College of Engineering, Science and Environment

School of Engineering

Mechanical Engineering Project B

Semester 2 - 2024 MECH4841 A

FINAL YEAR PROJECT

PROJECT TITLE

Chief Mechanical Engineer, Vehicle Dynamics, Cost, and Tech Inspection

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2024 Chief Mechanical Engineer, Vehicle Dynamics, Cost Event, and Technical Inspection

DESIGN REPORT

NU 24

Lachlan Fisher

2024

Abstract

NU Racing is the Formula SAE team from the University of Newcastle. NU 24, an electric vehicle, was designed and built to race in Calder Park in December 2024. The vehicle is designed and driven by engineering students.

Building on the resources of an impressive 2023 team, NU Racing aimed to build a sub-250 kg vehicle with 755 Nm of wheel torque with aims of taking home a podium. It was the first year of a ‘build first, design second’ philosophy where the previous year’s team designs larger systems and leave them ready for manufacturing before the new team overlooks the manufacture prior to undertaking their own design.

NU Racing achieved 4th overall in the FSAE-A competition, which ranks them 12th in the world.

The Chief Mechanical Engineer was required to manage a department of Mechanical Engineers and employ project management skills to ensure deadlines and goals were met. The implementation of drawing reviews accompanied design reviews in a fully developed Mechanical Design Process. This also included the manufacture of the Drivetrain, Pedal Box, and Steering.

Alongside the role of Chief Mechanical Engineer, the author was the Vehicle Dynamics Engineer, responsible for creating a balanced suspension setup suitable for four different driving events.

The Cost Event is one of three static events at competition, aimed to challenge students to accurately cost the manufacture a prototype of a FSAE EV, complete live costing events, and present a cost scenario to limit 5% of costs without losing 1% of performance. The Cost Event

Lead is vital to the management of resources and the overall score of the event. NU Racing scored 75.55 points of an available 100, the most in their history.

Technical Inspection is vital to ensure compliance and safety during the weekend. Due to mock inspections and thorough preparation, NU 24 passed Mechanical Inspection upon first attempt.

Declaration

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Student name: Lachlan Fisher

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Summary of Contributions

- Chief Mechanical Engineer
    - Created and utilised a framework for the management of the Mechanical Department
    - Design Reviews
    - Drawing Reviews
    - Assisted with the design of every mechanical system
- Manufacturing
    - Led all manufacturing
    - Consultation with the Prototyping Workshop
    - Consultation and ordering from external workshops
- NU 24 Mechanical Design and Manufacture
    - Steering
    - Drivetrain
    - Pedal Box
    - Head Restraint
    - Chassis
- Coordinated 2024 FSAE-A competition with the Leadership Team
- Vehicle Dynamics Engineer
    - Led physical testing and track days
    - Designed track layout to test suspension setups
    - Suspension set up and testing (spring rates, static camber, damper settings, etc)
- Competition and Test Driver
    - Endurance and Skid Pad driver at competition
    - Driver training in the backend of the year

- Cost Event Lead
  - Delegated all tasks in the Cost Report
  - Costed 69 parts and assemblies
  - Organised drawings and datasheets
  - Finalised the submission
  - Organised and completed the Cost Scenario
  - Completed the Cost Task at competition
- Tech Inspection Lead alongside Chief Mechatronic Engineer
  - Organised and completed Mock Inspections
  - Delegated Technical Inspection Tasks
  - Led Mechanical Inspection at competition that passed 1st try

Acknowledgements

I would like to firstly acknowledge the NU Racing team of 2024. Your hard work and passion for the project that brought us all so much pain and happiness never ceased to amaze me. We should all be incredibly proud of what we were able to produce in such a demanding year. I love you all.

I extend my thanks to the NU Racing team of 2023. Without your ingenuity and setting such a strong foundation for NU 24, we would not have been able to accomplish such great results.

I want to thank Dr Dylan Cuskelly for being brought in at the start of the year and immediately showing so much passion for the entirety of NU Teams. This was especially impactful at competition, and we were beyond lucky to have you.

I would like to thank Malcolm Sidney for being such a cool, calm, and collected source of reason and knowledge. Your continued assistance and dedication to the team is unparalleled and we are beyond lucky to have you.

To the Prototyping Workshop, especially Lachlan Barrell, Dave Dobson, and Michelle Hutton. Lachlan, for consistently not answering my phone calls but always wanting to assist in any capacity whatsoever. It is very clear that NU Racing never left your heart. Dave and Michelle, for putting up with me asking constant questions and being available to talk about manufacture or design at any time. The year would not have been how it was without you two.

Professor Bill McBride, thank you for taking my meetings and listening to me ramble. Your guidance and knowledge helped me develop more than you'll know.

Lastly and most importantly, to my partner Holly. Words cannot describe the support you provided me this year. The continuous admiration and celebration you threw towards me was beyond compare and you continue to make me luckier than I deserve.

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Introduction

Formula SAE Australasia (FSAE-A) is a yearly competition where students from various universities across Australasia design, build, and race their own open-wheel style car. There are three categories in the competition: Electric Vehicle (EV), Autonomous Vehicle (AV), and Internal Combustion (IC). In the last ten years there has been a transition where most universities are now competing in the EV competition over the IC competition and each year more are competing in the AV competition as well. The University of Newcastle has competed in the FSAE-A EV competition since 2019 under the team NU Racing. The team was able to design and take their competition platform, NU 24, to Calder Park in Melbourne and achieve 4th overall in the competition.

2024 was a new shift for NU Racing as it is the first year that a build first philosophy has been implemented. This means that the 2024 team began the year by manufacturing systems designed by the 2023 team. This shift allowed each team member to gain a deeper appreciation and understanding of their system through overseeing the manufacture. This meant that when designing the new system that the team member has more context of the system and is aware of the challenges of manufacture and commissioning.

The author began 2024 as the Vehicle Dynamics Engineer. Each Final Year Project (FYP) student begins their semester in NU Racing with a starter project. The author was given the Steering System, designed by Drew Bender [1]. This design was complete, however required design changes. As the first time the build first philosophy has been used it was anticipated that there would be many overlooked sections of systems.

On 25/3/24 the author accepted the role of Chief Mechanical Engineer for NU Racing for 2024. This included a change in scope that included responsibility for overlooking of manufacture, design review of all mechanical systems, and coordinating timelines throughout the year. This was a large change in scope as it meant the author was required to thoroughly understand each sub-system of NU 24 in a short period of time. Despite the change in scope the responsibility of Vehicle Dynamics was kept. Creating a balanced suspension setup for the entire competition was undertaken primarily by physical testing. This included gathering lap times and driver feedback for every setup change.

As Chief Mechanical Engineer the author had inputs into every mechanical system, with extended inputs on the Suspension and Drivetrain. These inputs were in the form of advice and design reviews, usually centred around the manufacturability and feasibility of parts in a system. This also included a strong relationship with the Prototyping Workshop and external partners to discuss designs, manufacturing processes, and oversee the manufacture of each system.

Once the manufacturing load began to diminish on the team, it was known resources would need to be assigned to the Cost Event. Due to limited team size, among other contributing factors, it was decided that the Chief Engineers, the author and the Chief Mechatronic Engineer Alec Chapman, would be responsible for filling the Bill of Materials (BOM) for the Cost Report. The Cost Report is predominantly mechanical focused; therefore, the author had an initial extensive role. Following the early phase of the Cost Report it was clear that the NU Racing had limited members with the required attributes to excel, restricted further by workloads that were on the critical path. Following this the author became the Cost Event Lead and was responsible for assisting members of the team with costings associated components, allocating team members to systems, and the overall Cost Report including approving every completed part and assembly.

Technical Inspection is arguably the most important part of the FSAE Competition. It is required for all vehicles to pass scrutineering before they can enter the Dynamics Events. There are seven inspections: Accumulator, EV Static, EV Functional, Mechanical, Egress, Tilt Test, and the Brake Test. NU Racing has previously been extremely successful through Technical Inspections through thorough rehearsal and preparation. 2024 was no different. Again, the Chief Engineer's took the lead for the rehearsal and preparation of the inspections. The Chief Mechatronic Engineer, Alec Chapman, was responsible for Accumulator, EV Static, and EV Functional. The author was responsible for Mechanical, Egress, Brake Test, and the Tilt Test. All Technical Inspections were passed before the first Dynamic Event at Competition.

