suspension system at both front and rear of Jettison 1.

Throughout the design of the suspension, the integration of this system with the chassis, driveline, steering, bodywork, engine and braking systems was considered. Figure 6.7 shows the rear suspension under construction.

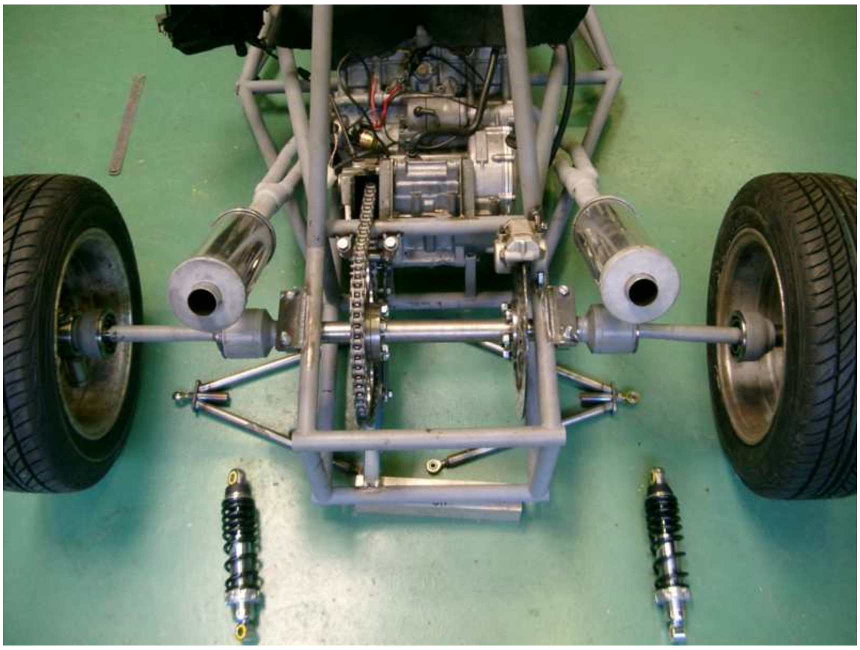


Figure 6.7: Rear suspension under construction

From this picture, it can be seen that the following factors were important:

- Provision of strong points on the chassis to which the suspension is mounted.
- Provision for driveshaft assemblies.
- Routing of exhaust around suspension components.

- Location of the rear brake assembly.
- Adequate strength in the suspension for the loads generated through the engine, driveline and braking systems.
- Provision for inboard strut mounts.

Wishbones

Design

After researching suspension geometry theory Rex established some specifications for suspension geometry and located the position of the rose joints for the front suspension. From these specifications he was able to establish a design and the front wishbones were manufactured. The suspension mounts were made and welded to the chassis.

During assembly of the front suspension some faults with the design were discovered. The rose joints had a limited degree of articulation in some orientations. It was found that because the wishbones were mounted at an angle to the front uprights, the rose joints were not able to provide adequate suspension travel. This initial design is depicted in Figure 6.8.

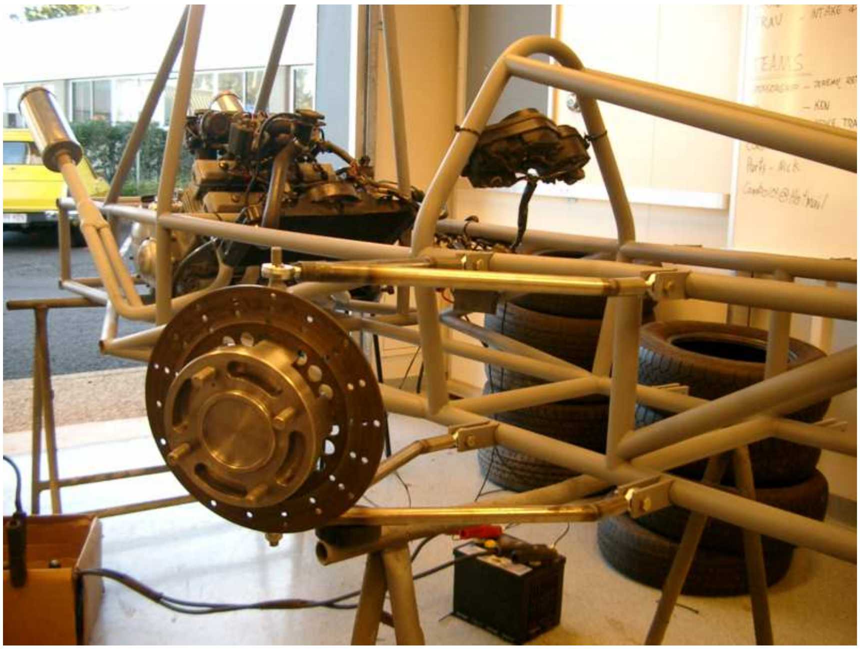


Figure 6.8: Initial front suspension design showing the angled wishbones

Also following discussion with Formula SAE judges, we were advised to mount the rose joints at the chassis to wishbone interface horizontally. This orients the joint so that the large forces due to braking are taken along the strong axis of the joint.

The chassis mounts were also found to be inadequate and needed to be relocated to improve the transfer of forces into the chassis.

To resolve these problems I conducted several meetings with the project team and supervisors. Several solutions were discussed before deciding to remanufacture the wishbones and suspension mounts. The mounting points for the wishbones were raised to make the wishbones horizontal in the neutral position. This resulted in adequate suspension travel. This required a full redesign of the suspension system.

Unfortunately at this time Rex became ill and was unable to continue work in this area for several weeks. I made the decision to reassign the design of this system and discussed this with Chris Snook. After further discussion and negotiation between Rex, Chris and I, Rex retained responsibility for the suspension design.

Rex redesigned the suspension and resolved the problems identified. At this stage construction of the suspension was behind schedule by many weeks. I organised several additional work days to fast track the construction of the redesigned system. The new suspension system can be seen under construction in Figure 6.9.

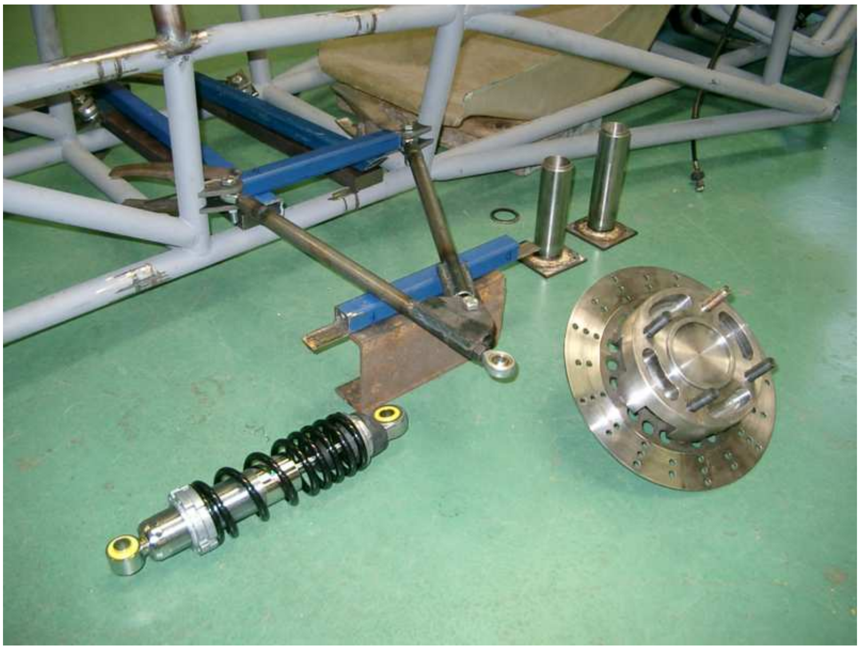


Figure 6.9: Modified front suspension under construction

The suspension system has not yet been completed. Design and manufacture of the inboard struts system is underway and is expected to be finished in two weeks.

