

University of Southern Queensland
Faculty of Engineering & Surveying

System Design for Formula SAE-A Racecar

A dissertation submitted by

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Abstract

This project aims to provide a managerial structure that will ensure future success of the University of Southern Queensland's Formula-SAE entry.

In order to provide such a structure, a thorough investigation of previous years results at Formula SAE-A was carried out in order to determine where such deficiencies lay.

Strategies are discussed to further improve results through communication, training, and better organisation.

Successful implementation of the management structure put in place led to the seamless integration of the vehicles' systems and the race car is now in the final stages of construction.

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BARTON JAMES SMITH

Q1120760

Signature

Date

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Chapter 1

Introduction

The over-riding aim of this project is to put into place a management structure to ensure that USQ Motorsport's entry in Formula SAE-A in 2006 will have a substantially better result than it has previously achieved.

USQ Motorsport is a club (made up of students from the University of Southern Queensland), formed to compete in the Formula SAE-A competition.



Figure 1.1: The USQ Formula SAE-A race car racing in 2004.

1.1 Formula SAE-A Overview

Formula SAE was originally started in the USA in 1981, and is an annual competition which gives engineering students real-world experience in design, construction and competition environment, thus enhancing engineering knowledge at University level.

In Formula SAE, the students are to assume that a manufacturer has employed them to produce a prototype car for evaluation with a view to production. The intended sales market is the nonprofessional weekend autocross racer.

Therefore, the car must have very high performance in terms of its acceleration, braking, and handling qualities. The car must be low in cost, easy to maintain, and reliable.

Beginning in 2000 in Australia, Formula SAE-A was a small competition with just six teams; this has grown to twenty-six teams in 2005 involving four overseas teams; one each from New Zealand and India and two from Japan.

Teams entering the competition are run entirely by the students, usually by appointing a student team manager, and the conceptual and design work is performed solely by university students. Work is supervised by Faculty academic and technical staff.

At the Formula SAE-A competition entrants are judged in both static and dynamic events, under criteria of innovation, cost effectiveness, ergonomics, aesthetics and performance. The teams are required to develop their car around the technical specifications included in appendix B. These minimal requirements are intended to encourage creativity in each team's solution.

The static events are presentation, design, and cost reports. Dynamic events include acceleration, skid pan, autocross, endurance and fuel economy. Each of these events are given a score, with the total maximum scores achievable being 1000 points.

The University of Southern Queensland first competed in 2004.

1.2 Overview of the Dissertation

This dissertation is organized as follows:

Chapter 2: Review of Previous Performance. Analysis of previous years results will highlight areas of improvement in regards to the events at the Formula SAE-A competition.

Chapter 3: Recommendations Based on Performance. After analysis of previous years performance, a list of recommendations for each event will be compiled to assist in improvement in 2006 and following years.

Chapter 4: Management of Timelines. Details the procedures used to manage deadlines during the design, construction, and competition phases.

Chapter 5: Design Work. Covers extra design and construction that was performed during this project.

Chapter 6: Information Management. Collecting, maintaining, and recall information is vitally important for not only the entry into the 2006 F-SAE competition, but for future F-SAE teams from USQ.

Chapter 7: Conclusion and further Recommendations.

Chapter 2

Review of 2005 Performance

2.1 Chapter Overview

In order to determine areas of potential improvement within the Formula SAE-A team, it is necessary to review past performance. I will only review in depth the 2005 entry. This past performance will be studied in 2 areas.

1. In the Formula SAE-A competition there are eight events, both static and dynamic. I will analyze the teams performance in each of these areas to determine areas of possible improvement.
2. Investigate overall management of the 2005 team and its performance leading up to, during and after the Formula SAE-A 2005 competition.

2.2 2005 Results

The University of Southern Queensland Formula SAE-A team finished twenty fourth out of twenty five in 2005, with 74.8 points out of a possible 1000.

It must also be noted that there is a technical inspection of the car which carries no points, but must be carried out before the car is allowed to participate in any of the dynamic events. Therefore this event is a consideration as well, and will be reviewed.

The breakdown of the points allocation can be seen in table 2.1

Table 2.1: Formula SAE-A USQ Results

Event	Possible Score	Score	Rank	min	max	average
Presentation	75	43.3	20	0	75	50
Engineering Design	150	53	21	0	150	84
Cost Analysis	100	-62	25	-62	96	67
Acceleration	75	20.5	16	0	75	46
Skid Pan	50	12.6	17	2.5	50	31
Autocross	150	7.5	14	0	150	43
Fuel Economy	50	0	12	0	50	15
Endurance	350	0	12	0	307	167
Total Points	1000	74.8	24	41.8	952	386

The total points do not give an all over indication of USQ's performance. There were 25 teams competing, and particularly in the dynamic events that they competed in, USQ's performance was fairly reasonable.

It is interesting to note that the average for the cost event (67) is fairly high when compared to the maximum (96), which is very close to the maximum possible of 100, indicating that improvement in that event alone might dramatically alter the final rank for USQ.

2.2.1 Technical Inspection

The objective of technical inspection is to determine if the vehicle meets the FSAE rules requirements and restrictions.

Each vehicle must pass all parts of technical inspection and testing, and bear the inspection stickers, before it is permitted to participate in any dynamic event or to run on the practice track. (rule 4.2.2)

This inspection takes several hours and involves checking compliance to the Formula SAE rules. The rule book is some 125 pages long, often with many sub-clauses.

Vehicle inspection consists of three separate parts as follows:

1. Scrutineering: Each vehicle will be inspected to determine if it complies with the requirements of the rules. This inspection will include examination of the drivers equipment (Rule 3.4.2) and a test of the driver egress time (Rule 3.4.7). Part 1 must be passed before a vehicle may apply for Part 2 or Part 3 inspection.
2. Tilt Table Tests: Each vehicle will be tested to insure it satisfies both the 45 degree fuel spill safety requirement (Rule 3.5.3.6.1) and the 60 degree tilt table requirement (Rule 3.4.8.1). Parts 1 and 2 must both be passed before a vehicle may apply for part 3 inspection.
3. Noise, Master Switch, and Brake Tests: Noise will be tested by the specified method (Rule 3.5.5.3). If the vehicle passes the noise test then its master switches (see Rule 3.4.9) will be tested. If the vehicle passes both the noise and master switch tests then its brakes will be tested. Each vehicle must be able to lock all 4 wheels after an acceleration run.



Figure 2.1: USQ 2005 entry on the Tilt Table

The USQ car was presented for technical inspection on the first day of competition, and several items of non-compliance were found. These were:

1. The main suspension securing bolts had insufficient bolt thread extending from the lock nuts.
2. No lockwire securing the brake caliper mounting bolts.
3. Engine would not stop when the main master switch was turned off.
4. Front roll cage main hoop appeared undersize in regards to the wall thickness, at the many inspection points.

The USQ team was about to strip down the car to add extra bracing to rectify the front roll cage hoop being undersize, however intervention by the faculty advisor saw a remeasurement conducted with a different measuring device , and was subsequently found to be of the correct size.

Had the car been passed at the technical inspection on the first inspection, they would have saved themselves about 8 hours of work at the track, and gained valuable time on the practice track.

2.2.2 Presentation

The presentation is a static event.

Member of the team (usually about 4-6 members) gives a presentation to upper level executives of an imaginary manufacturer. Presentations will last no longer than ten minutes with a five-minute question and answer period following the presentation. Only judges may ask questions during this time.

The presentation should tie together all factors that would influence the marketability and manufacturability of their design. Competitors must convince the judges that their prototype represents a profitable enterprise for the manufacturer.

In evaluating the presentation standard of the team, there were several faults that have accounted for the low score.

1. No visual aids used. Posters, advertising material etc.
2. Only one of the speakers has had any business acumen at all. The other speaker had no training or experience in this field.
3. Lack of preparation. The presentation was still being compiled a few hours prior to the event. No rehearsals were done for this.

Had the team allowed more time to prepare, and dedicate a person/persons early enough in the year to do this, then it is anticipated that a much higher score would have been achieved.

Given that USQ scored 43 out of 75, with an average for all teams of 50, along with the faults listed, it is likely that they can achieve a higher than average score next time.

2.2.3 Engineering and Design

Engineering and Design event is a static event.

The concept of the design event is evaluate the engineering effort that has gone into the design of the car, and how that engineering meets the intent of the market.

The team that illustrates the best use of engineering to meet the design goals, and the greatest understanding of the design will win the event. The car must be presented in race ready condition, and the presentation may include the use of visual aids.

Judging will start with a Design Review before the event. The principal document submitted for the Design Review is a Design Report. This report must not exceed eight pages, consisting of not more than four pages of text, three pages of drawings and one optional page containing content to be defined by the team (photos, graphs, etc). This document contains a brief description of the vehicle with a discussion of any important design features and vehicle concepts. It includes a list of different analysis and testing techniques, of which evidence of this analysis and back-up data should be brought to the competition and be available, on request for review by the judges. This design review is submitted at the end of October.

1. The design report and spec sheet were submitted on time, but then major design changes were made, resulting with the finished car at the competition bearing little resemblance to what the design review and spec sheet said. An example of this would be the design review stating that the car used fuel injection, yet at the competition, had a carburettor.
2. No visual aids used. Posters, advertising material etc. Many of the other teams make substantial use of such aids.
3. Two of the students who were involved with the design phase of the car, were present at the presentation. The rest were not. Little of the thesis design went into the car, with the result that other team members built the car could not justify their design criteria through engineering, or in a coherent manner.

4. The cars general appearance was poor. It appeared that it was cobbled together in someones backyard garage.
5. Design documentation that should be taken to the event was not at hand. There very little engineering drawings or any other documentation pertaining to the design process.

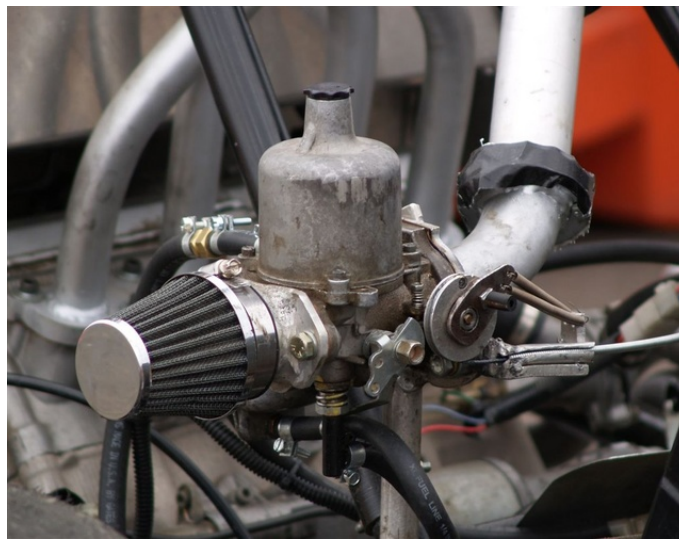


Figure 2.2: Poor engineering led to items such as this carburettor

Figure 2.2 shows the carburettor fitted to the engine. The fitment of this was unprofessional, and not thought out. Note the duct tape sealing up the joint on the manifold.