DESIGN REPORT

NU 24

Chief Mechanical Engineer

Lachlan Fisher

2024

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1. Introduction

NU Racing has held a similar leadership structure for its last few years. This is shown in Figure 1. The team is fronted by a Team Leader, responsible for a large number of administrative tasks, as well as holding team meetings, managing team moral and conflicts. The rest of the leadership team is comprised of the Lead Engineers. The Chief Engineer is responsible for the future direction and development of the vehicle. They lead optimisation and identify issues to increase performance of both the team and the vehicle. The Chief Mechatronic Engineer and Chief Mechanical Engineer both share similar responsibilities. They manage their respective teams, provide assistance to their engineers, develop timelines and scopes with the leadership team, and review and approve designs.

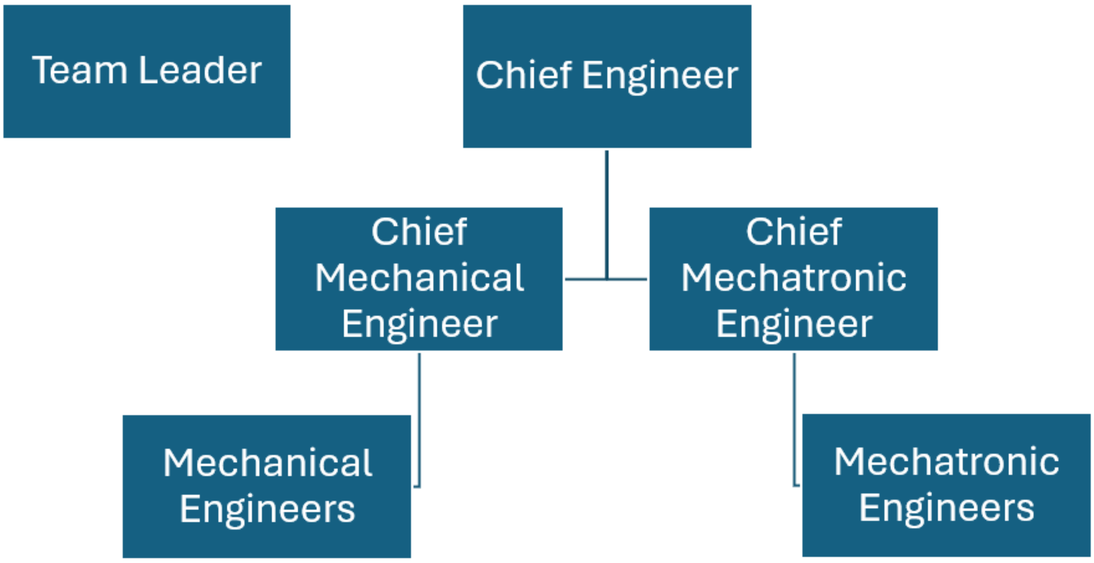


Figure 1. NU Racing Organisational Chart

In 2024 the Team Leader was Timothy Kerr. The Chief Engineer was Joshua Wenham. The Chief Mechanical Engineer was the author. The Chief Mechatronic Engineer was Alec Chapman.

The author did not begin the year in the role and instead was only the Vehicle Dynamics Engineer. Prior to this, the intention was that the Chief Engineer, Joshua Wenham, would handle the management of the Mechanical Engineers alongside his other duties. This quickly proved to be too large a workload for one person and the leadership team made the decision to promote the author into the role. Due to the late implementation of the role, it meant the author was not involved when deciding the scope and goals of NU 24, nor the initial design phases such as the finalisation and purchase of the Chassis.

The author accepted the role of Chief Mechanical Engineer on 25/3/24 and had a very short turnaround to thoroughly understand every system on the vehicle. Initially there was some reliance on the Chief Engineer to assist, however after reading previous FYP reports and heavily conversing with each Mechanical Engineer to understand their current project and scope the author was able to quickly upskill.

2. Role of the Chief Mechanical Engineer

2.1. Role

The role of the Chief Mechanical Engineer is multi-faceted and requires the engineer to have a broad skillset as it relies on not only the engineering skill, but largely also on people management, and time management.

The largest role of the Chief Mechanical Engineer is the control of the design process and management of the Mechanical Department. The responsibilities include, but are not limited to the following:

- Scoping of Mechanical tasks
- Project management of the Mechanical Department
- Design reviews
- Drawing reviews
- Managing all manufacturing tasks
- Ensuring integration between systems
- Testing setups and experiments
- Budget
- Design compliance and Technical Inspection

2.2. Previous Chief Mechanical Engineer's

The two previous Chief Mechanical Engineers were Jye Hollier in 2023 and Liam O'Neil in 2024. For the engineer set to take up the role in 2025 I heavily suggest reading their reports.

Hollier and O'Neil both had extensive roles in their respective teams. Both were responsible for the Chassis, Powertrain, and Pedal Box in their respective years [2], [3]. There other main responsibilities were to ensure that each Mechanical system was designed and manufactured to suit their goals for each iteration of NU Racing's platform, NU 23 (2023) and EV.Three (2022).

3. 2023 Goals and Performance

The goals of the NU Racing in 2023 were as follows [3], [4]:

- Aligning bottlenecks
- Simple self-documenting systems
- Reduced part count
- Reduce manufacturing load
- Prioritising long term performance

NU Racing performed well at competition in 2023 despite NU23 failing during Endurance. The team were able to achieve 7th overall highlighted by 2nd in Skidpad, 2nd in Autocross, and 2nd in Business.

During the second half of Endurance the car stopped and as a result the team did not gain the projected 200 points from the event [3]. Despite this it was very clear that the philosophy of NU 23 worked, as the team was able to show dynamically that it had the 2nd fastest car in the field.

4. Scope and Goals of NU 24

The known shortcomings of the 2023 platform were quite easily selected by the 2023 team to be the weight of the vehicle, weighing in at 265 kg at competition, and the lack of output torque from the drivetrain. These issues were transferred to achievable goals for the 2024 team.

The list of goals for NU 24 are listed below:

- Simple self-documenting systems
- Increase serviceability
- Increase manufacturability
- Reduce weight by 25 kg
- Prioritise long term team performance
- Tend to evolve previous designs over mass redesign
- Traction limited EV

Each of these goals were scoped at the start of the year, tied alongside achievable deliverables for each goal.

It should be noted that redesign of parts and systems can often be required before mass performance gains can be realised. However, mass design changes can often create bottlenecks in the manufacturing process in the lead up to a driving electric vehicle (EV). Therefore, these changes should be done in parallel to the critical path to avoid delays to valuable training and testing time. These large charges should be utilised in the year after their development.

Namely to reduce weight, changes to the Accumulator, Steering, Chassis, and Drivetrain were all designed and manufactured. The changes are listed in Table 1 and explained in Overview of Subsystems.

Table 1. Large changes from NU 23 to NU 24

System	*2023*	*2024*	*Δ Weight (kg)*
Chassis	Similar to the 2022 Chassis. 4130N Chromoly Steel CHS. 77 Chassis members	Large changes. Use of SHS for SIS, EVP, and FBHS members to decrease mass per length of material and increase stiffness. 67 Chassis members	-12.56
Accumulator	Steel Accumulator Container	Aluminium Container	-6.35
Steering	8 Parts in Steering Wheel Shaft assembly. Steel shaft to Steering Rack	5 parts in Steering Wheel Shaft assembly. Aluminium shaft to Steering Rack	-1.01
Drivetrain	188 Emrax Motor (7 kg), 3 Aluminium plates for supports, chain tensioner	228 Emrax Motor (12.3 kg), 2 Aluminium Plates, no chain tensioner	0.61
Total			**-19.31**

To address the lack of output torque from NU 23, the solution from the 2023 team was to increase motor size from the Emrax 188, which is capable of 100 Nm and 60 kW, to the Emrax 228, which is capable of 230 Nm and 124 kW [5], [6]. It should be noted that the FSAE Rules dictate that no drivetrain can have an output greater than 80 kW, as per EV.3.3.1 [7]. This increase in motor size meant that the NU 24 had a motor that can match the maximum power dictated by the rules.