Material Source

The materials used in the construction of the wishbones was provided by the workshop. USQ Motorsport purchased the rose joints.

Manufacture

Manufacture of the wishbones was done using the workshop facilities. The majority of the work was completed by students.

Cost

Rose Joints $ 1174.25

Strut System

Design

Jettison 1 was designed using an adjustable inboard strut system. This system used a purchased spring and shock assembly which was activated by a pushrod operating through a lever system. This design had the following advantages:

- Spring and shock rate could be adjusted by changing the geometry of the lever system.
- A large range of adjustment for vehicle ride height could be provided.

The design of this system is still under development. Currently the struts have been selected and purchased and the preliminary positioning of components has been completed.

Material Source

The struts were purchased by USQ Motorsport. Material for the rod and lever system will be provided by the university workshop.

Manufacture

The manufacture of these components will be completed using the workshop facilities.

Cost

Struts $ 590.00

6.3.8 Driveline and Brakes

Jeremy Little was responsible for the design of the driveline and braking systems on Jettison 1. This required the design of the rear axle assembly, axle drive system, wheel and tyre selection, brake caliper, rotor and hydraulic system design.

The rules for the braking system are listed in §3.2.5 of the Formula SAE rulebook.

Axle Assembly

As discussed previously, the rear axle was a solid design and had to incorporate independent rear suspension.

Design

The axle assembly consisted of a solid centre axle which is fixed to the chassis and two short axle assemblies incorporating CV joints to provide for suspension travel.

The short axles used second hand Ford Telstar CV joints. This reduced manufacturing costs of the CV shafts and rear axle as only external splines were required to be machined on the shafts. The CV joints were purchased as an assembly and the centre shaft was shortened to provide the correct length.

The centre axle is supported at each end in a bearing and features two flanges for the mounting of the rear sprocket and brake rotor. Jeremy originally intended to machine this axle from a single length of steel bar. Through consultation with Chris Galligan, the axle was redesigned with welded flanges. This represented a significant saving in material and machining cost.

Material Source

The university workshop supplied the required raw materials. USQ Motorsport purchased the CV shafts.

Manufacture

Manufacture of the centre axle and the shortening of the CV shafts was performed by the workshop.

Cost

2nd hand CV shafts and hubs $ 140.00

Axle Drive System

Design

Jettison 1's axle drive utilises a chain and sprocket system. A 60 tooth rear sprocket was manufactured to provide optimum acceleration. This gave a final drive ratio of 4.00:1 using a 15 tooth front sprocket.

Problems in the design of this system were discovered after the engine was fitted to the chassis. A chassis rail behind the engine had the potential to rub against the chain. This can be seen in Figure 6.10.

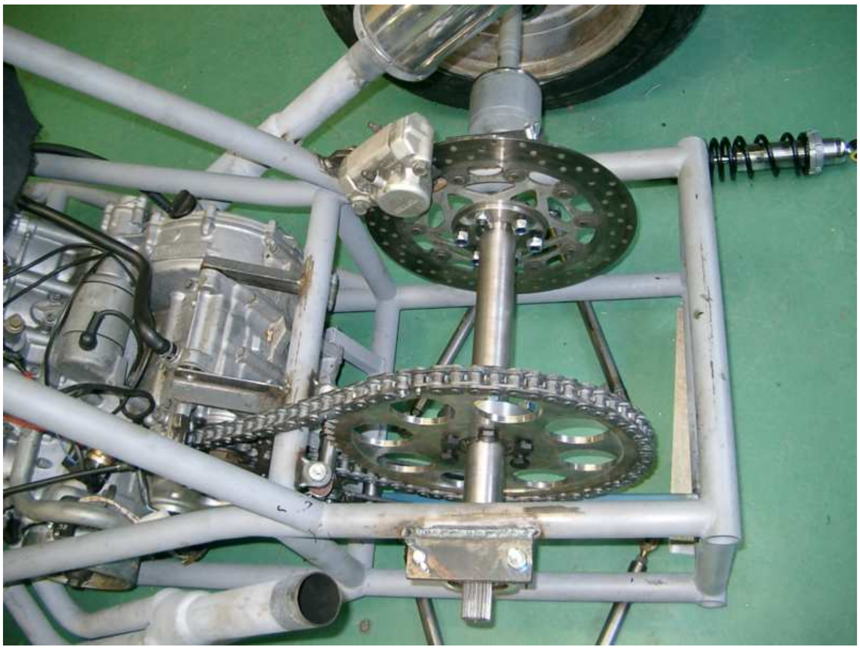


Figure 6.10: Axle drive system

To address this issue the centre axle was moved forward slightly. This increased the angle of the chain and gave greater clearance between chassis and chain.

The chain and sprocket system also required the use of a chain tensioner. Most chain systems achieve this by moving the rear axle, however this could not be done as the brake rotor also mounted to the axle required that the axle be fixed to maintain the relationship between rotor and caliper. I designed the chain tensioner system.

The tensioner was designed with a large range of adjustment to provide for chain stretch throughout service. The tensioner was mounted on the bottom side of the chain. This side is only under tension while decelerating in gear. In this situation the rear axle drives the engine. The forces involved in this situation are much lower than the forces during acceleration in the top side of the chain.

Some consideration was given to a spring loaded tensioner, however due to time constraints and the lack of data on the forces present in the chain it was decided to use a rigid system. The manufactured tensioner is shown in Figure 6.11

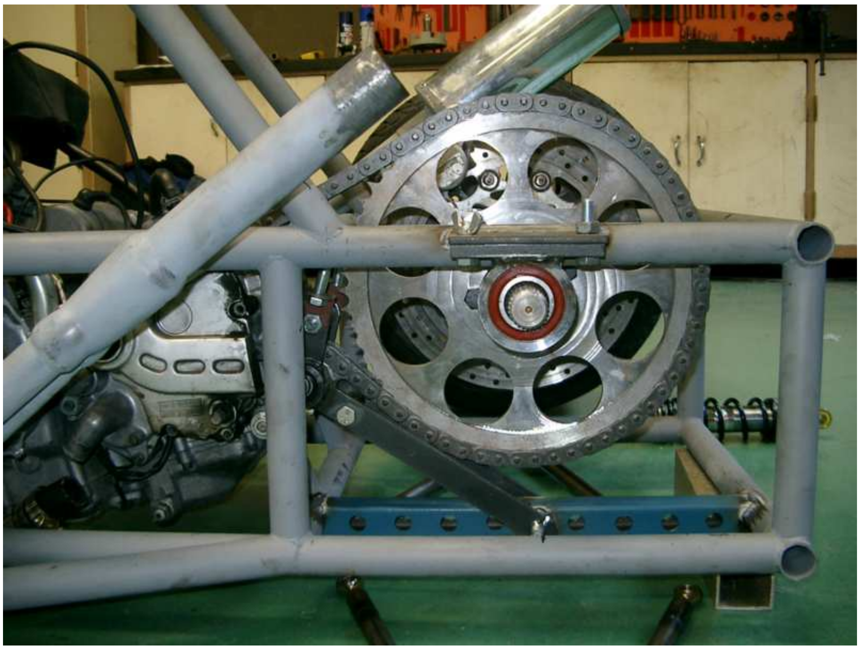


Figure 6.11: Chain tensioner system

The long arm acts as a pivot and locator for the tensioner sprocket. The arm is long to minimise the arc through which the tensioner moves. This was required to give adequate adjustment. The chain is adjusted by tightening the studs which are connected to the chassis. The top of these studs can be seen in Figure 6.10. The studs were angled so that the load on the tensioner is transferred axially through them.