The car was constructed largely with the knowledge of "Backyard Mechanics", and as such it was under-engineered, and over built. Little thought had gone into the paint scheme, with the result that the 2005 car visually, was not a patch on the 2004 car.

Had the design documentation been available, along with the design spec sheet being a true reflection of the presented car, and tidying up the appearance of the car would have resulted in a far higher score than what was achieved, and potentially well in excess of what the average score was.

2.2.4 Cost Analysis

The Cost Analysis event is a static event. (Ref: Rule 4.3)

This was the worst scoring event for USQ, with a score of -62 out of a possible 100.

The objective of the Cost and Manufacturing Event is twofold:

1. To teach the participants that cost and a budget are significant factors that must be taken into account in any engineering exercise.
2. For the participants to learn and understand the manufacturing techniques and processes of some of the components that they have chosen to purchase rather than fabricate themselves.

This event is comprised of two (2) parts:

1. The preparation and submission of a written report (the Cost Report), which is to be sent to the Cost Judges prior to the competition. (Due end of October)
2. A discussion at the Competition with the Cost Judges around the teams vehicle. (Rule: 4.3.5) This evaluates not only the cost of the car, but also the teams ability to prepare accurate engineering and manufacturing cost estimates.

There were various reason for the score that was received in this event. More so it was a chain of events, and are chronicled.

1. Cost report was left to one member who volunteered to do it all off campus. They then cam in the day before it was due (31st of October), unfinished and "out of time"
2. Report was hastily finished and sent to SAE in Melbourne. The return address was the team leader and above team member. The team leader did not ask for confirmation of receipt of the cost report.
3. Most data was inaccurate/estimated because of late design changes.

4. At the event, judges said they did not have the cost report. They were told it was submitted, and asked for a copy but the team copy was off-site and the team member who had this either had the wrong time, or had ignored the event time.
5. At this point USQ were scored -80 for late report, and were scored on the other parts of the event.

Had the cost report that was submitted sent registered post and another copy always stay onsite at the competition, it is unlikely this problem would have occurred.

If USQ achieved an average score in the cost event they would have finished in twentieth place for the whole FSAE event.

2.2.5 Acceleration

This event is a dynamic event, and evaluates the cars acceleration in a straight line on flat pavement. The cars accelerate from a standing start over a distance of 75 metres, with a maximum acceptable time of 5.8 seconds. (ref: Rule 5.4.6)

USQ came 16th out of the 18 cars that competed in this event. USQ finished with a time of 5.2 seconds, where the quickest was 3.9 seconds, and the average was 4.6 seconds. They did however record a valid time. Several factors were behind this performance:

1. The car weighed 350 kilograms, where most of the others were somewhere in the 250-300 range. This effected the power to weight ratio, already putting USQ at a disadvantage to most of the other entries.
2. The driver had difficulty in accelerating the car quickly from a standing start. This was a result of lack of practice before the event.
3. The engine in the car was down on power compared to some of the other entries, and was more than likely a result of the use of a carburettor over fuel injection.

In general, poor driver training and a heavy car which was underpowered all contributed to the poor result in this event.

With some driver training, and a lighter car, it is possible than an improvement of about 0.5 seconds would be entirely achievable.

2.2.6 Skidpan Event

This event is a dynamic event and is designed to measure the vehicles maximum cornering capability by measuring the total time required for the vehicle to complete one left hand and one right hand circle (ref: Rule 5.6). The event is designed to focus on the vehicles suspension design characteristics and tuneability for maximum lateral grip, and minimize the effect of driver reflexes during transitional maneuvers.

USQ finished 17th out of 18 vehicles that competed in this event. Several factors contributed to the times that they achieved:

1. The heavy weight of the car, combined with the longest wheelbase of any car in the competition meant that doing tight turns was always going to be difficult.
2. Lack of driver training in this event. Several cones were knocked down in this event, and that costs the team 0.25 seconds for each cone knocked down.

It should also be worth noting that the car does not run a differential, but a solid rear spool, thus cornering is a little more difficult without one. However the University of Queensland also ran a rear spool and they finished 4th in this event. Thus I suspect it is not quite such a limiting factor as what we are lead to believe.

USQ scored a time of 5.88 seconds for this event, with the best tim 5.05 seconds. Thus thus an improvement will be seen by driver training and shortening of the wheelbase.

2.2.7 Autocross Event

This is a dynamic event that is designed to test the cars manoeuvrability and handling qualities on a tight course without the hindrance of competing cars(ref: Rule 5.6). This event combines the performance features of acceleration, handling, braking and the overall driveability of the car. It is an extremely tight course that is marked out by way of orange marker cones, and is at times difficult to follow the course laid out by these cones.

The course must comply with several criteria,(ref: Rule 5.6.3) and the following specifications will suggest that average speeds should be 40 km/hr to 48 km/hr:

1. Straights: No longer than 60m with hairpins at both ends (or) no longer than 45m with wide turns on the ends.
2. Constant Turns: 23m to 45m diameter.
3. Hairpin Turns: Minimum of 9m outside diameter (of the turn).
4. Slaloms: Cones in a straight line with 7.62m to 12.19m spacing.
5. Miscellaneous: Chicanes, multiple turns, decreasing radius turns, etc. The minimum track width will be 3.5m. The length of each run will be approximately 0.805km and the driver will complete a specified number of runs.

The sole judging criteria of this event is how fast the car completes the circuit, with a 2 second penalty incurred for each marker cone knocked over, and a 20 second penalty incurred for going off course and not re-entering prior to the missed gate.

This is perhaps the strongest event that USQ performed in. They finished 14th, out of the 20 cars that competed in this event. Their fastest time was 50.3 seconds compared to the fastest time of 39,9 seconds. The average time was 47.7 seconds. Analysis of the individual times have indicated that disregarding any time penalties for cones knocked over or going off the track, USQ would not have increased it's overall position in this event, or bettered it's fastest lap.

The main reasons for results obtained in this event:

1. Heavy weight of the car. This effects the overall power to weight ratio.
2. Lack of driver training. Whilst the time penalties did not hinder USQ, training for such an event will only make the driver more confident, and therefore quicker. Lack of manoeuvrability. The USQ car was the longest of the field at $1750mm$. This particularly hindered performance at the hairpins turns, where avoiding the cones was very difficult, and required the car to slow down considerably to negotiate.
3. Poor turning circle. Insufficient turning angle on the front wheels meant that negotiating the tight corners was very difficult. The total steering rack travel was only $100mm$, and as such greatly restricted the available turning circle.

Not all teams completed this event, or even made it to the dynamic events. As an aside to be given a score, you must be within 1.33 of the fastest car, and the top teams at the competition are very fast.

With driver training it is estimated that USQ could have bettered their lap times by about 2 seconds, bringing them into the average realm, and increasing their finishing position to 13th, achieving a score of 30.8 points.



Figure 2.3: Result of poor driver training for another team

2.2.8 Endurance and Fuel Economy Event

This is a dynamic event, which tests the cars durability and fuel economy. It is run on the same course that the Autocross event is run on, but instead of being timed over 1 lap, it is timed over 24 laps. A time penalty exists with a 2 second penalty incurred for each marker cone knocked over, and a 20 second penalty incurred for going off course and not re-entering prior to the missed gate.

Not only is it demanding upon the car, it is demanding upon the drivers as well.

During the event the times recorded for the USQ car were reasonably competitive, however this was being hampered by the same factors that affected the Autocross event, namely poor power to weight ratio, maneuverability, and driver training.

USQ competed in this event, but did not complete it due to a mechanical failure. An oil leak resulted from cracked pistons, which appeared to be a direct result of overheating. With one lap remaining, track marshalls had stopped the cars on the course because a car in front of USQ had stalled on the course with a cone stuck in the suspension, and had to be cleared from the track.

During the time while the USQ car was stationary waiting for the marshalls to clear the car in front, oil leaked onto the hot exhaust, causing a fire, ending this event

prematurely. Given enough track testing time, the overheating problem may have been located, and rectified.

In general insufficient driver training, poor car maneuverability and lack of track testing time, and low engine power contributed to the poor result in this event.

Had the race not been held up, USQ would have finished the first endurance event, and recorded a score of about 90 (estimated). They may have also avoided further damage to the engine and been able to repair and run in the second endurance race gaining more points. Even with gaining 90 points for this event, would have lifted their overall place for this event to tenth.

2.3 2005 Team Management

The 2005 team was in general made up of four students who were completing their final year thesis on the race car. They each had their own section to work on and design. The analysis of 2005 management is as follows:

1. There was a Team manager appointed, whose responsibilities were workshop liaison and integration of designs into the car, as well as doing his thesis on the chassis design for the USQ FSAE car. In essence he devoted little time to the actual management of the team, and experienced long term absences from the team itself.
2. There was a Team Leader appointed, whose responsibilities were to liaise with sponsors, SAE-Australia, fundraising. Little information is available from 2005 to transfer over to 2006 to assist in gaining sponsorship in 2006.
3. Very little co-ordination between the various people designing parts.
4. Unrealistic deadlines set. For instance, the new chassis that was constructed did not turn up until July. This left no time to fully construct a new car.
5. Only 2 of the design team students (there were 5) went to the F-SAE competition. None had been before, so had little knowledge of what the competition was about, nor any idea of how their work turned out. The manager did not attend.
6. It was some considerable time before any meaningful work was done on the car. Too much time was spent on talking, but not recorded and enacted upon.
7. The car was only completed by one student (who was not doing his project), who took over responsibility of the construction phase. This was done essentially with a large knowledge of "bayckyard mechanics" and merely trying to adapt/modify the 2004 car without any engineering process being applied.
8. The car was under engineered, and over built. The students who did have the skills to engineer a car, did not have time to implement their findings, hence it was left up to the less experienced members (2nd year students) to build the car. They did most of this themselves, rather than letting the workshop staff perform

much of the work. Mostly they were grabbing a piece of metal, and making it fit, with little or no regard in analysis to see if it was either too big or too small for the application.

9. There was no continuation of team members from the 2004 team, to 2005. Nor was there any transference of information. Essentially the 2005 team was starting off from scratch.

In particular recording information, and successfully transferring such information is vitally important, which did not happen from 2004 to the 2005 team. Had this been done, some of the management mistakes listed may not have occurred.

Chapter 3

Recommendations Based on 2005 Performance

3.1 Chapter Overview

This chapter shall provide recommendations based upon the results of 2005. It is intended that most of the suggestions put forward here are enacted upon in 2006. In line with the findings from the review of 2005 it is therefore placed into 2 sections:

1. Recommendations based upon performance at F-SAE 2005
2. Recommendations based upon 2005 team performance.

3.2 Recommendations based upon car performance at F-SAE 2005

1. Appoint a manager for the 2006 F-SAE event. They will co-ordinate all the events, and ensure that the people in charge of the individual events have access to all resources necessary to efficiently complete their events.
2. Appoint a person in charge for each of the events. It is then their responsibility to oversee that particular event. They are also to have a second in charge for the event, and duplication of all and any documentation given to that person. For instance, a person would be in charge of the cost event, and have all the documentation, but would also have a backup copy with someone else.
3. Educate and train the drivers for specific events. It is imperative that people be given enough track time to become fully conversant and comfortable with driving the car for any particular event. At least 6 driver training days should be organised throughout the year, along with trails to see who is the best at particular events. to accomplish this. This will result in faster track times, and less cones being knocked over.
4. Decrease the overall weight of the car. Can be achieved by use of lighter materials, and lighter drivers. A design target of 280kg would be a good target, and represent an achievable but modest improvement over last year. The biggest weight savings is in the driver. A small driver is going to weigh considerably less than our heaviest.
5. Decrease the wheelbase of the car. Will greatly increase maneuverability. This can be achieved by fitment of a differential or by relocation of the pedal box at front of car.
6. Decrease the turning circle of car. Will greatly increase maneuverability. This can be achieved by a greater ratio between the rack and pinion gears. Suggested ratio is 180 degrees lock to lock.