5. Management of Mechanical Engineer’s

The largest role of the Chief Mechanical Engineer is to manage the Mechanical Engineers and ensure that they are completing their tasks. The most important of these are the design and manufacture of their systems.

5.1. Commitment and Contribution

Engineers are managed differently depending on their commitment to the team.

Final Year Project Engineers make up the largest part of the workforce and due to this are given the most opportunities and expected to contribute the most. These engineers are generally handed entire systems to design and manufacture and are vital to building a competitive vehicle. FYP’s are given deadlines and deliverables for tasks delegated by the Chief Mechanical Engineer.

Directed Reading Engineers, as they get course credit for their contributions, are below the FYP’s and are often handed smaller sub-systems. They are still expected to have noticeable contributions to the team. They also are given deadlines and deliverables as the FYP’s are.

Extra-Curricular Engineers are different to both FYP’s and Directed Readings in the management style required for them. Any commitment they make to the team is decided between the student and the Leadership Team. As they have no course credit, how much they want to contribute is purely up to the student and sometimes limited by the Leadership Team. As they have no real responsibility, care must be taken not to delegate too much work to them without a real level of trust. There is no incentive for them, such as course credit, to complete tasks or continue to contribute. The risk of the student disappearing and not continuing to engage with the team is often large.

5.2. Project Management Tools

Different project management tools are required to be used by the Chief Mechanical Engineer to ensure the Mechanical Team is always completing tasks on time and to a high standard.

These tools were not well established at the beginning of 2024, so many of these are first generation formats and examples that could be improved. It is suggested that all of these are re-used or evolve for 2025.

5.2.1. Gantt Charts

Gantt Charts are incredibly effective in planning the workload for NU Racing. It allows to illustrate where each engineer and the team as a whole is experiencing peak and low workload periods.

Gantt Charts were most useful for in 2024 for drawing out the critical path for different systems, especially throughout the manufacturing period. An example of a Gantt Chart is shown in Figure 2.

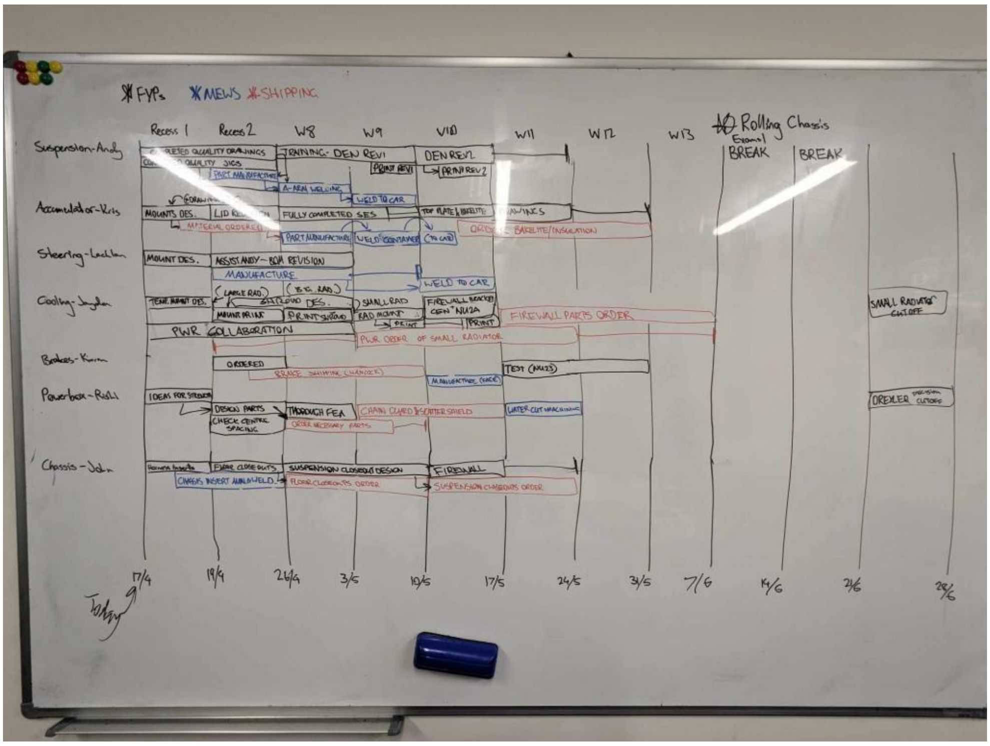


Figure 2. Gantt Chart from 2024

Gantt Charts were made by the Leadership Team on a whiteboard during weekly meetings. This was effective as it allowed both the Mechanical and Mechatronic timelines to be drawn together to see where resources are being utilised and where they can be shifted.

When creating a Gantt Chart a few questions should be considered. A few are listed below:

- Is this timeline realistic?
    - How do you know?
- Have you completed a similar activity before?
    - Have you asked someone who has?
- Can the Prototyping Workshop perform this task at this time?
- How much float is assigned to this task?
- What tasks are on the critical path?
    - What tasks will be delayed if this task isn't complete?
    - What tasks can run in parallel without affecting the critical path?

- What are the deliverables of each task?
    - What can they show at the end to show the work is finished?
- Are the required people for each task free currently?
    - Do they have a large number of other tasks?
- What tasks have the highest risk?
- How will they affect the timeline?
- What contingency plan is there?

These questions, whilst not mandatory to ask, can assist in seeing weaknesses or issues in timelines that can often lead to delays or large issues.

5.2.1.1. Recommendations

Whilst Gantt Charts worked very well in 2024 there are improvements that could be made.

Making the Gantt Charts digitally would be an easy improvement. When creating Gantt Charts the physical drawing scale of the timeline greatly influences the perspective of the team as to how many tasks there are and how much time they have to complete them. Digitalising the chart also has the benefit of being able to quickly make changes or to simulate different timelines to see how different tasks affect the timeline. Software such as Project Libre, a free open-source software, should be used as it is simple and easy to use.

Instead of going in Leadership Meetings blind, the Chief Mechanical Engineer should make an effort to make and maintain their own Gantt Chart in conjunction with the Chief Mechatronic Engineer. This will allow them to make changes on the fly easily, convey details with their team easily, and go into Leadership Meetings planned, concisely deliver information, and reduce meeting time.

5.2.2. Task Lists

It became clear immediately once taking over the role of Chief Mechanical Engineer that there was not a solid framework or template for communicating due dates and deliverables to each engineer. The author, admittedly later in the year than optimal, developed a Task List spreadsheet for the tasks for Technical Inspection preparation. Upon realising the usefulness of the spreadsheet, it was immediately used for delegating tasks for the remainder of the year. An example of a Task List is shown in Figure 3.

Tasks - Jayden

Date Revised: 29/10/24

System	Task	Priority	Assignee	Deliverable	Due Date	Complete?
Cooling	Finalise Catch Can mount	High	Jayden	Finalised design and CAD	31/10/2024	Yes
Cooling	Final drawings for catch can weldment	Medium	Jayden	Drawings submitted for review	1/11/2024	No
Cooling	Design mounts to make the new radiator fit NU 24	High	Jayden	Designed mounts for the new radiator	6/11/2024	Yes
Cooling	Put in a PO for new cooling hoses (replacements for what is on the car + spare)	High	Jayden	New hoses ordered for comp	8/11/2024	No
Cooling	Drawings for the new radiator mounts	Medium	Jayden	Drawings submitted for review	9/11/2024	Yes
Cooling	Alter the position of the pumps to go over rear suspension pickups	Low	Jayden	New pump position	9/11/2024	N/A
Cooling	Design a potential coolant bleeding valve (will fill you in next time you're in TA, might be for NU 25 but would be nice for this year)	Low	Jayden	Design for a coolant bleed valve	13/11/2024	No

Figure 3. Task List Spreadsheet Example

The spreadsheet used Data Validation Lists to provide dropdowns for the System, Priority, Assignee, and Complete columns. This made filling out the spreadsheet faster and more consistent.

Each engineer managed by the author had their own sheet, within the same spreadsheet, to easily modify and show each engineer what their tasks were.

The author also added Conditional Formatting to the Priority and Complete tabs to make them a certain colour depending on the value of the cell. This was especially useful. It can be difficult to have an engineer read a whole table of information. Adding colours, especially to the Priority column, let them know what was and wasn't complete and how urgently it needed to be completed.