Material Source

The chain was purchased by USQ Motorsport. Armstrong Automotive donated the bearings for the chain tensioner. All other material was supplied by the workshop.

Manufacture

All components were manufactured using the workshop facilities. The rear sprocket was machined using CNC milling equipment.

Cost

Chain $ 185.00

Wheels and Tyres

Selection

Under the Formula SAE rules if the track condition is declared to be wet, grooved tyres must be fitted to the race car. USQ Motorsports' budget was sufficient for one set of tyres only, therefore a set of grooved tyres were specified.

The wheels selected were 13 x 6 inch aluminium rims. These wheels were available second-hand for $100 for a set of four.

After some research Jeremy selected Falken 185/60R13 tyres. These are road legal tyres that have a performance tread pattern and a soft compound. Cut racing slicks were investigated but were approximately $120 per tyre dearer. The project team decided that the performance benefit of the slicks was not justified by the large increase in price.

Material Source

The rims and tyres were purchased by USQ Motorsport.

Cost

Rims $ 100.00

Tyres $ 500.00

Total $ 600.00

Brake Calipers and Rotors

Design

The braking system on Jettison 1 consists of cross drilled rotors and four pot calipers at the front and a single inboard rotor and two pot caliper at the rear. The brake calipers and rotors were production items from the purchased 1993 Yamaha FZR600.

The design of the front brake caliper and rotor system needed to consider the following factors:

- Space available inside the wheel.
- Suspension design.
- Upright design.
- Hub design.

Hence it was important to promote design integration and communication between Rex, Les and Jeremy during the design of these components.

The rear brake caliper and rotor design had to consider the chassis design. Figure 6.12 shows Jeremy and I discussing rear brake location.

Figure 6.12: Investigating rear brake system location

Material Source

The components were sourced from the purchased motorbike.

Manufacture

Some modification was required to the front brake calliper mounts. This was performed in the university workshop.

Cost

Total \$ 0.00

Hydraulic System

Design

The Formula SAE rules specify that two independent hydraulic circuits be included. To achieve this two master cylinders were specified using a mechanical bias bar to adjust brake force distribution between the front and rear brake calipers.

Design of the brake hydraulic system required integration with the design of the pedal box. Jeremy calculated a suitable brake master cylinder size of 19mm and Brad specified a part with this bore size which suited his pedal box design.

Material Source

USQ Motorsport will purchase the brake master cylinders and lines.

Cost

Total $ 0.00

6.3.9 Cockpit Design and Instrumentation and Control

Brad Moody was responsible for instrumentation, control systems and vehicle testing.

Jettison 1's cockpit was designed for adjustability to suit any driver, while retaining simple components. Seat fit can be modified using foam pads cut to appropriate sizes and the pedal box incorporates a large range of fore-aft adjustment.

Driver Control Systems

Design

The car is controlled using a two-pedal layout: right pedal for accelerator and left pedal for brake. This allowed for the option of using left foot braking as employed by many professional racing drivers. The clutch is actuated by a hand lever within easy reach behind the steering wheel. Gearshifts are made using a sequential shifter operated by the left hand.

The design of the pedal box requireed the consideration of the available space within the chassis structure. Design of the pedal box is not yet complete.

Material Source

The required materials will be provided by the university workshop.

Manufacture

The components will be manufactured using the workshop facilities.

Cost

Total $ 0.00

Vehicle Instrumentation

Design

Instrumentation includes engine speed and coolant temperature, with warning lights for neutral position, oil pressure and charging system. The instrumentation system was designed using components from the purchased motorbike. The speedometer was removed from the instrument cluster but the gauges were otherwise unmodified. Figure 6.13 shows the modified gauge cluster.

Figure 6.13: Jettison 1 uses a modified gauge cluster from the donor bike

Cost

Total $ 0.00

Seat

Design

A fibreglass seat from a formula style car was donated to USQ Motorsport. This seat was found to be acceptable.

The seat location and mounting system is yet to be finalised.

Cost

Total $ 0.00

Vehicle Testing

Vehicle testing has not yet begun. The team has presented a proposal to the university safety officers to use a surfaced carpark at the university for testing procedures. A discussion of the safety issues involved is given in §8.5.

6.3.10 Bodywork

Ken Nelder was responsible for the design of bodywork and aerodynamics.

The design of the bodywork depended on the final chassis design and the location of front suspension mounts. The relocation of the front suspension system had to be considered in the design of the nosecone.

Design

The project team had specified bodywork manufacture from GRP. The university workshop did not have facilities for fibre composite construction so Ken sought sponsorship or assistance from outside companies. Buchanan's Advanced Composites (BAC) volunteered their support and provided advice and assistance with the design and construction of the bodywork sections.

The bodywork was designed in three major sections which facilitated easy access to all systems for maintenance.

1. The nose extending forward to front roll hoop (with cutouts for the suspension)
2. RH cockpit section
3. LH cockpit section

Initially an engine bay cover was included but was removed due to time constraints.

Ken used the Fluent Computational Fluid Dynamics package to analyse models of the bodywork. This enabled him to optimise the shape of the bodywork for minimal aerodynamic drag.

Prior to construction Ken verified his design by constructing sections of the nosecone from cardboard and checking them for fit over the chassis. This can be seen in Figure 6.14.

Figure 6.14: Checking nosecone fit with cardboard sections

The bodywork is currently under construction with the assistance of students at BAC.

Material Source

BAC have provided all materials for the construction of the bodywork.

Manufacture

The bodywork is being constructed at the BAC premises with the assistance of students.

Cost

Total $ 0.00

6.4 Chapter Summary

This chapter has described the design development and construction of Jettison 1. The design of the race car required good communication and design integration to be maintained throughout the process. The Formula SAE team was faced with several unforseen difficulties but were able to overcome them through commitment and teamwork.

Chapter 7

Cost Analysis

7.1 Chapter Overview

This chapter provides a summary of costs incurred in the production of Jettison 1 and some predicted costs for the competition. Cost analysis and documentation is an important part of the management of USQ Motorsport and is critical to the success of the team.

7.2 Construction Costs

These costs are discussed in §6.3. They are presented here in summary divided into systems. For a breakdown of each system refer to that systems' discussion in the Component Design section.

Only costs already incurred are included.