3.3 Recommendations based upon 2005 team performance.

1. Appoint a team manager, whose sole job is to manage the F-SAE team as a whole. They have no other job.
2. Records to be kept in central database that pertain to all aspects of the cars design, construction, and competition. This will ensure a transference of information to the 2007 team.
3. Actual construction of car to be performed mostly by qualified tradesmen, not the students themselves, The students are the engineers, not the builders! Whilst it can be argued that building a car is highly beneficial to the educational process, the students have in the past got too bogged down constructing, rather than designing.
4. Realistic timelines to be set, and use of a management tool such as gantt charts to monitor the entire project.
5. A work procedure system to be put into place to ensure smooth interfacing between suppliers/workshops and the F-SAE team. It is vitally important that the team knows what is occurring at any time in regards to the construction phase.
6. Appointment of various "teams" within the F-SAE team. Example: Design Team, Fundraising Team, Management Team.

Chapter 4

Timeline Management

4.1 Chapter Overview

This chapter will give an overview of the management of deadlines in regards to the design, construction of the car, sponsor commitments and competition documentation.

In attempting to set guidelines, consideration had to be given to parts availability, workshop lead time and personnel availability.

It is to be noted that in trying to manage people and set guidelines, I am dealing with volunteers (no-one gets paid for doing this, nor is there any academic reward for doing so save that of the thesis students), and students in their late teens/early twenties, and as such does not represent a real world scenario in this respect.

4.2 Design and Construction

It was desirable to complete as much design work as possible prior to construction. Timelines were initially set, but with each passing deadline that was not met, it became increasingly obvious other deadlines were not going to be met.

There was a general lack of personnel throughout the design and construction process. Without any drawings from 2005, and having to construct a whole new car, there was no evolutionary process at all. Thus we were starting from scratch.

During the design phase there were four students who produced designs that were ready to go to the workshop for construction. Only two of these students were doing their final year project on the car (one of those was myself), the other two were volunteers. There is no doubt students who did do design and construction work were seriously overloaded academically, and as a result put other subjects at risk.

Therefore our human resource in so far as design is concerned is extremely stretched, given that we have about six month design window at best. What was needed was the design work to begin in 2005 for the 2006 car, or a team of 8 people designing the car in order to meet deadlines.

There were several new team members this year who were keen, but did not possess the necessary design skills to assist in the design process. Overcoming this would mean other more senior members of the team assume a mentoring role, but doing so would overload their own already heavy workload.

In general we had (early on) people willing to participate but several resources could have greatly helped the team:

1. Smaller, easier jobs for people to do.
2. More people with required skills, particularly in the design phase.
3. People who are willing to take on jobs, and to deliver the goods, on time

Early on in the project a gantt chart was used, along with "Microsoft Project", but

meeting the deadlines was near on impossible. Deadlines were not being met due to other students inability to adhere to a timeline, or inability to complete the work.

At the time of writing the new car is still not much more than a chassis awaiting parts to be placed upon it.

4.3 Sponsor Commitments

We had several commitments this year, which were well supported by the team. These included:

1. USQ Open Day.
2. Science and Engineering Challenge.
3. Engineers Australia display at Grand Central shopping centre.
4. USQ Orientation week.
5. FSAE technical conference with Engineers Australia.

I am unable to discern why these events were better attended than doing the design and construction work, but most may have felt that they could contribute more here than anywhere else. Other possible factors include:

1. There is the possibility that some of the junior members of the team were intimidated by the older members of the design team.
2. A fear of not really knowing what to do.
3. Laziness, unless a senior member/staff member stands over their shoulder.
4. Because it is viewed as someone else's project.

4.4 Competition Documentation

The majority of the competition documentation was handled by myself. As such the adherence to the deadlines set down by SAE-Australia were relatively easy to achieve.

4.5 Timeline Conclusions

There is no doubt that *any* project will run more efficiently when proper charting and management tools are used. Adherence to timelines can only be achieved if the following conditions are met:

1. Sufficient economic resources allocated.
2. Sufficient manning.
3. The desire to achieve a goal.
4. Reward for doing so.

In general there was a lack of all of the items, and as such makes such management difficult.

In order to assist in adherence in the future to such timelines, it is recommended that the University of Southern Queensland begin to address these issues.

Such measures could include:

1. Academic credit given to students who become *actively* involved with USQ Motorsport. Mech prac 1,2 and 3 come to mind. As the students are working in a team it encourages problem solving issues as well, and I feel a student could well learn more by becoming involved in USQ Motorsport than what they could in certainly Problem Solving 1 and 2.
2. More economic resources from the University. This is the only competition that USQ competes in (Engineering Faculty) that is of international standard, and with international teams. Students having to spend lots of time raising funds may turn them away.
3. Encourage students to become involved within USQ Motorsport. By becoming involved in a competition, it not only benefits the student, but engenders a feeling of pride as well which reflects upon the University favorably.

Chapter 5

Design Work

5.1 Chapter Overview

No Technical Director was appointed, and so by defacto I was doing system integration, and quickly moved to the necessary design/manufacture of several components to ensure the car was constructed in time for the Formula SAE-A competition. In general this was due to a lack of students capable of doing such design work.

Specifically this chapter will deal with the design, and manufacture of these components, which were:

1. Impact Attenuator
2. Fuel Injection

5.2 Impact Attenuator

The impact attenuator is fitted to the front of the racecar(ref: Rule 3.3.6.3). In previous years, the rules stipulated that an impact attenuator was to be fitted to the front of the car, but no specifications were given, nor any proof of energy absorption capabilities was required. 2006 marks the first year the new rules for this has been applied. These rules are set out below:

1. The Impact Attenuator must be installed forward of the Front Bulkhead.
2. The Impact Attenuator must be at least 150 mm (5.9 in) long, with its length oriented along the fore/aft axis of the Frame.
3. The Impact Attenuator must be at least 100 mm (3.9 in) high and 200mm (7.8 in) wide for a minimum distance of 150 mm (5.9 in) forward of the Front Bulkhead.
4. The Impact Attenuator must be attached securely and directly to the Front Bulkhead such that it cannot penetrate the Front Bulkhead in the event of an impact. The use of adhesive tape and/or Dzus type fasteners is prohibited. The Impact Attenuator shall not be attached to the vehicle by being part of non-structural bodywork. The attachment of the Impact Attenuator must be constructed to provide an adequate load path for transverse and vertical loads, in the event of off-center and off-axis impacts.
5. The team must submit calculations and/or test data to show that their Impact Attenuator, when mounted on the front of a vehicle with a total mass of 300 kgs (661 lbs) and run into a solid, non-yielding impact barrier with a velocity of impact of 7.0 metres/second (23.0 ft/sec), would give an average deceleration of the vehicle not to exceed 20 g.

5.2.1 Testing Procedure

In order to effectively determine the correct material, and size of the impact attenuator, it was decided to do several quasi-dynamic tests with the MTS machine, then do a final dynamic test with a testing rig.

The total amount of energy required to be absorbed will be calculated. Then a force-deflection plot will be obtained from the quasi-dynamic tests, and the size, and type of material to be used can be determined from this data. By integrating force with respect to deflection, it will yield the total energy required to deform the sample. eg

$$W = \int F ds \quad (5.1)$$

Obtaining this data will be from an MTS machine. The MTS machine (located in the non-destructive testing room, level 1 Z block) will only accommodate a test sample of $200mm$ by $200mm$ by $300mm$, and is capable of a ram movement of $100mm$. Thus these preliminary tests were conducted on a scaled down version of the impact attenuator. Testing will be carried out on a number of materials, and then once a suitable material found, it will be scaled up.

Three sample tests were conducted on materials, and the most suitable selected to be scaled up to be built. Two will be built, one for the car, the other for dynamic testing.

Dynamic testing will comprise dropping a $300kg$ weight onto the impact attenuator and measuring deceleration with an accelerometer, as well as total deflection of the attenuator.

5.2.2 Energy to be Absorbed

Determining the total energy to be absorbed, I applied the basic equation for energy:

$$E = \frac{1}{2}mv^2 \quad (5.2)$$

where m =mass of car, v =velocity of car.

mass of car: 300kg Includes driver (ref: Rule 3.3.6.4)

velocity: 7m/s

Peak acceleration allowed:

$$A = 20g = 20 \times 9.81 = 196.2m/s$$

Peak force allowed during deceleration:

$$F_{max} = 20g \times mass = 196.2 \times 300 = 58860N$$

Total energy to be absorbed whilst bring the car to rest (min):

$$E = \frac{1}{2} \times 300 \times 7^2 = 7350 \text{ Joules}$$

5.2.3 1st Test Material

The first material to be tested is expanding polyurethane type foam (Bostick brand). This was used on the 2005 car in an aluminium skin frame.. This was initially chosen as it possibly represents a cheap, easy way to make the attenuator.

A 100mm length by 50mm diameter sample was tested first in the MTS machine, and compressed until it could not be compressed any more. The MTS records force versus deflection as shown in figure 5.1. Specimen was crushed to approx 30 percent of it's original length with some buckling observed.

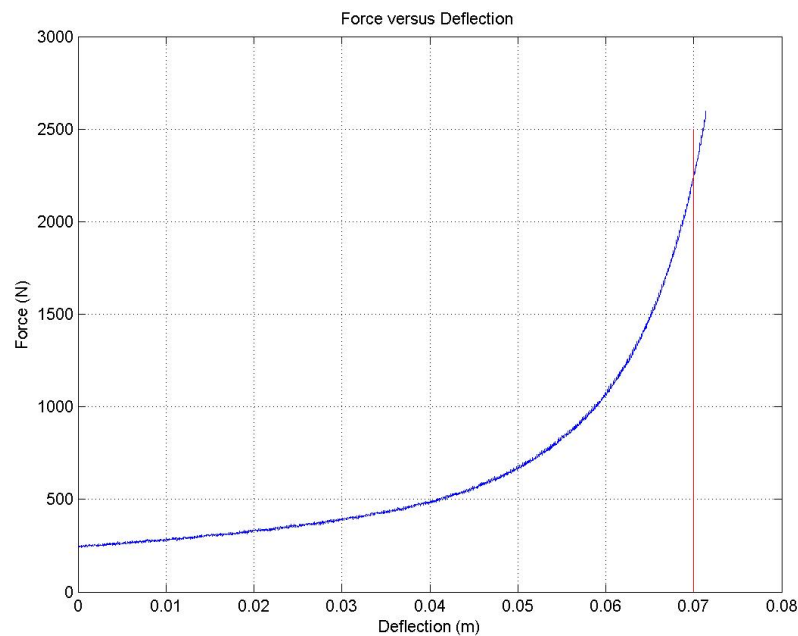


Figure 5.1: Results from testing of foam sample

The total energy required to compress the foam was 46 Joules, derived from equation 5.1. The peak force was 2400N.