Having a deliverable section is highly recommended. It clearly states to the engineer what is required of them, and what they must show to prove the task is complete.

Adding filters to each column also allows to easily filter between what has and hasn't been completed, and what high priority tasks remain non-complete.

In 2024 Task Lists were delivered to the Team using Discord and taking a screenshot of their tasks. In 2025 the same approach could be taken, or instead the entire spreadsheet is shared with the team. However, when adding a new task it must be communicated to the responsible engineer. Therefore, the author found it easiest to simply communicate the Task List at the same time as the tasks.

5.2.2.1. Recommendations

A Task List, whether the one created by the author, or a modified version should be implemented for 2025. It positively impacted the communication ability of the author to the team and was instrumental in the latter half of the year when preparing for competition.

5.2.3. Remaining Manufacture Lists

The Remaining Manufacture List was another spreadsheet made by the author to list what parts or assemblies required manufacturing. This was broken down into systems and allowed the author to keep track of what was still to be designed or made before a system was complete. During the manufacturing part of the year this is vital to ensure no parts are forgotten or left too late. An example of the spreadsheet is shown in Figure 4.

		Powertrain						Date Revised	23/10/2024			
Part	**Priority**	**Due Date**	**Complete**	**Internal/External**	**Sent**	**Water / Laser Cutting**	**Manufacture**	**Jigs**	**Welding**	**Drawings Made**	**Notes**	**Date Updated**
New Motor Plate	High		No	Internal	Not sent	Required	Yes - General Manufacture	Not required	Not Required	Required	Pending plate from Calm	23/10/2024
Scatter Shield	High		No	External	Sent	Required	Yes - Bending	Not required	Required	Finished	Sent to Hancock	23/10/2024
Scatter Shield Tab	High		No	External	Sent	Required	Yes - Bending	Not required	Required	Finished	Sent to Hancock	23/10/2024
Chain Guard	High		No	External	Sent	Required	Yes - Bending	Not required	Not Required	Finished	Sent to Hancock	23/10/2024

Figure 4. Remaining Manufacture List Example

Especially when beginning the role as Chief Mechanical Engineer it can be quite difficult to have a good understanding of every part in every system and what is required to be manufactured. This list will assist in making Task Lists and ensuring that the Mechanical Department is aware of what parts are required to be manufactured.

The Remaining Manufacture List also has brief columns that describe what is required for each part, or what has been completed for each part. This includes if the part will be made internally, by the Prototyping Workshop, if it will be watercut or laser cut, if bending or welding is required, if jigs are required, and drawings have been made. This allows concise information to be kept and recorded in one place.

5.2.3.1. Recommendations

The creation of a Remaining Design List would have the same benefits as the Remaining Manufacture List. This should be made in the beginning of 2025 and used throughout the year.

The list is quite clunky and could quite easily be refined. The functionality is there, just lacking with respect to the visuals and the user-friendliness.

5.2.4. Communication Tools

Throughout 2024 Discord was used as the main communication tool for NU Racing. This can be incredibly effective as all the vital information is in one place. However, it does have its downsides.

Some students, namely those who haven't used Discord often, simply do not engage with messages if they are sent to them on the platform. There is little the Leadership Team can do besides asking them to enable their notifications for the platform.

Members of the team may need to be communicated to on a separate platform. This is not the ideal solution, however it should be noted that this often occurred in 2024.

Microsoft Teams is used to a lesser extent. The service is mostly used to store files and data. This becomes especially important between years and for Static Event such as the Cost and Design Event.

5.2.5. Diary

Keeping a daily diary is one of the easiest but important things any NU Teams engineer should be actively doing. An effective manager is always organised. A key way to do this is keep a diary of happenings throughout the day. The important benefit, besides reflection, is to have information, that can be so easily lost, readily available at any given time. With the loss of Project Hours in 2024, the author believes that there was a significant amount of information lost over the course of the year by each engineer and strongly urges everyone to keep a diary.

6. Mechanical Design Process

Following a Mechanical Design Process is vital to ensuring that parts and systems are being designed and manufactured following overall vehicle goals and specific system scopes. Changing parts or systems should always have data supporting their inclusion on the car, whether this is a performance gain or a serviceability increase.

6.1. Scope

A fully developed scope is vital to a successful design. A scope defines the goals, constraints, deliverables, resources, and timeline.

The goals of a design are often performance oriented and are decided following an evaluation of vehicle performance in previous competitions or testing. These evaluations highlight design flaws or areas for improvement for any parts or systems of the vehicle. When selecting goals, it is vital to converse with fellow engineers, for example the Leadership Team, for input.

Selecting overall vehicle goals is the responsibility of the Leadership Team, and perhaps the Leadership Team from the year previous. These are important for driving the direction of design and every part or system scope should be able to be traced to these goals.

When evaluating the performance of a vehicle it is essential that the car is evaluated as a whole, both positives and negatives. Failure to do so may lead to focus being placed on the negatives and the goals leaning away from the positive aspects of previous cars.

System specific goals are often derived from the overall goals. These are more thoroughly developed and specific. These are often measurable, such as shedding weight or size. There are times where they aren't easily measurable, such as making a system more maintainable.

It is important to clearly define the constraints of a design early. Examples of these can be the volume of space a system is allowed to occupy to accommodate other systems, restrictions from the FSAE Rules, and budget. Without a clear outline of constraints, designs can breakdown and become non-feasible quickly.

Deliverables are crucial throughout the design process to measure progression. These are things that can be shown or complete to highlight a completed phase of work. Examples of this include a 3D printed prototype, finalised CAD model, or finalised bill of materials (BOM).

Deliverables need to be assigned to tasks when managing engineers as a method of proving the progression of their work. With clearly defined deliverables, it makes it simple for them to show what they have done.

Resources need to be outlined to allow the engineer to know what limitations they have during the design and manufacturing process. The main resources that are spoken about are time, budget, manpower, and manufacturers.

Timelines are essential to managing specific projects within the timeline for the entire car. It is essential that the entire vehicle has a timeline with specific goals outlined, such as NU 25 running before June. With a goal like this the workload can be written into a timeline which is then used to manage progress of every system/part.

6.2. Initial Design

The Initial Design phase is where the Mechanical Department should be allowed to generate ideas. During this phase mainly the critical function of a system or part is considered. It is key that the scope is heavily referred to and kept in mind whilst making design choices.

The Chief Mechanical Engineer is responsible for being the link between all systems and engineers. They should heavily promote working together within the department to have designs complement each other. In the case where systems do not immediately interact with each other they must be able to ‘wear multiple hats’ and consider the integration of all systems.

It should be noted that even though this is a time for idea generation, the Chief Mechanical Engineer still offers assistance and guidance to their department.

Importantly, the Chief Mechanical Engineer must also be constantly reviewing the manufacturability and serviceability of designs. This means considering the assembly of given parts within the car and the space that tools can have to tighten or loosen fasteners.

6.3. Machinist Consultation

Once an initial design is complete, it is critical that the machinists at the Prototyping Workshop in EC are consulted. All parts must be manufactured and consulting with the people who have the skills to do this can save delays and headaches further down the line.

When designing a part, it is vital to consider how the part is manufactured. This makes conversing with the machinist easier and makes them appreciate your efforts to make their lives easier.

The machinist should be asked how they would make the part, if they can see any issues with the design that will make the part hard or impossible to make, if they have had experience making a similar part in previous years, and if a specific material is being used if they have machined it before.

The Prototyping Workshop is incredibly eager to assist at any time and should be consulted as often as possible. Conversing with them should not be a once off and should occur as often as possible or required.

Ensuring that the Mechanical Department is in regular contact with the workshop will reduce bottlenecks and delays in the overall timeline of the vehicle.

6.4. Validation

Validation of designs are required to ensure that designs fulfill their requirements. Methods of validation can differ from part to part. The most common types of validation are Finite Element Analysis (FEA), hand calculations, 3D Printed Prototypes, and practical testing.

Validation is arguably the most important part of the design process. Without this there can be no real certainty that a design satisfies its scope.

FEA is a useful tool to help understand stress distributions and deflection of a part. It is not something that can be rushed and care must be taken to correctly define the materials, contacts, mesh, supports, and loading conditions. Poorly defined FEA is useless and provides more issues than solutions.