System	Subsystem	Cost Incurred
Chassis System	Spaceframe	$ 0.00
	Crush Zone	$ 114.29
	Firewall	$ 0.00
	Floorpan	$ 0.00
	Brackets	$ 0.00
Engine System	FZR 600 Engine	$ 500.00
	Intake and Fuel System	$ 0.00
	Exhaust System	$ 141.40
	Cooling System	$ 0.00
Steering System	Steering Rack	$ 0.00
	Uprights	$ 0.00
	Hubs	$ 72.29
Suspension System	Wishbones	$ 1174.25
	Strut System	$ 590.00
Driveline and Brakes	Axle Assembly	$ 140.00
	Axle Drive System	$ 185.00
	Wheels and Tyres	$ 600.00
	Brake Calipers and Rotors	$ 0.00
	Hydraulic System	$ 0.00
Cockpit Design, Instrumentation and Control	Driver Control System	$ 0.00
	Vehicle Instrumentation	$ 0.00
Bodywork	Bodywork	$ 0.00
General Components	Fasteners	$ 219.84
	Paint	$ 101.93
	Taps	$ 74.24
	Total Cost	$ 3913.24

7.3 Competition Costs

Participation in Formula SAE-A incurred the following costs:

Team Registration	$ 660
SAE-A Student Membership ($ 45 each for 8 members)	$ 360
CAMS Licenses ($ 83 each for five drivers.)	$ 415

SAE-A Membership and CAMS License fee were paid by the individual students.

In addition to these fees, travel expenses and accommodation for the competition are expected to be approximately $ 600. These expenses will be incurred by the attending USQ Motorsport members. Currently fundraising is being performed to reduce this cost.

7.4 Other Costs

7.5 Total Cost Summary

Total Fund Pool	$ 10 050.00
LESS Current Construction Expenses	3913.24 $
LESS Predicted Additional Construction Expenses	3000.00 $
LESS Competition Expenses	$ 660.00
Remaining Funds	**$ 2476.76**

Chapter 8

Safety Review

8.1 Chapter Overview

Safety is a major consideration in any motorsport activity. The majority of the specification for Formula SAE related to the safety of the team and driver. In addition to this, other factors had to be considered to ensure the wellbeing of all people: drivers, team members, officials and spectators. This section discusses the safety factors considered during the design, construction, testing and competition phase of the project.

8.2 Safety Issues

The Formula SAE project involved a number of instances where safety must be strongly considered. These instances occured during these phases of the design:

Design The design of the Formula SAE car had an impact on safety. There were some basic regulations that had to be complied to but safety was considered further than this. For example, effective brakes and good human factor design contributed to the passive safety of the vehicle. Each designer considered the relevant factors to his area of the race car.

Construction The construction of a race car involves performing tasks where special safety considerations need to be met. Welding, grinding, spray painting and other related activities all represented their own risks. Also the construction of the vehicle involved contact with dangerous substances such as petrol. Proper safety precautions needed to be observed at all times.

Testing and Competition Driving a race car is by nature a high risk activity. All drivers always complied to the safety regulations detailed in the Formula SAE rulebook. In addition, consideration was given to the pit crew and spectators while testing was carried out.

Project management involved the consideration of all of these factors. It was my responsibility to ensure that safety is always considered a high priority in every Formula SAE activity.

8.3 Design Phase

The majority of the Formula SAE rulebook contained specifications which provided minimum safety standards for the Formula SAE car. These rules protected both the team and spectators. Examples of these rules were:

- Maximum engine noise levels.
- Rollover protection.
- Provision of fire extinguishers.
- Kill switch locations.
- Crush zone requirements.

Compliance with the Formula SAE rules resulted in Jettison 1 representing a low risk to the USQ Motorsport team and to spectators.

8.4 Construction Phase

The construction of Jettison 1 was primarily performed at the university workshop. The workshop must comply to all relevant legal safety legislation which included:

- Use of Personal Protective Equipment.
- Safe workshop practices.
- Supervision of students.

Chris Galligan and Brian Aston were responsible for the supervision of students in the workshop.

8.5 Testing Phase

The testing phase of Jettison 1 has not yet begun. However USQ Motorsport have submitted a testing proposal to the university safety officers. This proposal is included in Appendix H.

The testing proposal involves the use of a surfaced carpark within university grounds for weekend testing of Jettison 1.

8.6 Competition Phase

Safety at the competition will be supervised by SAE-A and CAMS officials. They will ensure that USQ Motorsport and Jettison 1 comply with the relevant specifications as given in the Formula SAE rulebook.

It is USQ Motorsports' responsibility to ensure compliance with these rules.

8.7 Chapter Summary

The safety of all activities related to Formula SAE were the responsibility of USQ Motorsport. Safety considerations were made throughout the design and construction phases, and continue to be investigated as the team completes construction and enters the testing and competition phases.

Chapter 9

Additional Work

9.1 Chapter Overview

This chapter details additional work undertaken which was not detailed under the project scope.

9.2 Reports to SAE

USQ Motorsport were required to make several reports to SAE-A during the course of the year. This is detailed in §**??**.

I was involved in the preparation of the Safety Structure Equivalency report. I checked the relevant data with Chris Baker and forwarded it to Chris Snook. Chris Snook then completed the report and submitted it to SAE-A.

I collated the data for the Design Specification Sheet (Appendix E) and wrote the Design Report (Appendix D). These were checked by Chris Snook before submission to SAE-A.

9.3 Exhaust System Design

I completed the exhaust system design, including the design of the header pipes and mufflers. This design process is described in §6.3.5.

9.4 Chain Tensioner Design

I completed the chain tensioner design. Jeremy had some involvement in this process in the specification of the idler sprocket and shaft. This design process is described in §6.3.8.

9.5 Wiring Harness

I completed the design of the wiring harness for the engine system. This included the documentation of the existing motorbike harness, followed by the manufacture of the new harness.

9.6 Website Content

The website was originally intended to be updated by each project team member throughout the project. This was not successful and I wrote each section relating to each team members project. The website can be found in Appendix F.

Chapter 10

Conclusions and Future Recommendations

10.1 Future Recommendations

In order to further improve the performance of the USQ Motorsport team the following recommendations are made:

Increased use of 3D models in design

Greater use of 3D models would increase the efficiency of the project information system and would assist in the integration of design. This would serve to locate problems earlier in the design phase.

Creating a two year development cycle for the car

This could be done by identifying potential Formula SAE project team members at the beginning of the students third year of study. The design of the following years car could be initiated within this team with a view to having major systems such as suspension, engine and driveline designed by the beginning of the following year. This would enable more effective design, especially for the chassis system.

10.2 Conclusion

This project was successful in developing effective design management tools and practices which assisted in the integration of all aspects of the design and construction of Jettison 1.

The investigation into design and project management techniques facilitated the application of standard engineering practices to the USQ Formula SAE project. A project management scheme was successfully implemented and enabled USQ Motorsport to compete in Formula SAE in 2004.

This management scheme assisted in the control of unforseen circumstances, which included major design revisions to the suspension system and the extended absence of team member Rex due to illness. A strong team atmosphere was created and the team was successful in achieving its' goals.

Design overview and integration were achieved through the application of standard engineering design processes, good communication skills and interaction within the USQ Motorsport team. Some minor issues were encountered during the construction of Jettison 1, however these issues were always able to be resolved through teamwork and consultation. The most critical part of making design integration work is promoting interaction within the team: the USQ Formula SAE team were successful in achieving this.

This project has shown that effective management of the team and of the design process are both critical to the success of any complex engineering project.

Because this project achieved it's objectives, USQ Motorsport were successful in designing and constructing Jettison 1. The team looks forward to competing in Melbourne in December.

References

Davidson, P. & Griffin, R. (2003), *Management: An Australiasian Perspective*, John Wiley ans Sons Australia, Ltd, Milton, Australia.

Ertas, A. & Jones, J. (1996), *The Engineering Design Process*, 2nd edition edn, John Wiley and Sons, Inc, USA.

Greenfield, T. (2002), *Research Methods for Postgraduates*, 2nd edition edn, Arnold, London, UK.

Hancock, D. N. (2004), *ENG4111/4112: Project Reference Book - A*, University of Southern Queensland, Toowoomba, Australia.