To determine the amount of material required by scaling:

$$\text{Volume} = \frac{\text{energy to be absorbed}}{\text{energy absorbed by sample}} \times \text{specimen volume} \quad (5.3)$$

Specimen volume:

$$= \frac{\Pi \times D^2}{4} = \frac{\Pi \times 0.058^2}{4} = 2.86 \times 10^{-4} m^3 \quad (5.4)$$

Volume of material required:

$$\text{Volume} = \frac{7350}{46} \times 10^{-4} = 4.87 \times 10^{-4} m^3 \quad (5.5)$$

Taking the cubed root of this will yield the size as a cube:

$$(4.87 \times 10^{-4} m^3)^{\frac{1}{3}} = 0.36m$$

5.2.4 2nd Test Material

This was comprised of square based pyramid (0.5mm steel) filled with expanding polyurethane foam. The pyramid measured 200mm square at the base, and 200mm high, with a top section of 50mm square at the top. As before, this was tested in

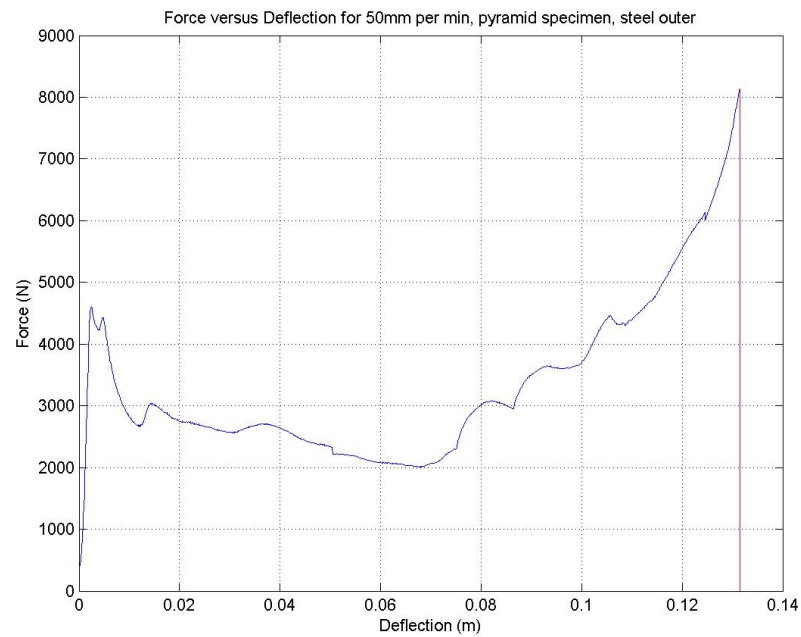


Figure 5.2: Results from testing of foam filled pyramid sample

an MTS machine, and a force deflection graph obtained. This material did not prove overly successful, but the steel outer did provide a more stable crushing than the foam alone.

5.2.5 3rd Test Material

The third test was comprised of aluminium tubes 25mm OD by 1.2mm wall thickness, nine tubes stacked, then welded together on the ends. Original specimen 75mm high, 100 mm long, by 75mm wide. Then loaded perpendicular to their centreline. See figure 5.3

It was anticipated that material would provide a more stable ride down, and a more constant force during compression.



Figure 5.3: Initial testing of tubular sample

This sample had force applied to it, (with a ram speed of 100mm/minute) and the results seen in figure 5.4



Figure 5.4: Results from testing of tubular sample

The details of energy absorbed are seen below:

Crush: To 45 percent of original height.

Peak Force: 31506Joules Total energy displaced to crush specimen: 527Joules

Volume of specimen (cubic metres) $4.4179^{-4}m^3$

Volume of material required to stop car (cubic metres) $0.0062m^3$

Size of Attenuator (as a cube) $0.1833m^3$

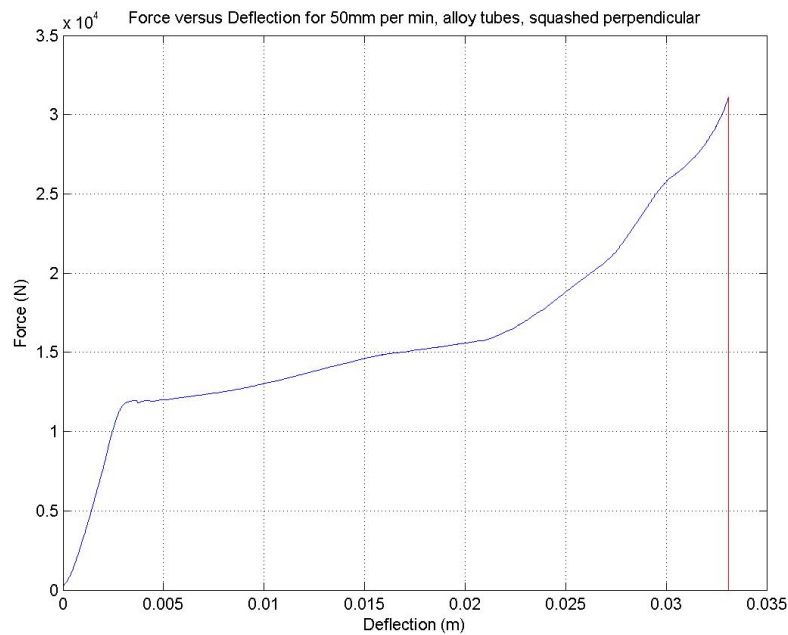


Figure 5.5: Graph of testing tubular sample

The graph in figure 5.5 shows a much more linear rate of force absorption than the other test samples.

This shows a rapid initial rise, followed by a near linear rise. There is no initial spike. This test shows that the approach achieves very nearly the ideal "rectangular" force / deflection curve for maximum energy dissipation.

The initial ramp up will serve to ensure that the occupant does not suffer a high secondary impact from the safety harness webbing which would result from a true rectangular application of force.

5.2.6 Current Design

As the third sample was the most appropriate it has been decided to use this material for the attenuator on the 2006 car. Scaling this up, I have settled on a $200mm$ by $200mm$ by $200mm$ cube as the attenuator.

The current design is shown in figure 5.6

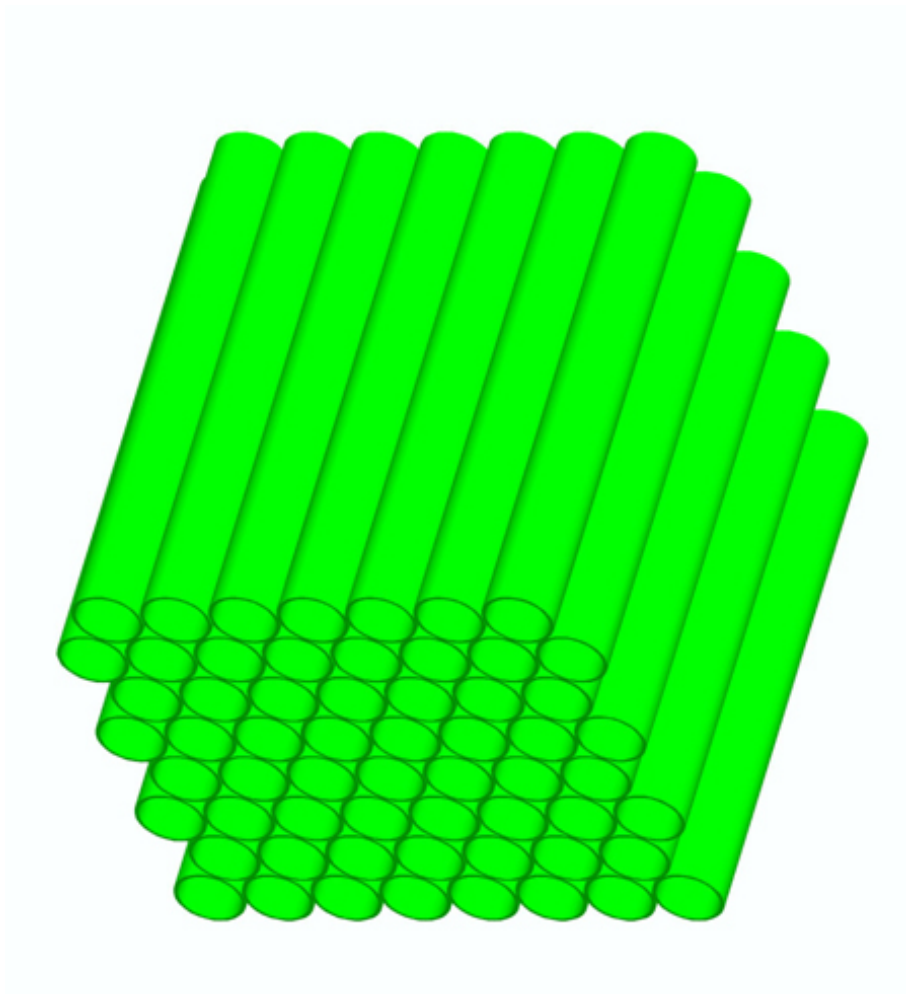


Figure 5.6: Current Design Attenuator

Two of these are to be built, one for the car, and the other for dynamic testing.

For the dynamic testing it is proposed to drop a $300kg$ mass on to the impact attenuator

from a height of 2.5 metres, and measure the deceleration and the total energy absorbed. For this design our target is a maximum of $18g$ and an average of $14g$ deceleration. This design is expected to completed construction by 20/10/2006.

5.3 Fuel Injection

A major decision for the 2006 car was to dispense with the carburettor and use fuel injection instead. Available material from a previous students project was an Adaptive ECU, injectors and a fuel rail.

In order to fit the fuel injection to the car it was necessary to design and construct a new inlet manifold, as well wiring up the ECU, commissioning and tuning the engine.

Components had to be selected, sourced, and placed onto the engine. Minor modifications were made to the engine as well. Along with this the system itself had to comply with various rules, these being:

1. 3.5.3.7 Fuel Lines, Line Attachment and Protection
2. 3.5.3.8 High Pressure System Requirements
3. 3.5.3.9 Air Intake and Fuel System Location Requirements
4. 3.5.4 Throttle, Throttle Actuation and Intake Restrictor

The primary components that were required are:

1. Inlet Manifold
2. Fuel Pump
3. Fuel Rail
4. Injectors
5. Sensors
6. Electronic Control Unit (ECU)

This section describes all of these activities.

5.3.1 Manifold Background

The primary function of the inlet manifold is to deliver the incoming air charge to the engine. It is possible with good design to achieve a better than 100 percent volumetric efficiency, however this is dependent upon many factors, such as valve timing, valve sizes, head design, ambient air pressure and ambient air temperature.

The main components of the intake manifold include the air filter, throttle body, plenum, and runners. The air filter removes impurities in the air so it will not hinder the combustion process. The throttle body provides the user with a means to manage the flow of air into the engine itself, increasing the opening to supply more air. The plenum serves as a reservoir for the incoming air to be drawn from when each cylinder requires a charge of air.

Depending upon design, fuel may be introduced to the incoming air in the inlet manifold. Then finally the air flows through the runners and into the engine where it is combusted.