Hand calculations can be used to validate FEA results and ensure that similar stresses can be calculated by both. Complex systems can often have load conditions that are difficult to calculate by hand. However, hand calculations should be done regardless. There can be a large discrepancy in the difference between FEA and hand calculations. This can be ok, if it is known why there is a large difference.

3D Printed prototypes are a simple way to verify that a designed part can complete its function. It is quick, consistent, and easy to repeat for design iterations. It allows easy checking of serviceability and clearances, as engineering students often struggle with clearances. This becomes especially useful when testing integration of parts. Bolting whole assemblies together, such as a suspension assembly, or printing brake rotors, is a great exercise to ensure there are no considerations that have been missed during the design process. Clearances for tools to assemble parts are often missed and 3D printing parts can highlight these issues. Every part, where appropriate, should be 3D printed and assembled.

6.5. Design Review

Following the design validation the Chief Mechanical Engineer and the design engineer undertake a design review. There is no strict guideline or review document that NU Racing uses. This should be developed throughout 2025.

A design review must check that the proposed design follows the scope and goals for the system and the vehicle overall. A scoping document can be used as a checklist when reviewing the design to ensure it meets the deliverables.

The design review considers the following for any part:

- Is it easily manufacturable?
    - If not, why? Does it have to be hard to make?
- Does it achieve its goals?
- Is it simple?
- Does it complete its critical functions?
- Is there sufficient clearance for tools to tighten / loosen fasteners?
- Does the validation make sense?
    - Is the FEA constrained properly?
    - Are the hand calculations correct?
    - Has the part been 3D printed and bolted together or to the car?
- Are there trivial elements to the design (serve no purpose)?
- Can it be made easier, or can this part be purchased?
    - For example, milling U-Channel from a steel block versus buying U-Channel

When conducting a design review the solution should be compared to previous iterations of the system. There should be a clear upgrade. If not, don't go ahead with its manufacture.

This is not an exhaustive list but are frequent questions that the author asked when reviewing systems and parts throughout 2025. More questions will be required, and the Chief Mechanical Engineer will grow confidence in the reviews as the year progresses.

It is critical if the Chief Mechanical Engineer decides at this stage in the design process that a redesign or design changes are required, that the logic behind the change is thoroughly explained to the design engineer. This will assist them in understanding the reasoning behind the change. If they understand this, they will be able to apply this same logic to their successive designs and make decisions in line with the scope and goals of the vehicle.

Specific design review items are recorded in 7. Design Reviews.

6.6. Internal Drawing Review

In 2023 and the beginning of 2024, drawings were created then immediately sent to the Prototyping Workshop to be reviewed by the Professional Engineer, Lachlan Barrell. This system did work, shown by how long it was the standard practise. The Engineering Drawing Checklist that was created by Lachlan Barrell with the intention that FYP students would check their drawings against the checklist. Following this the drawings would hopefully be close to complete, only needing approval before manufacture commenced.

The author quickly noticed in 2024 that the checklist was poorly utilised by NU Racing members and drawings were being sent to the Prototyping Workshop, far from a professional standard. The checklist is good, and should be used, however it does not guarantee that a drawing is clear and easily comprehendible. This is often due to students not understanding how to use views to convey information, poor general assembly and exploded view drawings, missing dimensions, and an overall lack of finesse.

Due to this, drawings would be sent to Lachlan Barrell, and due to his busy schedule, wait for review, before being sent back for silly mistakes. Time was wasted waiting for drawings to return annotated showing missing dimensions, views, and critical information. This was happening with every job NU Racing was trying to put through the workshop and was halting jobs often.

The author decided immediately to begin internal drawing reviews on every manufacturing drawing that NU Racing produced for the remainder of the year. This massively decreased the wait time that NU Racing incurred when placing jobs with the Prototyping Workshop.

The Chief Mechanical Engineer in 2025 should continue to review drawings before they are sent to the Prototyping Workshop. There is not a perfect method to review drawings. Using Engineering Drawing by AW Boundy and the Engineering Drawing Checklist as a basis is a good start. As the year builds reviews become easier, and issues tend to present themselves easier.

In 2024, to give clear and concise feedback, a pdf viewer, Foxit, was used to annotate drawings. An example of an annotated drawing is shown in Figure 5.

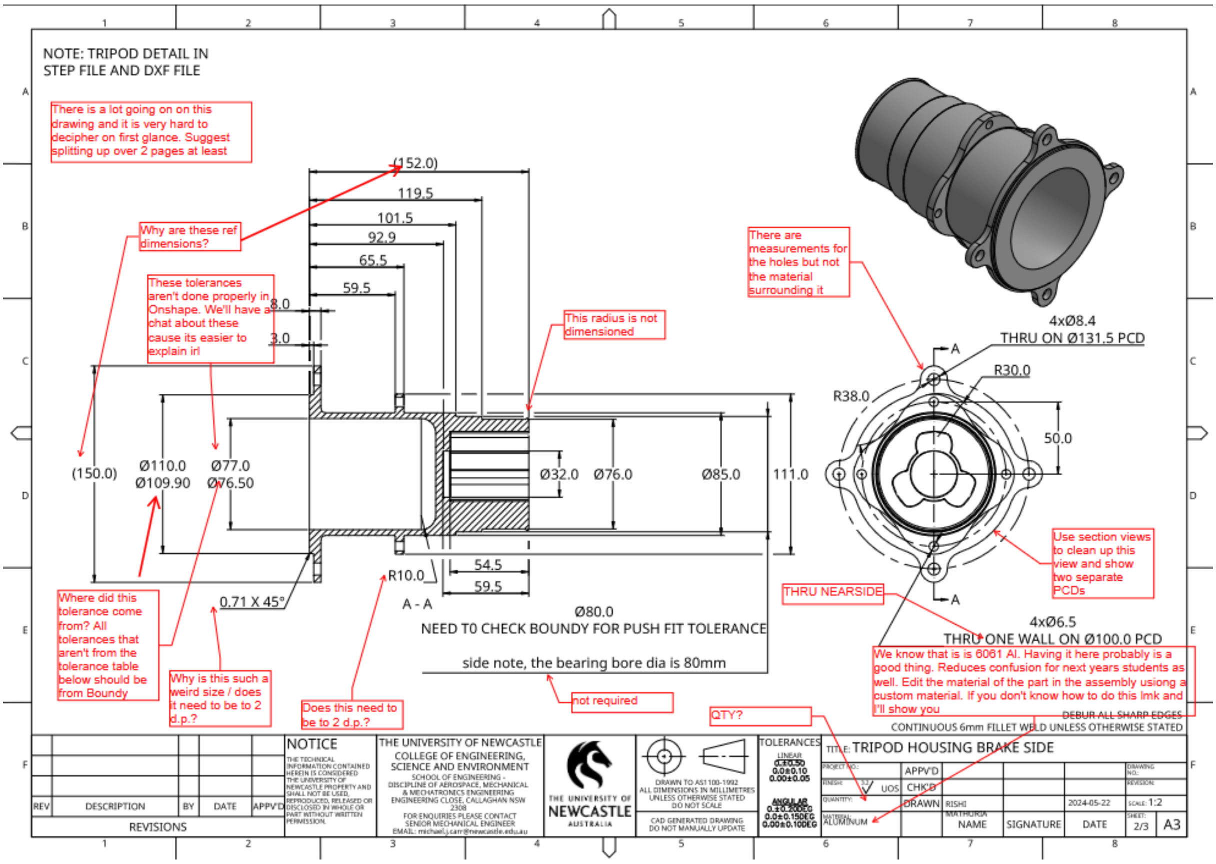


Figure 5. Example of an Annotated Drawing

Critical dimensions are often missed and not given enough respect. Critical dimensions are dimensions that define the function and performance of a part. If these dimensions are incorrect, it can drastically affect the intended function of the part. Bearing surfaces are a great example. If the tolerance of the bearing surface is not correct, the bearing may gain degrees of freedom that it was not designed to handle. Another good example is the internal walls of the Accumulator Container. If the tolerance allowed the internal walls to be too far apart, the segments would be allowed excess movement. If the tolerance allowed the internal walls to be to close, the segments would not fit in the container.