Juvinall, R. & Marschek, K. (2000), *Fundamentals of Machine Component Design*, 3rd edition edn, John Wiley and Sons, Inc, USA.

Kanawaty, G. (1992), *Introduction to Work Study*, 4th edition edn, International Labour Organisation, Geneva, Switzerland.

Meredith, J. & S. Mantel, J. (1995), *Project Management: A Managerial Approach*, John Wiley and Sons, Inc, USA.

Morgan, M. (2002), *ENG4004: Engineering Management Science: Study Book*, University of Southern Queensland, Toowoomba, Australia.

O'Leary, T. & O'Leary, L. (2002), *Computing Essentials*, McGraw-Hill/Irwin, New York, USA.

Preston, G. (2002), *Internet In Easy Steps*, Computer Step, Warwickshire, UK.

Society of Automotive Engineers (2004*a*), *2004 Formula SAE Rules*, Society of Automotive Engineers.

Society of Automotive Engineers (current June 2004*b*), *Formula Series - Collegiate Design Series - SAE Student Central*, `http://www.sae.org/students/formulaseries.htm`.

Society of Automotive Engineers (current June 2004*c*), *SAE - Formula Home Page*, `http://www.sae-a.com.au/fsae/index.htm`.

Society of Automotive Engineers (current June 2004*d*), *SAE International*, `http://www.sae.org/servlets/index`.

Society of Automotive Engineers - Australasia (2004), *Formula SAE-A: 2004 Rules Addendum*, Society of Automotive Engineers - Australasia.

Appendix A

Project Specification

University of Southern Queensland

Faculty of Engineering and Surveying

ENG 4111/4112 Research Project

PROJECT SPECIFICATION ISSUE B

FOR:	John Justin ARMSTRONG
TOPIC:	Formula SAE: Design Overview and Project Management
SUPERVISOR:	Chris Snook
ASSOCIATE SUPERVISOR:	Bob Fulcher

PROJECT AIM:

This project seeks to develop effective design management tools and practices to assist in the integration of all aspects of the design and construction of the Formula SAE vehicle.

PROGRAMME:

1. Conduct literature review of the design, construction and testing of automobiles.
2. Research the specification of the Formula SAE vehicle.
3. Provide and maintain general design overview of the Formula SAE vehicle.
4. Coordinate the integration of each subsystem into the overall design.
5. Create and maintain a project information system.
6. Document each step of the design process and provide justification for each design decision.
7. Investigate and utilise human resource management skills.
8. Conduct cost analysis and assist in the allocation of funds to each section of the project.

9. Write project dissertation.

AGREED:

____________________________(Student)

__________________________(Supervisor)

Dated / /

Appendix B

2004 Formula SAE Rules

Please refer to the folder "Appendix B" on the disc. This contains the Formula SAE rulebook and the Formula SAE-A Addendum.

Appendix C

Solid Models

Please refer to the folder "Appendix C" on the disc. This contains images and models of Jettison 1.

The folder "Images" contains jpeg format images of the solid models.

The folder "Models" contains files of the models created using the ProEngineer package. ProEngineer is required to view these files.

Appendix D

FSAE-A Design Report

D.1 Overview

Our prototype racing car has been dubbed *Jettison 1.*

Jettison1 has been designed with high reliability and low cost as the major design criteria. A review of the market has shown that reliability is often a problem and in previous years a number of competitors were unable to complete the design competition. Jettison 1 has been designed for high reliability while retaining high performance. It is our aim to compete in every event without any major reliability problem.

The production team for the prototype is called USQ Motorsport. This team is strongly affiliated with the USQ Faculty of Engineering and Surveying, the university workshop and the USQ Mech Club, and has members from all levels of staff and students. The Mech Club is an official student club supported by the USQ Student Guild.

USQ Motorsport is based at USQ, a regional University in a city with a small industrial base and this presented limited sponsorship opportunities. USQ Motorsport prides itself on the design and performance of Jettison 1, which was designed with a strong focus on doing more with less. The car demonstrates that low cost can be achieved while retaining high levels of performance.

USQ Motorsport prides itself on a strong team culture. There has been a lot of skill and responsibility sharing and this is a team strength. This approach is important as one team member was absent with a long and serious illness.

D.2 Chassis

Jettison 1's chassis design utilises a tubular steel spaceframe. The material is a high-tensile steel intended specifically for motorsport applications. This steel is cold drawn and electric resistance welded with a yield strength of 250MPa. The chassis has been constructed using Gas Tungsten Arc Welding (GTAW or TIG).

The spaceframe was designed using ProEngineer solid modeling software and simple timber models. These timber models allowed rapid testing and improvements to our design to be made for ergonomic relations.

The material used is n a larger diameter, thinner walled tube section than is commonly found in these vehicles. This tube is 31.75mm diameter x 2.1mm nominal wall thickness. These dimensions give a large increase in buckling strength while increasing the weight of the chassis only slightly. This has resulted in a strong and stiff chassis which is very simple to construct and is reasonably light.

The chassis design has been analysed using non-destructive testing and Finite Element Amalysis (FEA) using the ANSYS package. The non destructive testing consisted of torsional and bending tests. These results were used to confirm that the simplified FEA model was giving a reasonable approximation of the true stresses in the chassis.

D.3 Suspension and Steering

Jettison 1's front suspension is an unequal length, double wishbone design with inboard spring and damper units operated by a pushrod. The rear suspension uses a similar design with equal length wishbones.

The steering system uses a student design and built steering rack. This rack uses a pinion and shortened and modified rack gear from a Renault in a custom housing assembly. Manufacturing a custom steering rack enabled USQ Motorsport to obtain 100% Ackerman geometry while keeping cost low. The tie rods are parallel with the upper wishbone which minimises bump steer. The turning circle is 6.5 metres with a rack ratio of one turn lock to lock.

The cars upright and hubs have been manufactured from steel. The uprights have a five degree king-pin inclination which reduces the offset to 36.25mm. This gives good feel to the driver while minimising steering kickback. The front hubs and axles are machined from one piece of steel to simplify the machining process.

D.4 Brakes

The braking system consists of cross drilled rotors and four pot callipers at the front and a single inboard rotor and two pot calliper at the rear. The brake callipers and rotors are production items from a 1993 Yamaha FZR600.

Two pedal operated identical 3/4 inch master cylinders provide hydraulic pressure to the system with a mechanical bias bar to adjust brake force distribution.

D.5 Engine Systems

The engine is a four-cylinder, double overhead cam engine that is normally supplied in a 1993 Yamaha FZR600 motorcycle. This engine can be obtained at low cost and offers many advantages over later model designs. The engine has a longer stroke and milder camshaft profiles, giving more torque at lower engine speeds. This means that the 20mm intake restrictor has less of an effect on the power output.

Fuel metering is accomplished using a single 34mm Mikuni carburettor. The carburettor is a constant velocity (CV) design. The CV design is able to provide precise fuel metering across a large range of engine speeds. Using a carburettor represents a significant saving and allows fuel mixture adjustments to be made quickly.

The intake manifold is a log design. A trial manifold was constructed with an adjustable plenum volume and length, which is used to optimise the engine performance.

The exhaust system is a twin 2 into 1 design. This design has equal length primary pipes with equal bends in each pipe which provides equal back-pressure to all cylinders. The mufflers have been designed and manufactured by the team and feature removable baffle tubes. This allows the back-pressure and noise level of the system to be optimised.