The manifold of a formula SAE engine presents it's own series of problems, as the restrictor greatly cuts down the incoming air charge. This restrictor is 20mm in diameter, and typically this represents about 20 percent of the original flow capacity that was intended by this engine manufacturer.

In 2005, the formula SAE car used a carburetted manifold, with long runners. It's performance was reasonable, but the carburettor was less than reliable. In order to fit the carburettor and comply with the rules (ref: Rule 3.3.5.9), the total length between the engine and the carburettor was very long and this seriously hampered performance. Aesthetically it was unprofessional, as well as compromising performance.

There has been no data gathered as to the amount of air that was going into the engine, nor a baseline performance data to gauge what improvements may be realised through fuel injection.

5.3.2 Assumptions

In order to design an inlet manifold, there are various assumptions to be made, compounded by the lack of data from previous years. They are as follows:

1. Volumetric efficiency of 65 percent. This is due to lack of forced induction, and the restrictor.
2. Maximum torque is achieved at 7500 rpm. This based on the engine manufacturers specifications.(ref: YZF600 Workshop Manual)
3. That all values for air are assumed to be at sea level, and at 20°C

5.3.3 Manifold Design

The most important limitation in the design of the intake system is the restrictor constraint enforced by the rules of the FSAE competition. The restrictor must be placed between the throttle body, and before the engine and can be no larger than 20mm in diameter. This will severely limit airflow at full throttle so the rest of the intake system must be designed to be as effective as possible.

When designing a manifold there are several design criteria to take into consideration. These are:

1. Type of manifold
2. Restrictor
3. Plenum volume
4. Runner diameter
5. Runner lengths
6. Injector placement
7. Material

Other factors include:

1. Space constraints within the existing chassis
2. Need to provide a port for the manifold air pressure sensor, and the air temperature sensor.
3. Lightweight, and cost effective.
4. Ease of construction

5.3.4 Manifold Type

There are three main types of manifold set up:

1. Single Plane
2. Dual Plane
3. Tunnel Ram

Dual Plane: This type of manifold has a divided plenum (or two smaller plenums). It is a good choice for low rpm power and gives better throttle response than most other manifolds. The small plenum area gives good throttle response.

Single Plane : All intake runners come from a common plenum. The open plenum smoothes out the induction pulses better than a dual plane manifold and can give better top-end power, at a cost of low rpm power. With high revving engine, a single plane is probably the best choice.

Tunnel ram: All the intake runners are straight and meet at a common plenum (the tunnel). This type of manifold gives excellent fuel distribution and flow for top-end power. The large plenum area reduces signal strength and throttle response.

If the manifold design not include a plenum but provide singular paths into each inlet port, the type is called an "independent runner" or IR design. This is a typical method for fuel injected engines intended for mid to high rpm use, such as narrow engine speed ranges associated with sprint car or high speed only applications. The ability to transition from low- to mid-rpm engine operation is foregone to benefit higher rpm and sustained speeds.

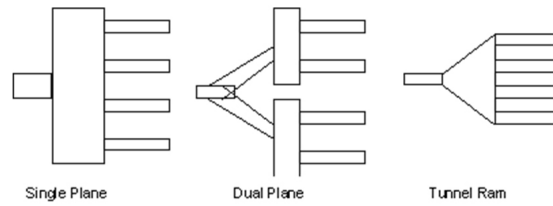


Figure 5.7: Manifold Types

For the FSAE application, a single plane manifold will be ideal, as it will provide a more even spread of torque, which will be more beneficial for the formula-SAE competition.

5.3.5 Restrictor

It is mandatory that a restrictor is placed after the throttle butterfly, and before the intake ports. (ref: Rule 3.5.4.3)

For the past two years USQ has taken the same conventional approach as most other FSAE teams and mounted the throttle butterfly about $300mm$ to $400mm$ away from the plenum chamber to allow fitment of the restrictor. This results in the throttle body mounted in a myriad of locations. The extra length imposed on such can be a cause of lag in regards to throttle response.

For this year I have decided to try an approach that no-one else has used before. I intend to place the restrictor into the plenum chamber. This will have several advantages:

1. It will greatly reduce the length of the inlet system, thereby improving performance. A reduction of about $300mm$ is possible.
2. It will enable the throttle body to be bolted directly to the plenum chamber.
3. Reduce weight of the system.
4. Aesthetically pleasing.
5. The restrictor is designed so that it can be simply unbolted and remounted elsewhere should on track testing of this component fail.

To effectively design the restrictor, we need to maximise pressure recovery. Assuming a pressure recovery of 95 percent, and frictionless flow we can design the outlet diameter and length of the restrictor.

For ideal pressure recovery:

$$Cp = 1 - \frac{1}{(AR)^2} \quad (5.6)$$

Where:

Cp = Pressure recovery Coefficient

$$AR = \frac{A_2}{A_1} \quad (5.7)$$

A_1 = Initial cross sectional area

A_2 = Final cross sectional area

$$A_1 = \frac{\pi D^2}{4} = \frac{\pi 20^2}{4} = 314.159mm^2$$

$$0.95 = 1 - \frac{1}{(AR)^2} \therefore \frac{1}{0.05} = (AR)^2 \therefore (AR)^2 = 20$$

$$AR = \sqrt{20} = 4.47$$

$$\therefore A_2 = A_1 \times AR = 314.159 \times 4.47 = 1404.29mm^2$$

$$D_2 = \sqrt{\frac{A_2 \times 4}{\pi}} = \sqrt{\frac{1404.29 \times 4}{\pi}} = 42.284mm$$

Pressure recovery is negligible with angles less than 15° . Therefore designing the outlet with an included angle of 15° will yield the greatest pressure recovery. (Fox & MacDonald 2004).

Loss coefficients for the inlet side of the restrictor are at their minimum at an included angle of 15° . (Fox & MacDonald 2004). The restrictor was then designed to have this angle.

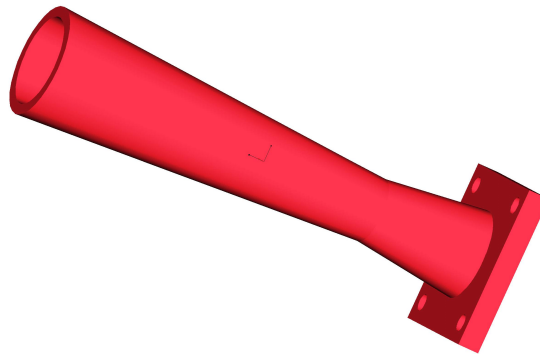


Figure 5.8: Restrictor for 2006 Engine

Figure 5.8 shows the picture of the restrictor, along with the mounting plate which will match up to the bolt pattern on the throttle body. The restrictor is constructed from aluminium, with a wall thickness of 3mm. The mounting plate is constructed from 5mm aluminium. Constructing this from steel would result in an excessively heavy item, (some 3 times heavier) with a small increase in cost over steel.

Aluminium also has a greater heat coefficient, which will help to cool the incoming air, resulting in an increase in density. Other materials that were considered were carbon fibre, but this was ruled out due to the high cost.

5.3.6 Plenum Volume

This is an area where there are many theories. In essence the job of the plenum is to provide a volume of air for the intake runners to draw from. The plenum must be large enough to ensure the engine is not starved of air under sudden acceleration, yet small enough to ensure adequate throttle response.

There are no truly accurate formulas to determine plenum volume, but most road cars use 60-80 percent of the engine volume. Racing cars can be as low as 50 percent. The main factor we have to worry about, is slowing the incoming air enough to take the intake pulses out. Small plenum volumes will lower the rpm of peak torque and large

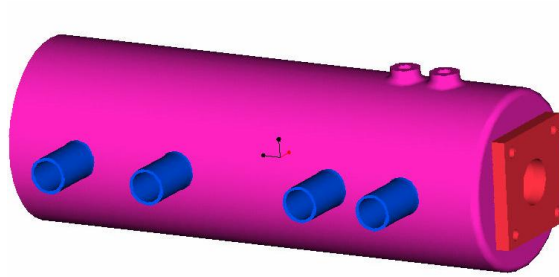


Figure 5.9: Plenum Chamber(with restrictor and top tubes inserted)

plenum volumes increase the rpm of peak torque.

Due to the restrictor being in place, the velocity of the incoming air into the plenum has been increased far beyond what is occurring in a normal automotive application. Without any data from previous years, it is impossible to determine mathematically the plenum volume required, thus as a rough estimate it is suggested that the plenum volume is twice to three times that of the engine capacity. Plenum volumes of this capacity have been used with success before on formula SAE cars.

The plenum chamber can be any shape, however for ease of construction, aesthetics, packaging, and assistance of flow I have decided upon a cylindrical plenum.

As the restrictor is inserted into the plenum, the internal volume is decreased, therefore I have increased the plenum size to take into account of the reduction in volume.

Final calculations yield a plenum 120mm diameter, an effective 350mm long, giving a volume of 1.74 litres, after subtracting the volume displaced by the restrictor placed inside the plenum.

Two ports are built into the plenum in the most stable region to provide pick off points for the MAP (manifold air pressure) sensor, and the air temperature sensor. To simplify construction, and to provide vibration resistance I have decided to make the runners in 2 pieces, with the top part of the runners attached to the plenum. The runners will be attached together by silicone hoses.

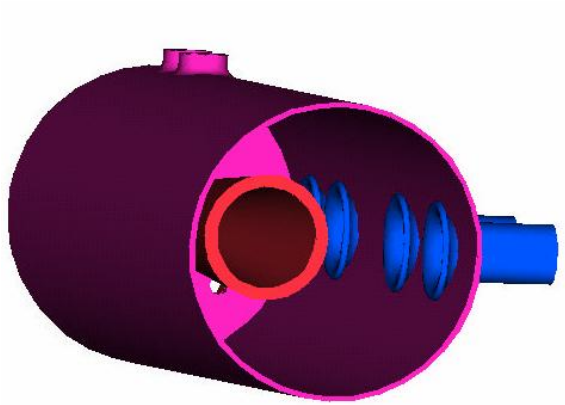


Figure 5.10: Plenum Chamber (side view, cover removed)

The plenum is constructed from 3mm thick aluminium. The plenum was made to be lightweight, and aesthetically pleasing. Constructing this item from steel would result in an extremely heavy item, which would then require extra bracing and supports to hold.

5.3.7 Runner Diameter

Some assumptions have to be made in order to calculate runner diameter.

The following formula is used by US based engine engineer David Vizard to determine runner diameter.

Runner Diameter (mm):

$$\varnothing = \sqrt{\frac{rpm \times vol \times VE}{3300}} \times 25.4 \quad (5.8)$$

Where:

rpm=revolutions per minute, of desired maximum torque=7500rpm

vol=engine capacity in litres=0.6L

VE= volumetric efficiency of the engine=0.65

∴ Runner Diameter=

$$\varnothing = \sqrt{\frac{7500 \times 0.6 \times 0.65}{3300}} \times 25.4 = 23.91mm$$

This seems about right, as the USQ team used 25.4mm internal diameter last year, without any detrimental effects.

If we were to assume a volumetric efficiency of 1 (100 percent, which would have been standard without the restrictor), then the calculations reveal a runner diameter of 29.6mm.