When reviewing a drawing, critical dimensions must be immediately identified and the correct tolerance applied to them to ensure that the part will function as intended. Caution must be used to not use tighter tolerances everywhere. This increases time the manufacturing time as machinists need time to get measurements within tighter tolerances.

Welding drawings are often the source of much confusion. The critical information a welding drawing needs to represent is the dimensions between the parts (such that every degree of freedom is fixed, like a CAD assembly) and the weld type and dimensions. Following this drawing notes can be incredibly useful to the machinist to understand how the parts can be orientated to weld.

Drawings are limitless and allow many ways to show the same information and it up to the engineers to decide the best dimensions and views to give to the machinists. However, consideration must go into how a machinist can measure these dimensions. There are times when this isn't clear. This is when the machinist should be consulted on what dimensions they want or require. Do note this can change machinist to machinist as it can be a personal preference how they attack manufacture, so keeping them informed throughout this process can ease the manufacturing period.

The author found the easiest way to conduct a drawing review was to annotate the drawing alone before then holding a meeting with the engineer responsible. This was important to then explain your logic for suggested changes. This was important as one of the biggest gains from drawing reviews, like the design review, is upskilling the Mechanical Department. If you can effectively explain your logic to them throughout the year, they will improve. With this the drawing reviews will become easier and quicker each time. You do need to invest time into each person to create a functional team member. It can be slow, but it will progress quickly and assist in the long term.

6.7. External Review

Once a design is cleared within the Mechanical Department, it is sent out to the manufacturer. Most commonly this is the Prototyping Workshop. This is where the design and the drawings are reviewed by the Professional Engineer.

During this period there is a lot of communication between the Chief Mechanical Engineer, the design engineer, and the workshop, mostly the Professional Engineer. This is often through meetings where design choices and drawings are conversed through and explained. During these meetings, it should be the design engineer and Chief Mechanical Engineer who maintain communication with the Prototyping Workshop. This is vital as any design changes can impact the rest of the car, and the Chief Mechanical Engineer needs to understand and be aware of this.

Manufacturers that aren't the Prototyping Workshop undergo a slightly different procedure. A meeting or initial consultation where a designed part is shown, and the feasibility of manufacture, costs, and lead time is discussed. Meetings can be organised to discuss potential design changes. The same as Prototyping Workshop, the Chief Mechanical Engineer and design engineer should both be in those meetings. Examples of these are Hancock Speedway and Newcastle Gears.

6.8. Manufacture

When manufacture begins it not the end of the design process and it is can be the busiest part of the entire process.

Consistent communication is often required with the manufacturer to manage how the job is progressing. Going into the Prototyping Workshop and speaking with the machinist to see what stage they are up to, taking photos, and trying to learn from them is heavily advised.

Designs can change during this period due to design or machining oversights. This is extremely common and should be relished and recorded, such that a similar mistake is not made in the future. They can be minor, or just additions to drawings to decrease confusion.

Manufacturers, including the Prototyping Workshop, will not always initiate communication if an issue does arise, and will wait for NU Racing to initiate. Machinists will just begin other jobs they have. Being proactive and ensuring that there are no issues, or if there are they are quickly delegated or solved, limits lost time. Note, there is a fine line between checking on a job and annoying the machinist and care must be taken.

7. Design Reviews

Design review checklists and items change depending on the type of part and the manufacturing methods that accompany it.

7.1.1. Review of Sheet Metal Parts

Like most mechanical parts, the review of Sheet Metal Parts is checking that the designed part can be manufactured by the required tools / machinery.

Laser and waterjet cut parts are often only restricted by the bed size of the cutter, the type of material, and material thickness.

Bent sheet metal parts need to have a dedicated review where consideration is placed on the order of operations to bend the part. There can be instances where proposed parts cannot be made as some bends will remove the ability for other bends to be made.

Bends that are parallel to each other are also limited depending on the machine they are being bent on. For example, Hancock Speedway state that they can only bend two parallel folds at a minimum of 7 mm.

Laser cut holes near bends can also become an issue, where the hole can distort due to the material displacement from bending. In this scenario, if a hole is required a pilot hole can be utilised instead, or a drawing made, and the hole drilled after bending.

7.2. Review of Machined Parts

Design considerations for different machining methods are largely about reducing the required operations and operating time.

Most design considerations for machining can be easily solved going through the order of operations for any given part. Through this it can quickly be determined if something has been missed or if there is great difficulty. Again, consulting with a machinist from the Prototyping Workshop will make this easier.

Some general questions to ask for both milling and turning are:

- How is the part going to be held in the machine?
    - Does the blank material need to be increased in size so there is enough non-machined material to hold?
- Are there unnecessary details in the model that provide no benefit (only to make the part look pretty)?
- Can tool changes be minimised?
- Fillets or radii should be used often where cuts are taken and given a radius larger than the tool diameter.
- Making parts such that they only need to be placed in the mill or lathe once
    - The machinist does not need to spend time aligning and zeroing the workpiece again in different orientations.
    - Often this isn’t the case it they will need to be reorientated
- Is there any operations where a long end mill or drill bit is required?
    - If so, does the Prototyping Workshop have this tool?
- Are specialist tools required?
    - If so, does the Prototyping Workshop have this tool?
    - If not, do we need this tool, or can it be done another way?
- Are there multiple parts that can be made from one blank of material (i.e. from the same size round bar)?
    - If so, account for extra material dependent on cutting thickness and some float.
- Has a similar part been made before?

- If so, how was it machined?

This is not a comprehensive list; however, it outlines the style of questions that must be asked in a Design Review.

7.3. Review of Welded Parts

Design reviews for welded parts commonly require communication with the Prototyping Workshop. This is because most items that require welding have had a previous iteration welded by them before.

Some important questions to consider with welded parts are:

- Is there enough material to resist weld blowout?
- Is there enough space for the machinist to restrain the part?
- Is there enough space for the machinist to hold the handpiece and welding/filler rod?
- Would a jig make the machinist life easier?
  - How can they restrain this part prior to welding (fix all degrees of freedom)?
- Can the design incorporate slots or equivalent to allow for easier weldment?

7.4. Ease of Manufacture and Simplicity

Designing things with the intent that they are simple and easily manufactured is not always easy, nor straightforward. However, this should always be at the forefront of design reviews.

Simple designs and simplicity are why NU Racing has achieved great results in the last few years. It means that parts can be manufactured faster, with less issues, and less chance of failure when compared to complex designs that incorporate many moving parts.

Taking a step back and considering what the main function of a design is and what it is trying to achieve can often be enough to see an easier solution.

8. Sheet Metal or Plate Parts

Sheet metal and plate (for example aluminium plate) parts account for a substantial number of parts on NU 24. These are often manufactured in batches and due to this, mistakes are prevalent. Once these parts have been through the Mechanical Design Process another set of checks must be taken, and relevant files gathered.

Onshape has tools that allow sheet metal models to be easily created, but care should be taken as not understanding settings and leaving them as default can lead to parts being manufactured outside of designated tolerances.

The Onshape tutorials should be mandatory for any team members before commencing in sheet metal design in 2025.

8.1. Laser/Waterjet Cut Parts

If sheet metal parts were made on campus, they are generally waterjet cut due to easy access, and quick turnaround. The negatives on doing it on campus was you needed to have material in stock, and if it needs to be bent, then a job needed to be submitted to the Prototyping Workshop.

The waterjet cutter was operated throughout the year by trained students or staff and one other person, who can be unskilled, to supervise. Throughout 2024 the overwhelming majority of waterjet cutting was carried out by the author and Jye Hollier, staff member and previous Chief Mechanical Engineer. Malcolm Sidney, Student Teams Managing Engineer, should be first point of contact for organising waterjet cutting.

If we did not have the material in stock the job was often submitted to Hancock Speedway, a sponsor of the team. They are beyond accommodating and care about the team. They provided material, laser cutting, and bending of material to the team for free. As they are not a part of the University, care must be taken when providing them files and drawings as they are a business and NU Racing should not waste their time as they are benefiting us.

8.2. Files and Organisation

Due to how many parts can be cut in one batch, caution is required to ensure that files are properly organised and available to reduce lost time when carrying out the process.

The files required for laser or waterjet cutting are DXFs, which are the 2D profile of the part that is going to be cut which are uploaded to the respective machine, drawings to show bending if required or to show overall dimensions such that an appropriate size sheet can be used, and a spreadsheet that lists out each part and its corresponding thickness and material.