D.6 Drivetrain

The cars drivetrain consists of a chain and sprocket drive to a solid rear axle which transmits torque through equal length constant velocity (CV) shafts to the wheels.

A 60 tooth rear sprocket was manufactured to provide optimum acceleration. This allows us to obtain a final drive ratio of 4.00 using a 15 tooth front sprocket.

The choice of using a solid axle can have some negative effects on the handling of the vehicle, especially in tight corners due to the rear wheels needing to slip. To minimise this effect Jettison 1 has a narrow rear track and a relatively stiff rear spring rate. This assists in unloading the inside tyre in a corner and allows the tyre to slip.

The advantages of a solid rear axle are:

1. Can use a single rear brake assembly, which reduces weight.
2. Can offer superior traction in straight line acceleration.
3. Reduces rotational inertia, making the car more responsive to drive.
4. Much lower initial cost and no maintenance.

The driveline uses Ford Telstar CV joints which have internal splines. This has reduced manufacturing costs of the CV shafts and rear axle as only external splines were required to be machined on the shafts.

D.7 Bodywork

The bodywork is made from 3mm thick fibreglass (250 grade woven cloth), laid up over a male core of MDF cross-sections and polystyrene foam blocks. It is constructed in four major sections which facilitate easy access to all systems for maintenance.

1. the nose extending forward to front roll hoop (with cutouts for the suspension)
2. RH cockpit section
3. LH cockpit section
4. engine bay cover (time permitting)

The engine bay cover will incorporate some ducting for the radiator and engine air intake, and will be able to be modified to incorporate ducting for a second radiator on the other side if required.

D.8 Cockpit Design

Jettison 1's cockpit has been designed for adjustability to suit any driver, while retaining simple components. Seat fit can be modified using foam pads cut to appropriate sizes and the pedal box has a large range of fore-aft adjustment.

The car is controlled using a two-pedal layout: right pedal for accelerator and left pedal for brake. This allows for the option of using left foot braking as employed by many professional racing drivers. The clutch is actuated by a hand lever within easy reach behind the steering wheel. Gearshifts are made using a sequential shifter operated by the left hand.

Instrumentation includes engine speed and coolant temperature, with warning lights for neutral position, oil pressure and charging system.

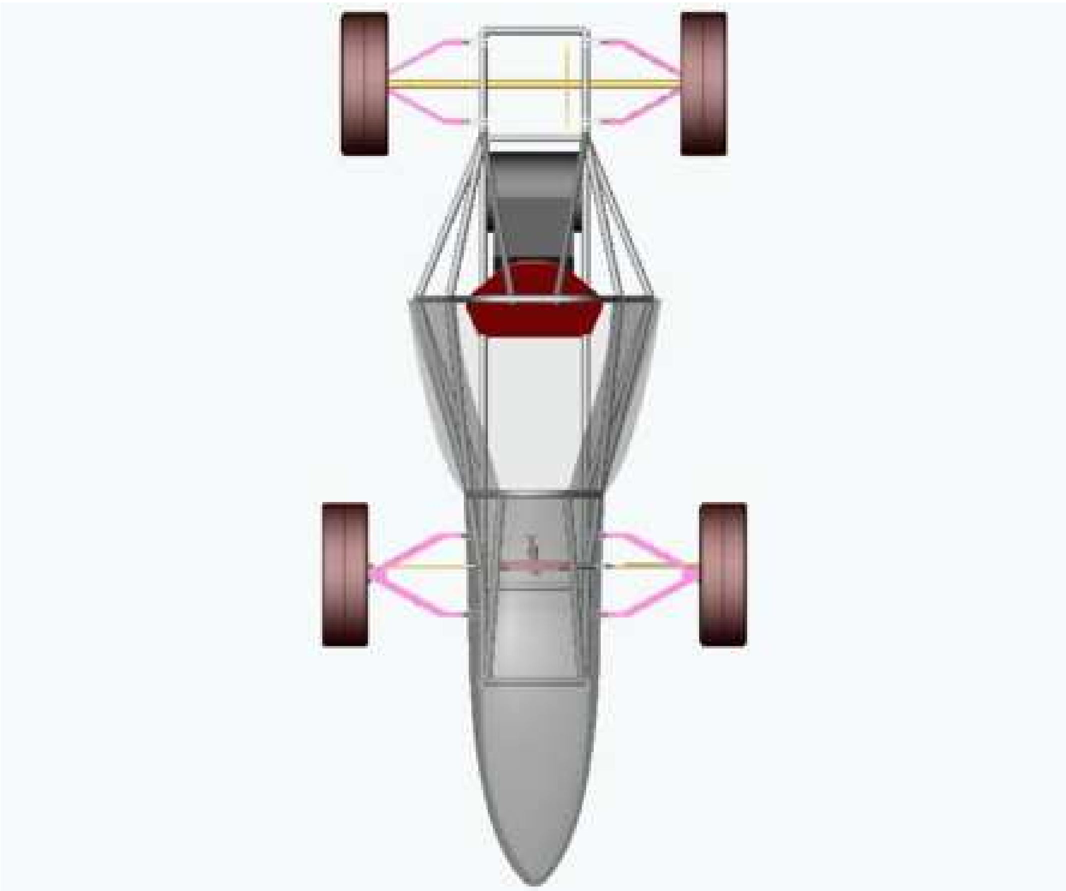
D.9 Conclusion

Jettison 1 is an affordable high-performance racing car that can be easily manufactured. It provides advantages to the purchaser through its' use of common components, simple design and high reliability. USQ Motorsport has been successful in producing performance at an affordable price.