Running a larger runner diameter, will decrease the velocity, and conversely a smaller runner diameter will increase velocity. Measuring the intake port diameter on the head reveals a diameter of 28mm, which again indicates the above calculations are reasonably close.

Pipe diameters of 25.4mm internal are very common, therefore I used to use this size. Should it be found at a later date that the volumetric efficiency is above that of 65 percent, then this diameter will ensure that choking of the engine does not occur.

5.3.8 Runner Lengths

When an engine is running, there are high and low pressure waves moving in the manifold caused by the inertia of the air and the opening and closing of the valves. The idea of tuning is to have a high pressure wave approach the intake valve just before it closes and/or just as it opens. The former timing increases the pressure and density forcing in a little more intake charge mass, where as the latter timing increases pressure in the port to reduce losses due to reverse flow in the intake.

There are two main theories that pertain to manifold tuning and allow the formulation of geometry that should lead to improved volumetric efficiency. One holds that a plenum- runner manifold combines the effects of a quarter-wave organ pipe and a Helmholtz resonator and that each can operate either independently or in conjunction as a "system." The other contemplates "wave motion" within the manifold, varying as a function of rpm, piston displacement and camshaft duration.

Helmholtz model peak determination:

The Helmholtz resonance model is an electrical circuit analogy developed by H.W Englemann for manifold design applications. It is not as complete as more recently developed models, as it does not include the effects of plenum volume and other resonant volumes such as secondary runners, but is nevertheless enough for our purposes.

Data for our basic design is as follows:

L = Primary runner length: (cm)

A = Primary runner area: (cm)

V = Displacement per cylinder: 150cc

C = Compression ratio: 12:1

c = Speed of sound is taken as 340m/s.

The Helmholtz peak, in RPM, will be given by the following equation:

$$rpm = 642 \times \sqrt{\frac{A}{L \times V}} \times \sqrt{\frac{C-1}{C+1}} \quad (5.9)$$

A plot of the runner lengths versus the target rpm appears in figure 5.11.

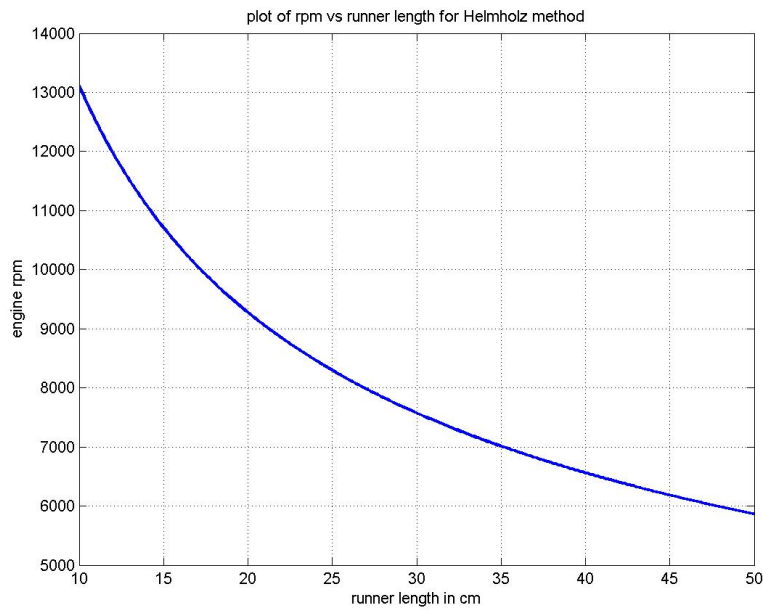


Figure 5.11: Plot of runner lengths vs target rpm, using Helmholtz method

Some simple rules:

- Short Intake Runners help high RPM torque.
- Long Intake Runners help low RPM torque.
- Large area intake runners help high RPM torque.
- Small area intake runners help low RPM torque.

Wave Motion Method:

Wave action tuning is a relatively easy way to augment volumetric efficiency within the cylinders. It stems from a simple phenomenon: as the intake valve opens, the downward motion of the piston causes the mixture to be literally sucked into the cylinder. When the intake valve closes, this accelerated air stops against the valve and stacks up on itself, creating a high-pressure area.

This causes a high-pressure wave to make its way up the primary intake runner away from the cylinder. When it reaches the end of the intake runner, where the runner connects to the plenum, the pressure wave is reflected on the opposite wall and is sent back down the intake runner. Sizing the runner appropriately will enable the pressure wave to arrive back at the intake valve as it opens for the next cycle. This extra pressure will make more mixture enter the cylinder, thus having a supercharging effect. The drawback of this process is that the tuning is only effective in a precise RPM range.

While some recent high-performance street cars use variable-geometry runners to spread the effect on a wider band, practicality in the scope of this competition dictates that we must use fixed-length runners.

A simplified approach to the wave motion theory also allows for simple approximate calculation of intake runner length. To do this you must subtract some duration, typically you take off 20-30°. from the advertised duration. 30°. works well for most higher rpm solid cammed drag motors. So the formula to figure effective cam duration (ECD) will be:

$$ECD = 720 - \text{Advertised cam duration} - 30$$

The formula for optimum intake runner length (L) is:

$$L = \frac{ECD \times 0.25 \times V \times 2}{rpm \times RV} - (0.5 \times D) \quad (5.10)$$

Where:

ECD = Effective Cam Duration

V = Pressure wave speed (approx 1115ft/s, speed of sound)

RV = Reflective Value - the utilised pressure wave set, (2 for high rpm, peaky engines, 4 for lower rpm tractable engines).

D = Runner Diameter (inches)

A reflective value of 3 was used for these calculations, as we are trying to maximise torque lower down, and create an engine well suited to the formula-SAE competition.

A plot of the runner lengths versus the target rpm appears in figure 5.12.

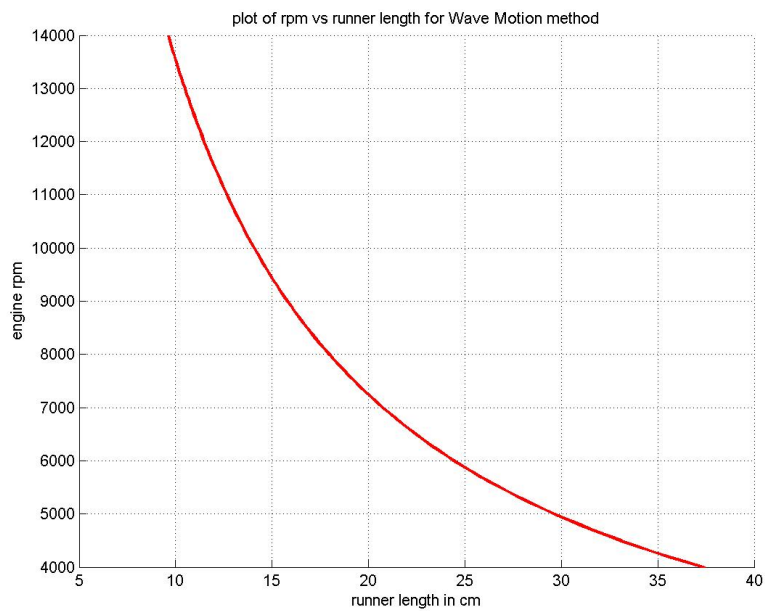


Figure 5.12: Plot of runner lengths vs target rpm, using Wave Motion method

Results

There is no right or wrong method to use for these calculations. Both have their merits and downfalls. An overlay plot of both methods is provided in figure 5.13.

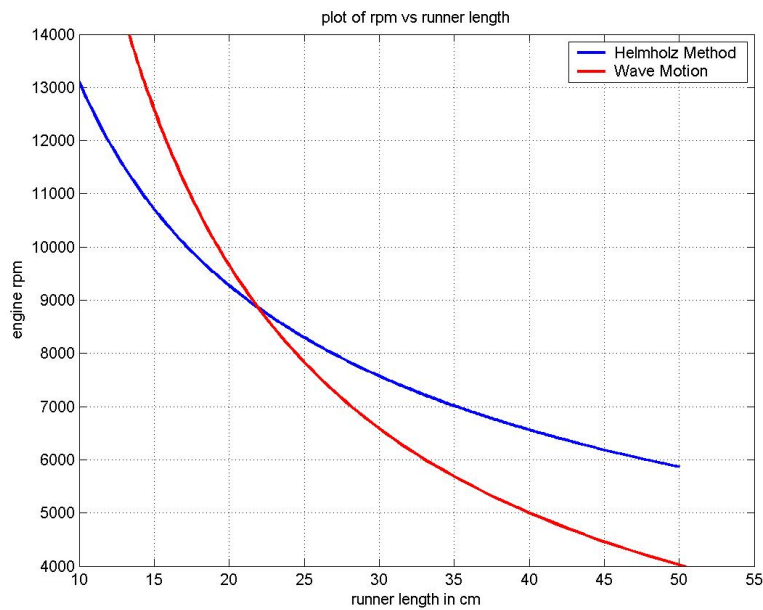


Figure 5.13: Plot of runner lengths vs target rpm

Within the target range of $7500rpm$ it can be seen that the graphs for both, are reasonably similar. I have decided to use the Helmholtz method, which for $7500rpm$ yields a runner length of 30cm.

5.3.9 Injector Placement

There are several places where the fuel injector can be placed:

1. Just behind the inlet valve so the fuel is injected onto the inlet valve.
2. Into the inlet runner, to be mixed with the incoming air stream.
3. Above the throttle butterfly.

As the distance from the inlet valve to the inlet port is 10cm, it will be impossible to mount the injector to spray onto the back of the valve. Mounting above the throttle butterfly is also undesirable, as we would then have a the plenum chamber filled with air fuel mixture, which would be in essence be like a small bomb should the engine backfire.

Thus the only placement is into the incoming air stream.

5.3.10 Construction

The inlet manifold was constructed as per the designs described in previous sections. As the plenum and top part of the runner tubes are constructed from alloy, and the lower half of the runners from steel, they are connected by rubber hose, and secured with clamps. This also helps alleviate any vibrations, and makes mounting easier.

I then mounted this assembly to the engine in the 2005 car to assist with tuning of the ecu, whilst other team members continued their work on the 2006 frame, suspension and electrical systems.

Figure 5.14 shows initial fitment of the manifold along with the fitment of the electronic components for the fuel injection.



Figure 5.14: Inlet Manifold

5.3.11 Fueling System

The fuel system consists of several components that are necessary:

1. Fuel Pump
2. Fuel Filter
3. Fuel Rail
4. Injectors

A high pressure pump is required to deliver fuel at the correct pressure to the injectors. A generic off the shelf item was selected for this purpose (Fuel Miser, Model Number: FPE-06), as it was low cost, easily obtainable, and provided the correct pressure, with the correct fuel flow. (250kPa, 5L per/min)

Similarly a fuel filter was chosen in the same way the fuel pump was.

The fuel rail was constructed in 2005 by another student who was in the process of putting fuel injection on the car, although time pressures precluded this being implemented in 2005. This component was perfectly satisfactory for this installation.

The injectors were sourced from a second hand Daihatsu Charade, with the injector capacity of 134cc. These units were rebuilt and fitted to the engine.