The DXFs are exported from Onshape and then need to be checked in a DXF viewer, such as AutoCAD, to ensure that all features are present and correct, and the scale is correct. Due to the modelling of sheet metal parts in Onshape, certain features can be added to a part but won't be carried through to the flat-pattern. This must always be checked.

Josh Bywater, previous NU Racing FYP, developed a Python script, providing that parts in Onshape followed a certain naming convention, that sorted parts and automatically generated a BOM [8]. The script, along with other scripts that are helpful for handling DXFs, are kept in the NU Racing GitHub Repository. It is recommended that these are used in 2025.

In 2024, as most of the manufacture of NU 24 was completed before knowledge of Bywater's script was made known to the author, an excel sheet was developed that allowed for manual entries, which then drove the naming convention of all DXF files. This is shown in Figure 6.

Name	Signed	Order To:	Date Submitted For Orde

Part Number	Part Name	File Name	File Type	Material Thickness (mn	Quantit	Section Typ	Material	Finish	Requires Folding
		- - mm - - Quantity							
		- - mm - - Quantity							
		- - mm - - Quantity							
		- - mm - - Quantity							
		- - mm - - Quantity							

Figure 6. Cut Order BOM

The BOM automatically generated files names dependent on their part number, name, thickness, material, and quantity. Once the names were generated from the spreadsheet the flat-pattern DXFs were exported from Onshape and named accordingly, which stopped double handling of file names. An example of this with the Negative Bus Bar is shown in Figure 7.

Name	Signed	Order To:	Date Submitted For Ord
LACHLAN FISHER	LF	N/A	N/A

Part Number	Part Name	File Name	File Type	Material Thickness (mn	Quantit	Section Typ	Material	Finish	Requires Folding
1	NEGATIVE BUS BAR	1 - NEGATIVE BUS BAR - 4 mm - COPPER - Quantity 1	.dxf	4	1	Sheet / Plate	COPPER	As Cut	Yes - On Campus

Figure 7. Cut Order BOM Example

The generated name is ‘1 - NEGATIVE BUS BAR - 4 mm - COPPER - Quantity 1’. In Figure 8 the File Name is changed to the generated name prior to export. This reduces confusion when uploading files to a water or laser cutter.

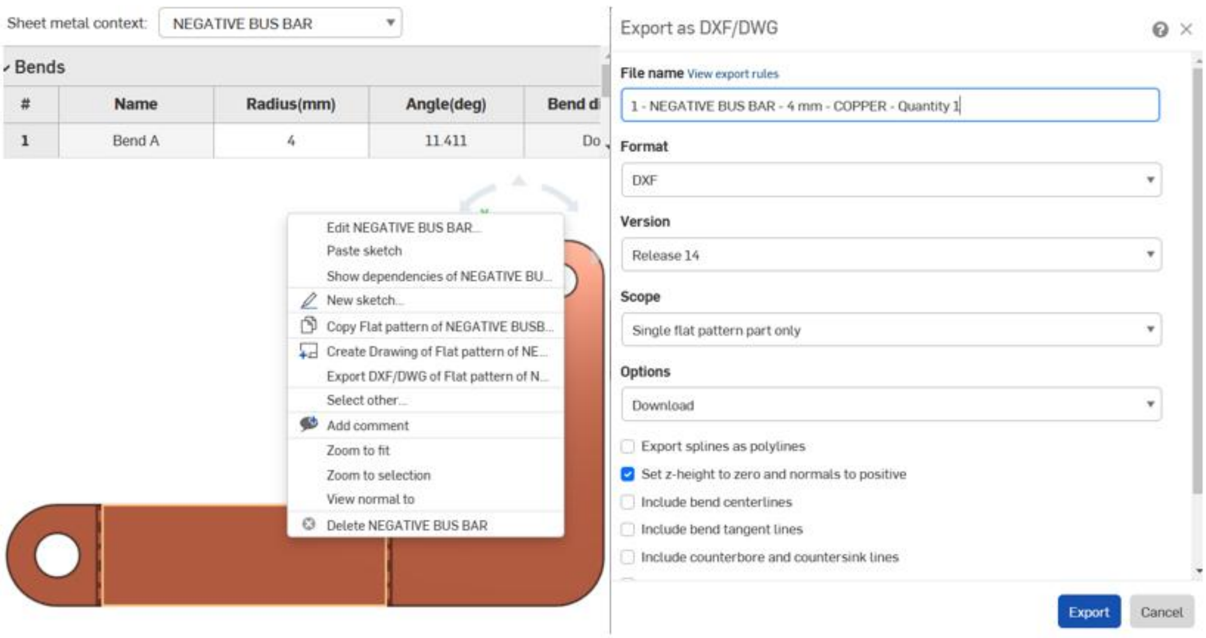


Figure 8. Exporting DXF Example

Other files that need to be managed are the PDFs of the bending drawings. The Cut Order BOM spreadsheet has a second sheet that organises what PDFs apply to what drawings.

File management was especially important when giving parts to Hancock Speedway, as clearly and concisely giving them drawings and files decreased their confusion and clearly stated all critical details for each part and the manufacturing requirements.

8.3. Bent Parts

8.3.1. K-Factor

K-Factor is a measurement that changes with material and the method of bending. It describes the change to the Neutral Axis during bending. To understand this, consider what is happening to the sheet metal as it is bending. On the inside radius of a bend, the material is being compressed. On the outside radius of a bend the material is expanding and in tension. Due to this the material on the outside of a bend gets thinner as it is stretched over a longer length. On the inside of the bend, the material increases in size as material is forced to fit in a smaller length. Due to the change in geometry the Neutral Axis is shifted towards the compressed side, as there is more material area. This can be seen in Figure 9.

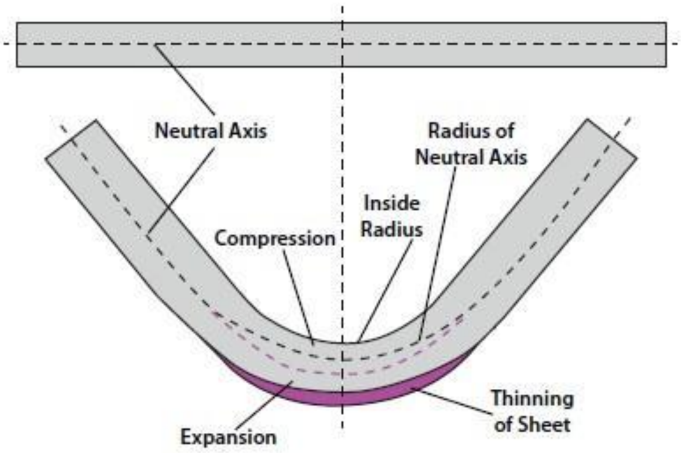


Figure 9. Change in Neutral Axis due to Bending [9]

Because there is compression and tension on either side of the bend, the overall length of the Neutral Axis changes. This means that the distance to features after a bend will change, depending on how much material is compressed and expanded in a bend.

This is important as flat patterns with the same model, only changing the K-Factor, will have different lengths following bends.

The K-Factor uses Equation 2.1 to describe the ratio of the change in position of the Neutral Axis.

$$K = \frac{t}{T} \tag{2.1}$$

Where t is the distance to the Neutral Axis from the inside of the bend, divided by the material thickness T. This is shown in Figure 10.

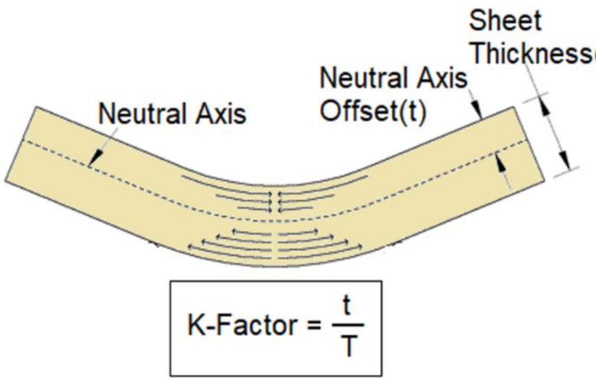


Figure 10. K-Factor Diagram

When modelling sheet metal parts in Onshape, a K-Factor is required as an input, and changing the K-Factor is vital in ensuring that the flat-pattern, or the pre-bent sheet, it the correct length. K-Factor can be selected from a chart or from testing. In 2024 K-Factors were selected from charts, such as the chart in Figure 11, with no issues.