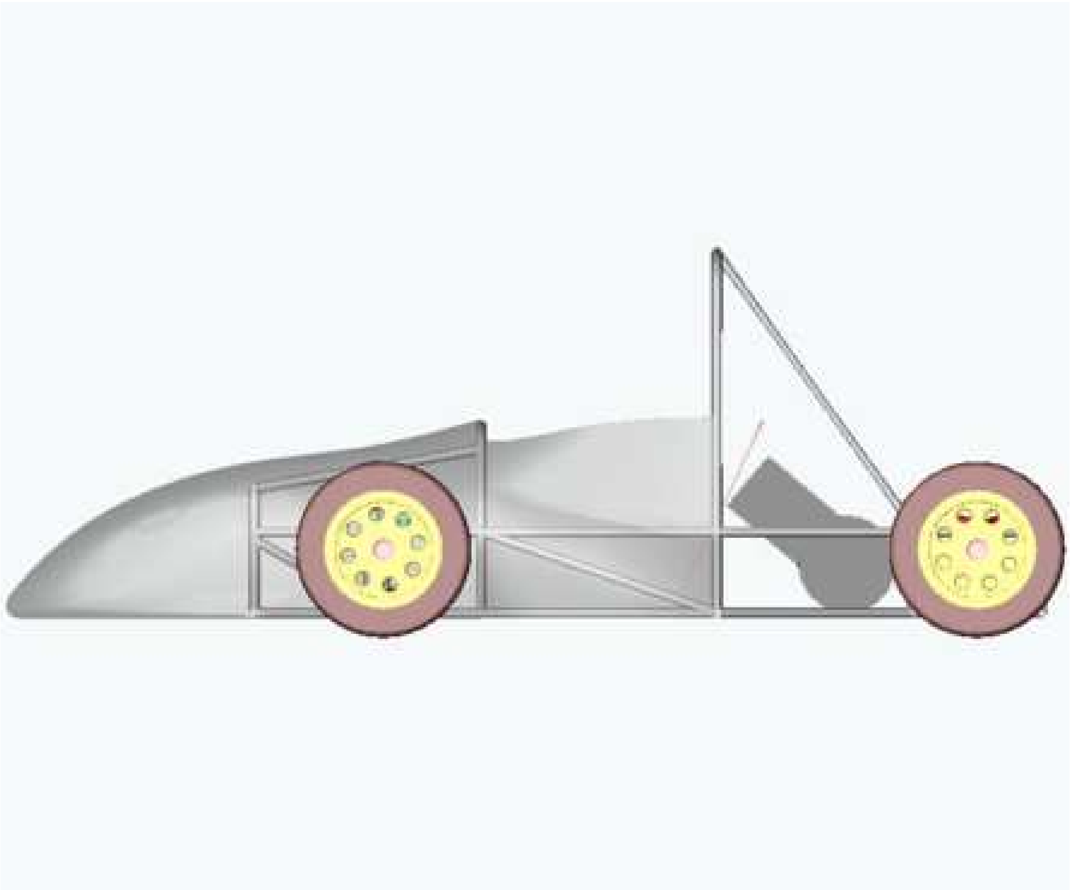
D.10 Drawings

Drawings are indicative of final design only.

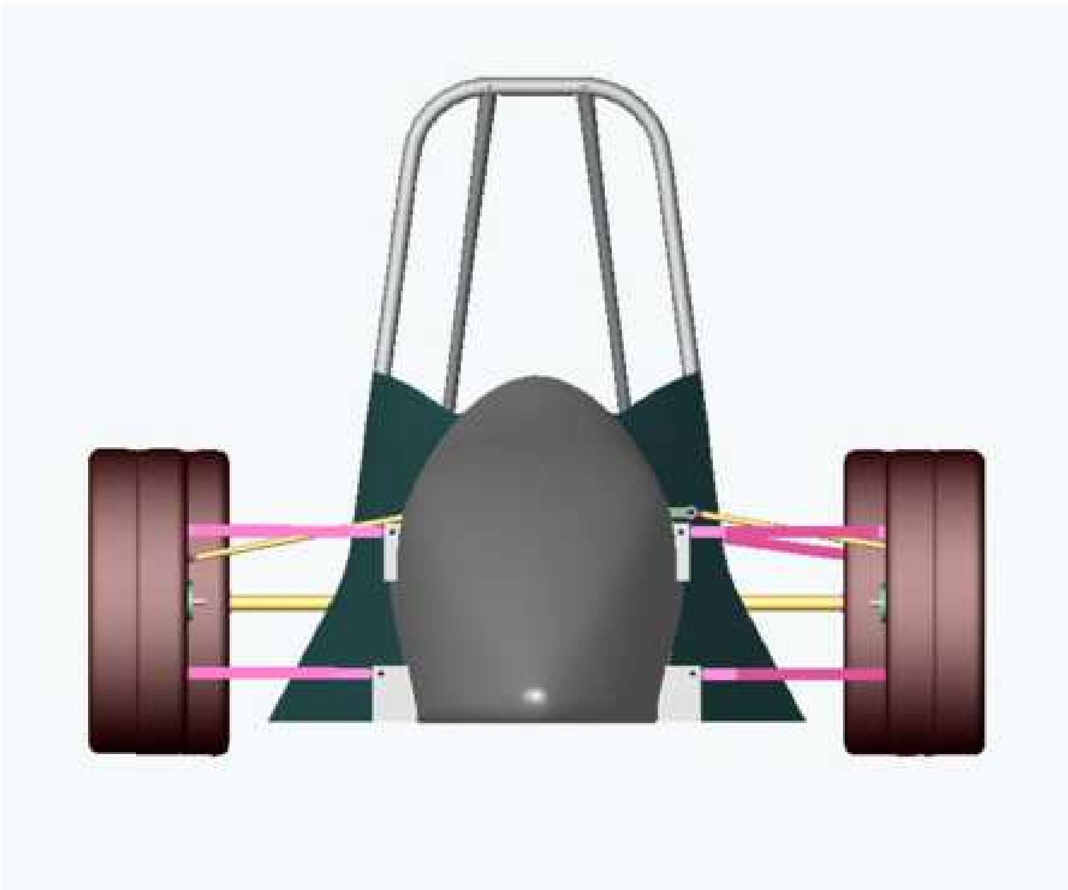
D.10.1 Top View



D.10.2 Side View



D.10.3 Front View



D.10.4 Other Photos and Diagrams

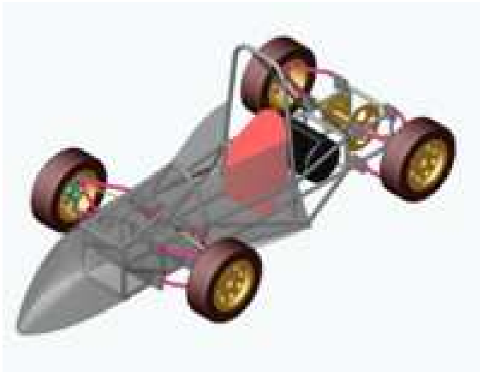


Figure D.1: Transparent Pictorial View

Figure D.2: Simple yet strong chassis gives good performance with low manufacturing cost.

Figure D.3: Twin exhaust and custom mufflers results in equal back-pressure to all cylinders and facilitates tuning of the system.

Appendix E

FSAE-A Design Specification Sheet

FSAE-A Design Spec Sheet 2004

Competitors: Please replace the sample specification values in the table below with those appropriate for your vehicle and submit this to with your design report. This information will be reviewed by the design judges and may be referred to during the event.
—Please do not modify format of this sheet. Common formatting will help keep the judges happy.
—The sample values are fictional and may not represent appropriate design specs.
—Submitted data will NOT be made public or shared with other teams.

Car No	13
University	University of Southern Queensland

Dimensions	Front	Rear
Overall Length, Width, Height	3200mm, 1495mm, 1180mm	
Wheelbase	1800mm	
Track	1300mm	1200mm
Weight with 68 kg driver (280kg total - to be confirmed)	126kg (To be confirmed)	154kg (To be confirmed)

Suspension Parameters	Front	Rear
Suspension Type	Unequal length double wishbone	Equal length double wishbone
Tyre Size and Compound Type	185/60R13 Falken	185/60R13 Falken
Wheels	13 x 6 inch. 110mm offset.	13 x 6 inch 110mm offset.
Design ride height (chassis to ground)	60mm	60mm
Center of Gravity Design Height	240 mm located 1400 mm from front of chassis (To be confirmed)	
Suspension design travel	26mm Jounce / 26mm Rebound (To be confirmed)	26mm Jounce / 26mm Rebound (To be confirmed)
Wheel rate		
Roll rate		
Sprung mass natural frequency (in vertical direction)		
Jounce Damping		
Rebound Damping		
Motion ratio		
Camber coefficient in bump		
Camber coefficient in roll		
Static Toe and adjustment method	Adjust by steering rack tie rods.	Adjust by tie rods.
Static camber and adjustment method	Static -1 degree. Rod end adjustment on wishbones.	Static -1 degree. Rod end adjustment on wishbones.
Front Caster and adjustment method	Static 5 degrees. Rod end adjustment on wishbones.	
Front Kingpin Axis	5 degrees non-adjustable.	
Kingpin offset and trail	36.25 mm offset. 0mm trail.	0mm offset. 0mm trail.
Static Akerman and adjustment method	100% Ackerman	
Anti dive / Anti Squat	0%	0%
Roll center position static	To be determined	To be determined
Roll center position at 1g lateral acc	To be determined	To be determined
Steering System location	Rear steer below and parallel to upper wishbone.	