5.3.12 Sensors

Several sensors had to be sourced to enable the fuel injection to run properly. These were:

1. Engine Coolant temperature (ECT)
2. Manifold Air Temperature (MAT)
3. Throttle Position Sensor (TPS)
4. Manifold Air Pressure (MAP)
5. Exhaust gas (HEGO)
6. Crank Angle Sensor

Standard off the shelf parts from Bosch were chosen for the coolant and air temp, the manifold air pressure, and exhaust gas sensors. These are cheap, readily available, and reliable.

The throttle position sensor is part of the throttle body. This part had been previously sourced in 2005 by another student who was in the process of putting fuel injection on the car. This component was perfectly satisfactory for this installation.

The original ignition pickup for the bike engine was from a reluctor positioned on the crankcase, sensing pickups on the flywheel. As there were insufficient pickups on the flywheel this was modified to provide the correct number. Modification was performed by myself, and required placing of additional pickups at thirty degree increments around the flywheel.

5.3.13 Conclusion

At the time of writing the engine was running on the fuel injection, but not tuned correctly. To do this, it is necessary to place the car on a chassis dynamometer to tune under all load conditions.

In general this has taken (timewise) far in excess of what I had anticipated, but the end result should see an overall improvement in the driveability of racecar.

Chapter 6

Other Work

6.1 Chapter Overview

As well as design and construction work, a vast amount of my time this year has been taken up with general administration of USQ FSAE team, and other activities. This chapter will provide an overview of the following activities:

1. Sponsorship
2. Cost Report
3. Design Report

6.2 Sponsorship

In previous years there had been little in the way of "in kind" sponsorship, which resulted in many parts of the car having to be paid for. Therefore if enough sponsorship could be obtained, particularly for the materials and parts to build the car, the overall cost to USQ Motorsport would be substantially less.

Several approaches were undertaken for in kind sponsorship:

1. Direct face to face approach. An appointment was made with the supplier for an interview, and they were approached whereby I would tell them the benefits of sponsorship of USQ Motorsport. This was always the method with local suppliers.
2. Phone/email contact. This was used for larger suppliers that required such proposals go through either a state or national office for approval.

Both of these methods were used, with varying success, however the majority of our sponsors were obtained through email/phone contact, and were the larger type of companies. Obtaining such sponsorship involved many phone calls, emails, and general chasing of personnel to achieve the results of this year. The following companies assisted USQ Motorsport this year:

1. Orrcon Steel
2. Bluescope Steel
3. Linear Bearings
4. CBC Bearings
5. Buchanan Advanced Composites
6. Adaptronic
7. Umbrako
8. The Battery Factory

Their assistance this year has meant that the majority of the materials to construct the car have been supplied to USQ free of charge.

6.2.1 Monetary Sponsorship

Along with in kind sponsorship, some companies have assisted with monetary sponsorship. These companies were approached to assist USQ Motorsport. With the exception of one company this year, all of the other monetary sponsors, sponsored USQ Motorsport in 2005. The following companies provided financial assistance to USQ Motorsport in 2006:

1. Engineers Australia (Toowoomba Branch)
2. GC Event Hire
3. Aerotec Queensland.

In general there was a reticence on the part of many local companies to support USQ Motorsport because of perceived benefit to them.

6.2.2 Retaining Sponsors

Apart from what stickers on the 2005 car, there was no information that indicated who our sponsors were, nor what they gave USQ Motorsport. As part of information transference for the 2007 team, I implemented a sponsor document, that outlined who their sponsors were, what they offered and relevant contact names, emails and phone numbers. This sponsor list is attached in appendix C.

This was also important as I was able to send out newsletter outlining the progress of USQ Motorsport in 2006. It is hoped that by this regular contact, that these sponsors will also assist USQ Motorsport in 2007.

6.3 Cost Report

The Cost report is part of the Cost and Manufacturing Event at the FSAE competition. This event is comprised of two parts:

1. The preparation and submission of a written report (the Cost Report), which is to be sent to the Cost Judges prior to the competition. (ref: Rule 4.3.4)
2. A discussion at the Competition with the Cost Judges around the teams vehicle. (ref: Rule 4.3.5) This evaluates not only the cost of the car, but also the teams ability to prepare accurate engineering and manufacturing cost estimates.

As part of the documentation for the FSAE competition, it was my responsibility to compile the Cost Report.

6.3.1 Format

The SAE rules are very specific in regards as to the layout of the cost report, which is not only exhaustive by time consuming. Part of these rules state that the cost report is submitted electronically as an excel file, and a hard copy with all thew other documentation is posted to SAE Australia, by 1st November 2006

The information to be compiled is information on every component that goes into the racecar, down to every last nut and bolt. Previously this has been exhaustive and time consuming for the team.

6.3.2 Required Information

There is substantial information that is required to be compiled, which includes:

1. All receipts from parts purchased.
2. All costs for parts donated.
3. Manufacturing process cost for parts manufactured.
4. All labour required to build the parts and assemble to the car.

The main problem was most of this information in the past was usually guesswork, and as such required a system be put into place to gather this information.

6.3.3 Construction of Cost Report

The excel file that SAE requires entrants to use, is broken into subsections for each category of the car of which they are:

1. Brake System
2. Engine and Drivetrain
3. Frame and Body
4. Instruments and Wiring
5. Miscellaneous fit and finish
6. Steering System
7. Springs and Shocks
8. Wheels, wheel bearings and Tyres

I decided to break each of these subsections into separate excel files, and link those separate files back to the master excel file SAE wished us to submit. The subsection

Part Name:		Quantity Required:		Total End Item:			0
Material Qty	Description	Volume	Weight	\$/Unit	Cost		
Material sub-total							
Process Labour Qty	Description	Amount	Unit	Manning	\$/Unit	Cost \$	
	Labor		hr		35	0	
	CNC Machine (time)		hr		70	0	
	Computer aided labor		hr		70	0	
	Welds		cm		0.14	0	
	Saw or tubing cuts		cm		0.16	0	
	Tube bends		bend		0.75	0	
	Non-metallic cutting		cm		0.08	0	
	Tube end preparation		end		0.75	0	
	Drilled holes		hole		0.35	0	
	Reemed hole		hole		0.35	0	
	Tapping holes		hole		0.35	0	
	Sheet metal shearing		cut		0.2	0	
	Sheet metal punching		hole		0.2	0	
	Sheet metal bends		bend		0.05	0	
	Sheet metal stampings		sq.cm		0.008	0	
	Sand castings		kg		6.61	0	
	Die castings		kg		8.82	0	
	Investment casting		kg		17.64	0	
	Plastic injection molding		kg		6.06	0	
Process Labour sub-total							
Component Piece Cost							0

Figure 6.1: Example of Manufacturing Process Cost Sheet

excel files were also inked to a word document which formed the basis of the hardcopy part of the cost report.

In each of the subsection excel files, there was a separate process engineering sheet for each part that was manufactured. The idea behind this was that the person in charge of that part being manufactured, could fill in the process chart on the excel file, thereby filling out not only the electronic excel file to be emailed to SAE-Australia, but the hardcopy cost report as well. An example of the manufacturing process sheet to be filled out can be seen in figure 6.1. All formulas were also placed into this excel spreadsheet, so the operation was as seamless as possible.

Once this information was into the cost report, it still required manual entry into the hard copy word document. Constructing, compiling and submitting the Cost Report consumed eighty hours of work.

A copy of the Cost report can be viewed in the appendix as a separate document "Cost Report 2006 .pdf"

6.3.4 Future Cost Reports

As the time of writing the cost report is completed, and is over 200 pages long, and the method I have implemented has been very successful.

This Cost report format can be used for future entries from USQ, and along with that i have also written an instruction manual that resides on the USQ Motorsport database to ensure successful transfer of such important information to following years teams.

6.4 Design Report

The Design Report is another report that must be submitted to FSAE prior to the SAE-A competition, and is a component of the Design Event. his report must be in the format specified by FSAE. (ref: Rule 4.5) This report was compiled by myself with some input from the other members of USQ FSAE team.

Chapter 7

Information Management

7.1 Chapter Overview

One of the recommendations that has been listed previously has been to effectively transfer work and knowledge from year to year within the formula SAE team. This is also essential should any member of the team be incapable of completing their work at any stage, and to have an effective record keeping practice in place for future teams.

During the course of the management of the team, information management has consumed considerable time, and has become an essential part of the project.

This chapter will cover the methods and measures put in place to deal with such information, along with what information was stored.

7.2 Information Control

Before any information could be stored, a few decisions had to be undertaken, those being:

1. What information to store.
2. Where to store such information.
3. Who has access to the information.

This decision making process was done without consultation with the existing 2006 team, but largely a collaborative effort between Chris Snook and myself.

7.3 What Information to Store

The formula SAE team has many facets to it, and as such it was easier to break down the information down into various categories which would then be self explanatory to future team members.

1. Design
2. Construction
3. Track Testing
4. Sponsorship
5. Previous Results
6. Formula SAE Rules
7. Meeting Minutes
8. Competition Documentation

These represent the main categories, however there will be many sub headings within these.

7.4 Where to Store Information

Such information is generated in either paper or electronic form. It was decided to set the CAD design lab (Z308) up as the USQ Motorsport office as well, as it had several features that suited this purpose:

1. Number of computer terminals that can be used to design and analyse components, together with the appropriate modeling and analysis software available.
2. An area where a cupboard and filing cabinet can be situated.
3. Direct access to a drive on the USQ server wholly dedicated to the Motorsport team.

In setting this area up, record keeping is much easier, more user friendly, and by keeping all information on campus and in one place it makes for easy transference of such information.

With a greater presence of USQ Motorsport doing their design work in this room, it has raised awareness of USQ Motorsport amongst other students in the faculty, which will hopefully translate into students who are keen to get involved in future years.

7.5 Access Permissions

There is a real danger should too many people have access to this information, as it can be easily tampered with, destroyed or inadvertently altered. Equally so it is vitally important that enough people can access this information.

It was decided this year, that there would be 2 levels of access:

1. Full Access. No restrictions placed upon the user. The faculty advisor, and the student design team to have such privileges. Other students may be granted this upon the discretion of the faculty advisor.

2. Limited Access. Generally this means those with access to the USQ portal. This means they will have read only permission.

Having a limited number of users who can write to this drive means that control is easier to administer.

7.6 Results of Database Implementation

With this implementation, several major improvements have been achieved:

1. The majority design work was carried out on campus, and as a result a record is kept of every part that has been created on the car. There were still some problems with people designing components off campus, however this was a major improvement on previous years.
2. A working 3d model of the entire car. This enables design work to be carried out without the need to make assumptions based upon other peoples design work.
3. With such a model minor changes can be carried out on any part, and checked to see their interaction with other parts after alteration prior to construction.
4. Incoming students can easily view and alter the previous years car during the design process. this means the majority of the design process is done, and all that is required is a refinement of such a design.
5. Any parts not being modified for the next year can be sent to the workshop much earlier for construction. Previous years competition documentation is also stored to assist in future competitions.

One of the largest hurdles to overcome this year was the total design time as there were no records from previous years. With this database now in operation, such design will reduce months off the design time for next year.

The implementation of the database and it's workings are perhaps the single greatest achievement of the FSAE team this year. Incoming FSAE teams will have a huge

head start when compared to previous years. In the future there may be a necessity to "lock" some aspects of CAD models to ensure students don't undo things they shouldn't. A team member for 2007 has been tasked with investigations and the main software supplier "Leap Australia Pty Ltd" has offered to help USQ integrate "ANSYS Workbench" and "Wildfire".

The full effect of the database will not be know until 2007, but I have written many introduction documents to each subsection in the database. This is designed to facilitate handover to the incoming manager for 2007. It is also my intention to have a formal handover (along with an in depth handover document) to the new manager (as what would happen in any workplace) to further ensure a smooth transition in 2007.

Chapter 8

Conclusions and Further Work

8.1 Achievement of Project Objectives

The following objectives have been addressed:

1. Analysis of 2005 FSAE entry.
2. Recommendations based upon 2005 performance.
3. Team structure was put into place, but not as successful as hoped. Structure is in place, but will require assistance from faculty staff to implement and administer.
4. Electronic database was set up to ensure transference of information to incoming FSAE team members.
5. Timelines were constructed, but again were not as successful as hoped.
6. Overall management of the FSAE Team during 2006.
7. Implementation of some of the recommendations made.

8.1.1 Other Achievements

Several other notable projects were completed on the FSAE entry for 2006 in my capacity as default Technical Director. These include:

1. Rebuilding of the engine after it was overheated and inoperable after the 2005 competition.
2. Design, construction and fitment of fuel injection system, and subsequent tuning of.
3. Design of frontal impact attenuator.
4. Design of braking system. Documentation is in separate appendix document "Braking System FSAE-2006 .PDF"
5. Role in design work of chassis.

8.2 Observations During the Project

During the course of this project, there has been several observations made:

1. The entry for this year was primarily the work of 4 students. There were other students who helped a little, but appeared less than enthusiastic, and had other priorities. From talking to other people, this has been the trend every year. This however drastically overloads the students to such an extent, that other subjects suffer dramatically. The challenge exists for the faculty to find ways to make the FSAE scheme more enticing, and for project students to better engage the junior students in achievable activities with positive outcomes.
2. Late design work has perhaps hampered the team more than any one problem this year. The team must begin design work well in advance of the start of the first semester of the year, along with concentrating on 3 or 4 major design changes each year. Trying to redesign a car each year does not work. USQ Motorsport needs to adopt an evolutionary process.
3. As manager I found myself totally overloaded with work. Not only was I managing, but chasing sponsorship, fundraising, designing and building the car. This workload has meant that I personally felt that I did not do my job as well as what I could have. In attempting to delegate I found it was easier to complete that job myself, as some team members found it difficult to adhere to a deadline. Having said that, there were also several team members who were exceptional in their ability to handle such work.
4. Lack of communication between some students. Some team members were very tardy in replying to emails, or even completing jobs.

8.3 Recommendations

There are some further recommendations I will make in regards to USQ Motorsport team, and it's potential:

1. Further student exposure to FSAE in some assignment work (as done in MEC3302 and MEC3303) and earlier in their program. The university should use the FSAE competition as an extremely valuable teaching tool, and integrate it into some subjects. Students will get a far greater appreciation of the engineering process by doing something, rather than simply learning equations, and doing nothing with them.
2. Appoint Technical Director and lock in main design for 2007 in December 2006.
3. Consider training seminars for new team members.
4. Start sponsorship and budgeting efforts in December.
5. Get more potential team members to the FSAE-A competition the year before.
6. Continue to develop the established electronic database and electronic design office.

8.4 Conclusions

There can be no doubt as to how valuable becoming involved in something such as the Formula SAE competition. Students are exposed to a wide range to skills that simply cannot be taught in the classroom.

As such it is recommended that the University of Southern Queensland do everything in it's power to encourage students to become involved. With such a powerful teaching tool at it's disposal, it has the potential to not only enhance the learning experience, but produce top quality students who are very much in demand by the private sector.

Irrespective of the 2006 competition outcomes, the advancements and improvements that have been achieved this year, means that the incoming team for 2007 are way ahead of where we were at the same time.

It is hoped that the 2007 performance will eclipse that of 2006, and that such measures that have been implemented, along with suggestions already given (if they are implemented) will greatly enhance and improve the team.

There are some dedicated students from 2006 who will undoubtedly be back for 2007. It would give me no greater pleasure to see them grow and learn from their involvement, and as such develop into world class engineers.

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Appendix A

Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 Research Project PROJECT SPECIFICATION

FOR: **Barton James Smith**

TOPIC: System design for the USQ Formula-SAE race car

SUPERVISORS: Chris Snook

SPONSORSHIP: Faculty of Engineering and Surveying

PROJECT AIM: This project aims to provide a managerial structure that will ensure future success of the University of Southern Queensland's Formula-SAE entry.

1. Critically evaluate the results of University of Southern Queensland's entry in the Formula-SAE 2005 competition.
2. Determine improvements that can be made, based upon previous results.
3. Manage the 2006 FSAE entry for USQ to ensure compliance to the rules and effectively manage the team as a whole.

4. Develop information management to guarantee successful transference of information to the 2007 team.
5. Construct timelines for all associated activities during management, design and construction phases for the 2006 car
6. Oversee integration of designs in the whole car and control/set specifications.
7. Undertake technical design and construction activities as necessary.

As time permits:

1. Implementation of above systems to 2006 Formula-SAE team
2. Management of 2006 Formula-SAE team during the design, construction and competition phases.

AGREED: (student) (Supervisor)

(dated) / /

Appendix B

Work and Hours Performed on FSAE Car

Many extra hours of work have been performed on the F-SAE car, that is not directly related to this thesis. Apart from being the manager of the team, I also spent many hours chasing sponsors, performing mechanical work, etc which is terribly hard to document.

Therefore I shall list individual jobs, along with the time spent (in hours) on each. It would be simply too exhaustive and unnecessary to list the actual events on a day to day basis. Thus this list represents.

B.1 Work Performed

Table B.1: Formula SAE-A Work

Job Performed	Hours
Rebuild Engine	32
Chassis design	13.5
Sponsor Chasing	48
IE Aust Promotion Events	18
Braking System Design	16
Display at Toowoomba Airport	9
Parts Ordering	5
Design of Inlet Manifold	16.5
Design of Fuel Injection System	24
Fitment of Fuel Injection	80
General Workshop Duties	120
General Meetings	8
Fundraising	8
Science and Engineering Challenge	12
Research for Dissertation	80
Write up Dissertation	40
Repair Clutch System	5
Design and testing of Impact Attenuator	32
Design Report	16
Competition Documentation	6
Cost Report	80
Construction of Car	80
Total Hours	749

Appendix C

Sponsors of USQ Motorsport 2006

C.1 Introduction to this Appendix

This appendix lists sponsors, and their commitment to USQ Motorsport for 2006. It also lists important information such as contact details, etc.

Sponsors Name: Bluescope Steel

Contact Name: John Szalla or Clare Hathway

Phone Number: 02 42753941 (Clare)

Email: John.Szalla@bluescopesteel.com

Website: www.bluescopesteel.com.au

What They Offer: Sheet Steel

Sponsors Name: Orrcon Steel

Contact Name: David Luckeraft

Phone Number: 07 3274 0525 Mobile: 0418 755 743

Email: d.luckeraft@orrcon.com.au

Website: www.orrcon.com.au

What They Offer: Pipe Steel

David was good, got the stuff pretty quick.

Sponsors Name: Linear Bearings

Contact Name: Martin Corcoran

Phone Number: (07) 3274 3388

Email: mcorcoran@linearbearings.com.au

Website: <http://www.linearbearings.com.au>

What They Offer: Bearings, rod ends

Martin is good. Has looked after us before. Look after him.

Sponsors Name: Umbrako

Contact Name: David Adams

Phone Number:

Email: dadams@unbrako.com.au

Website: www.umbrako.com.au

What They Offer: Fastners.

Sponsors Name: Brakeland

Contact Name: Glen Krog

Phone Number: (07) 46322788

Email:

Website:

What They Offer: brake master cylinders, pipes, hoses, technical assistance.

Sponsors Name: Independent Motorcycle Wreckers

Contact Name: Warren Platz

Phone Number: (07) 46321848

Email:

Website:

What They Offer: Warren has helped with various bits and pieces of wrecks for free.

Sponsors Name: Linear Graphics

Contact Name:

Phone Number:

Email:

Website:

What They Offer:

Sponsors Name: Buchanan Advanced Composites

Contact Name: Norm Watt

Phone Number: (07) 4633 1856

Email: bac@bac.net.au

Website: <http://www.bac.net.au/mainindex.htm>

What They Offer: Help in constructing the bodywork.. Must have the solid model files in IGES format, and will then create the plugs from that. We must supply the labour.

Sponsors Name: Adaptronic

Contact Name: Andy Wyatt

Phone Number:

Email:

Website: <http://www.adaptronic.com.au/>

What They Offer: ECU and fuel injection technical assistance.

Sponsors Name: Toowoomba Local Group, Engineers Australia

Contact Name:

Phone Number:

Email:

Website: Toowoomba Local Group, Engineers Australia

What They Offer: Cash 1000

Sponsors Name: Garden City Event Hire

Contact Name: Gary

Phone Number:

Email: gary@gardencityhire.com.au

Website: <http://www.gardencityhire.com.au>

What They Offer: Cash: 250

Nice person to deal with. Gary has helped us before.

Sponsors Name: Aerotec Qld Ltd

Contact Name: Lynette Zuccoli

Phone Number: 4633 1315

Email: aerotec@bigpond.com

Website: <http://www.aerotec.com.au/index.html>

What They Offer: 250

Sponsors Name: Grand Central shopping centre

Contact Name: Kym Ebenestelli

Phone Number: 46325866

Email: k.ebenestelli@gc.qic.com

Website: <http://www.grandcentralshopping.com.au/>

What They Offer: 100 shopping voucher. I tried to get a 500 voucher for the major prize of the raffle. They said that was not possible, but more than keen for a 100 one.

Sponsors Name: The USQ Works Health and Recreation club

Contact Name:

Phone Number:

Email:

Website:

What They Offer: A 6 month membership, and a 3 month membership to the gym. The manager was very helpful, easy to deal with and approach. These were used as prizes for the raffle.

Sponsors Name: The Portrait Place

Contact Name:

Phone Number:

Email:

Website: <http://www.photocorp.com.au/australia.asp>

What They Offer: 2 free photographic sessions. Includes 1 free 8 x 10 photo. Cost about 255 each. Used for prizes in raffle.

I approached the manager there and she organised the prizes. Very helpful and nice.

Store is inside Myer, top floor.

Sponsors Name: Skelta Racecars

Contact Name: Ray Vandersee

Phone Number:

Email:

Website: <http://www.skelta.com.au/>

What They Offer: Ray donated the seat.

Nice guy to talk to. He didn't seem to offer much more, but perhaps more may be on offer next year.

.

Sponsors Name: USQ Works

Contact Name: Shane McNeil

Phone Number: (07) 4631 1588

Email: mcneils@usq.edu.au

Website: <http://www.studentguild.com.au/DisplayPage.asp?pageid=285>

What They Offer: Donated a 6 month and 3 month membership for the raffle. Really easy guy to deal with. No doubt he will help us next year if we look after him.