Brake System / Hub & Axle	Front	Rear
Rotors	Modified rear FZR600 motorcycle 245mm	Singel modified front FZR600 motorcycle 298mm
Master Cylinder	Mechanical bias bar. Twin 3/4 inch cylinders with integral reservoir.	
Calipers	Front 4 piston FZR600 motorcycle	Rear 2 piston FZR600 motorcycle
Hub Bearings	SKF LM67048/Q Angular Contact roller bearing	AR Telstar front wheel bearing

FSAE-A Design Spec Sheet 2004

Upright Assembly	Student built mild steel with integral brake calliper mounts	Student built mild steel
Axle type, size, and material	Solid 1020 mild steel 31.75 mm diameter	Solid 1020 mild steel 38mm diameter. 25mm at CVjoint spline

Ergonomics	
Driver Size Adjustments	Fixed seating position, adjustable steering wheel height and adjustable pedal position
Seat (materials, padding)	Polyethylene base with customised padding to suit each driver
Driver Visibility (angle of side view, mirrors?)	200deg side visibility, mirrors placed on side of cockpit at front
Shift Actuator (type, location)	Left hand gear lever within close proximity to steering wheel on LHS
Clutch Actuator (type, location)	Steering column mounted lever on RHS upper quadrant
Instrumentation	Tachometer, water temperature guage, neutral light and oil pressure warning light

Frame	
Frame Construction	Steel tube spaceframe
Material	31.75mm x 2.1mm cold drawn steel tube. 250 Mpa Yield Strength
Joining method and material	TIG welded
Targets (Torsional Stiffness or other)	
Torsional stiffness and validation method	To be determined (Validated through non destructive testing and Finite Element Analysis.
Bare frame weight with brackets and paint	48 kg (To be confirmed)
Crush zone material	2mm Folded aluminium sheet with foam filler
Crush zone length	150 mm
Crush zone energy capacity	To be determined

Powertrain	
Manufacture and Model	1993 Yamaha FZR600
Displacement	599cc
Fuel Type	98 RON
Induction	Naturally Aspirated
Max Power design RPM	11 000 rpm
Max Torque design RPM	8 500 rpm
Min RPM for 80% max torque	6 700 rpm
Effective Intake Runner Length	75 mm
Effective Exhaust runner length	520 mm
Exhaust header design	2 into 1 by 2 (Twin exhaust system)
Fuel System (manf'r)	Modified Mikuni carburettor with student built log type intake manifold
Fuel System Sensors	N/A
Injector location	N/A
Intake Plenum volume	900 cc estimated (currently adjustable)
Compression ratio	12:01
Fuel Pressure	0.3 bar
Ignition Timing	Standard Ignition (non-adjustable)
Coolant System and Radiator location	Radiator and Electric fan on thermoswitch. Mounted in side pod on LH of main roll hoop at driver shoulder height.
Fuel Tank Location, Type	Student built aluminium tank mounted within chassis structure below drive axle.
Muffler	Student built aluminium muffler with removable baffle. Length 260mm. Diameter 100mm.

Formula SAE-Australasia

FSAE-A Design Spec Sheet 2004

Drivetrain	
Drive Type	Chain and sprocket (530 chain) through solid rear axle
Differential Type	N/A
Final Drive Ratio	4.00 standard. (15 tooth front 60 tooth rear) Adjustable with front sprocket changes to 4.28 and 4.61.
Vehicle Speed @ max power (design) rpm	
1st	59 (51) Brackets show 4.61 final drive ratio. All units km/h
2nd	86 (75)
3rd	108 (94)
4th	126 (109)
5th	141 (121)
6th	151 (131)
Half shaft size and material	4340 Steel (Estimated) 25mm diameter. Manufactured from Ford Telstar CV shafts.
Joint type	Inner plunging type CVjoint. Outer fixed type CVjoint. Both AR/AS Ford Telstar

Aerodynamics (if applicable)	
Front Wing (lift/drag coef., material, weight)	N/A
Rear Wing (lift/drag coef., material, weight)	N/A
Undertray (downforce/speed)	N/A
Wing mounting	N/A

Appendix F

USQ Motorsport Website

Please refer to the folder "Appendix F" on the disc. This contains the HTML files for the website.

To view the website, open the index file with your web browser. To view the HTML source open the HTML files with a text editor.

Appendix G

Sponsorship Data

The sponsorship support for USQ Motorsport was as follows.

Financial Support

SAE-A	$ 6000.00
Student Guild	$ 550.00
Butlers Toyota	$ 250.00
Boyd Young Suzuki	$ 250.00
Faculty of Engineering and Surveying	$ 2000.00
Engineers Australia Local Group	$ 1000.00

Merchandise Donations

Value of merchandise shown.

Southern Cross Ford	$ 30.00
Toowoomba Holden	$ 60.00
Retravision	$ 138.85

Burrell Outdoors	$ 48.60
Good Guys	$ 50.00
Mitre 10 Toowoomba	$ 60.00
Toowoomba Yamaha	Merchandise (net yet received)

Other Support

4AK and 4WK	Radio promotion
Armstrong Automotive	Trailor Hire and misc. supplies
Peugeot Renault parts and service	Steering rack
Buchanans Advanced Composites	Bodywork construction and supplies

Appendix H

Safety Considerations for Formula SAE Car Testing

H.1 Background

We require an area in which to test the performance of the Formula SAE car in order to optimise the car setup and to provide driver training.

Proposed activities include:

- Acceleration tests.
- Braking tests.
- Handling tests such as slalom.
- General driver training.
- Reliability testing.

Restrictions are:

- Maximum speed of 40km/h.

- Testing on weekends only.

Our proposal is to use one of the surfaced carparks on the university grounds. We have identified the carpark east of the engineering building as the most suitable for most of our testing requirements.

The advantages of this carpark are:

- Close proximity to the engineering faculty.
- Locked during the weekend.
- Large distance to other areas of the university.
- Adequate size.
- High quality surface.

H.2 Risk Assessment and Management Proposal

Description of Hazard	People at Risk	Risk Level	Controls
Fire hazard resulting from fluid leaks and hot surfaces.	Driver and team members	Slight	Ensure that the vehicle complies with all fire prevention rules in the FSAE specification. These include: 1. Firewall for driver protection. 2. One-way check valves in fuel lines. 3. Oil catch cans. 4. Driver wears fireproof suit, gloves and boots. 5. Fuel tank is mounted within the major chassis structure. In addition to these, a fire extinguisher of the correct type and size will be kept near the car at all times. One person will be on standby at all times to use extinguisher.
Damage to other property including other vehicles and buildings.	N/A	Significant	The vehicle will only be driven within the confines of the carpark while there are no other vehicles or property present. The vehicle will not be driven under its' own power in any other area.
Crashing of vehicle resulting in injury to driver.	Driver	Significant	Ensure that the driver and vehicle are equipped with the following safety equipment as specified in the FSAE rulebook. This includes: 1. Helmet and visor. 2. Fireproof suit, gloves and boots. 3. 5 or 6 point racing harness. 4. Arm restraints. 5. Chassis constructed with roll hoops.
Crashing of vehicle resulting in injury to team members or spectators.	> 20	Slight	The carpark will be isolated using hazard tape. Spectators and team members will be behind the tape whenever the vehicle is being tested. Team members will always be present to enforce this rule upon any spectators.