Generic K-Factors	Aluminum		Steel
Radius	Soft Materials	Medium Materials	Hard Materials
Air Bending			
0 to Thickness	0.33	0.38	0.40
Thickness to 3x Thickness	0.40	0.43	0.45
Greater than 3x Thickness	0.50	0.50	0.50
Bottoming			
0 to Thickness	0.42	0.44	0.46
Thickness to 3x Thickness	0.46	0.47	0.48
Greater than 3x Thickness	0.50	0.50	0.50
Coining			
0 to Thickness	0.38	0.41	0.44
Thickness to 3x Thickness	0.44	0.46	0.47
Greater than 3x Thickness	0.50	0.50	0.50

Figure 11. K-Factor Chart

The Negative Bus Bar is shown as an example of how the K-Factor works. The Bus Bar is shown in Figure 12. Because the part has two bends between the critical dimensions, which is the length between the two holes, getting the K-Factor correct is vital to ensure the part functions correctly.

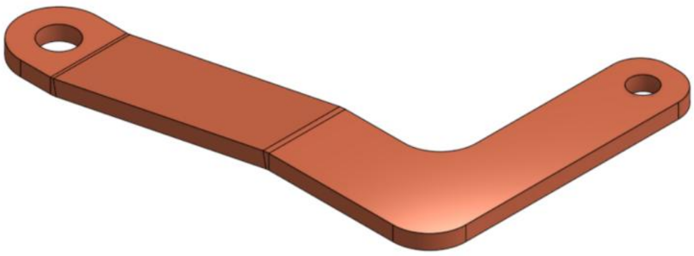


Figure 12. Negative Bus Bar

With a K-Factor of 0.45 we can see the distance between the two holes on a flat pattern of the part is shown as 104.4 mm in Figure 13. A K-Factor of 0.45 means that the Neutral Axis moves towards the inside bend radius.

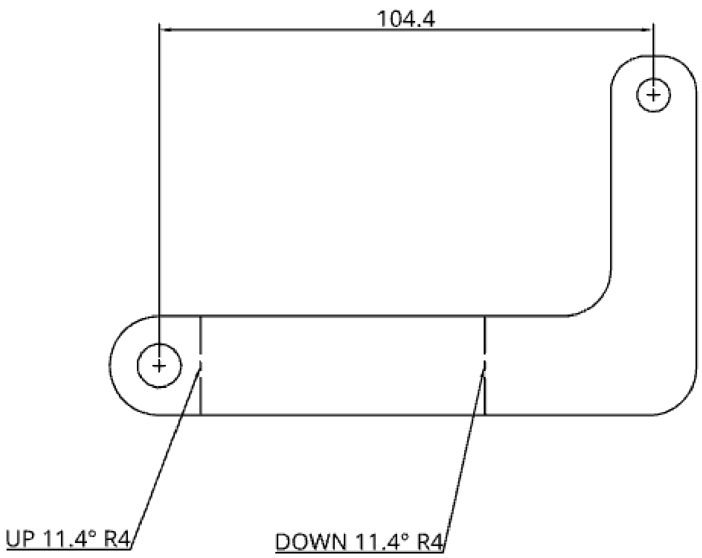


Figure 13. Negative Bus Bar with K-Factor of 0.45

If we change the K-Factor to be 0.5, which means the Neutral Axis does not move during bending, we can see in Figure 14 the distance changes to 104.5 mm.

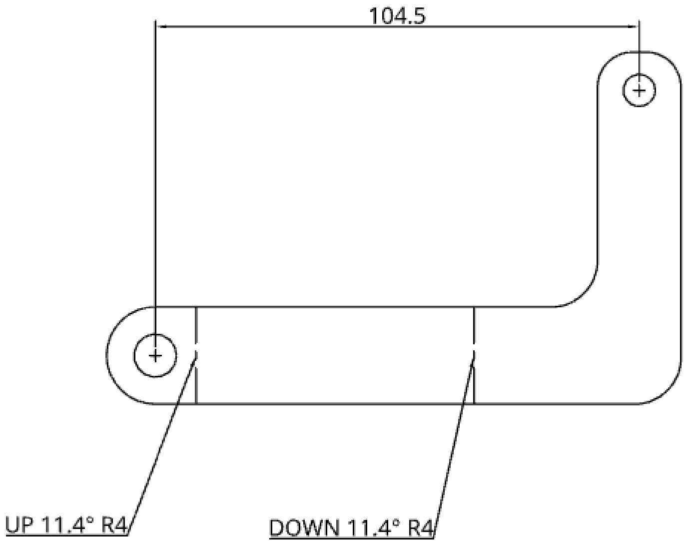


Figure 14. Negative Bus Bar with K-Factor of 0.5

This a small difference and can often be insignificant, however in parts with stack ups of bends the distance can change quite dramatically and result in parts that do not function correctly.

8.3.2. Bend Radius

The bend radius is the inside radius created by the bending tool. A common rule of thumb is the bend radius is approximately 1-1.5 times the thickness of the material. Throughout 2024 the material thickness was used as the bend radius with no issue.

9. Overview of Subsystems

NU 24 is comprised of different systems that achieve different roles in its function. The Chief Mechanical Engineer must have a good understanding of these systems especially how they impact each other. These systems are shown in the Figure 15. Systems and parts that are removed from this image for clarity are the Wheels and Tyres, Suspension, Tie Rods, Driveshafts, Head Restraint, and Harnesses.

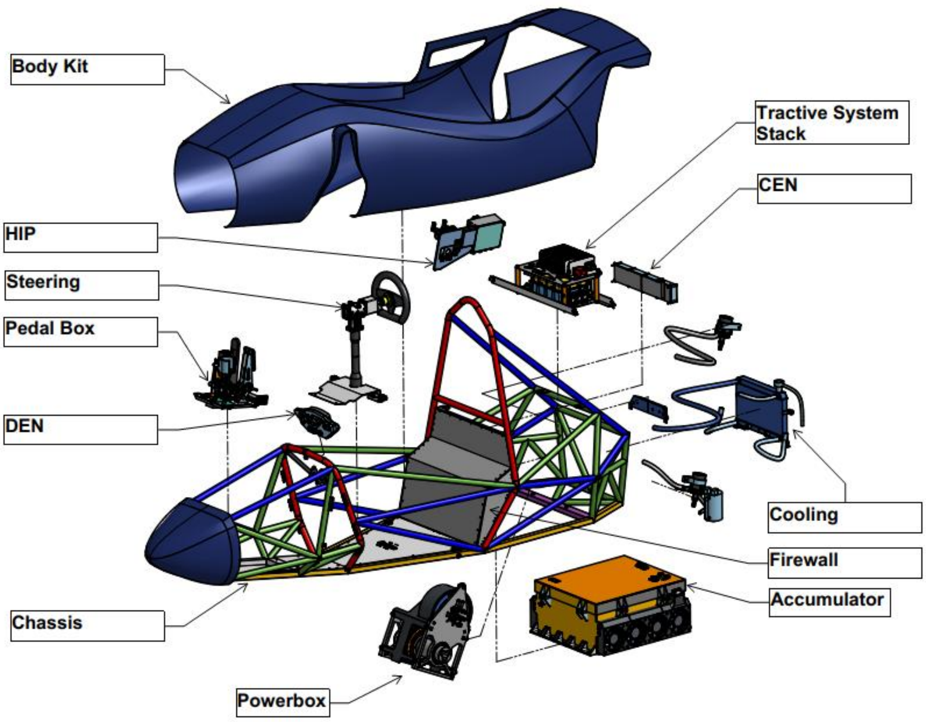


Figure 15. Breakdown of NU 24's Systems

9.1. Drivetrain

NU 24's drivetrain is comprised of a 'Powerbox', which includes the Motor Assembly, Spool Assembly, and Brakes. The Powerbox is shown in Figure 16. When fully assembled, the Powerbox can be removed from the car as a unit, which makes it incredibly easy to maintain.

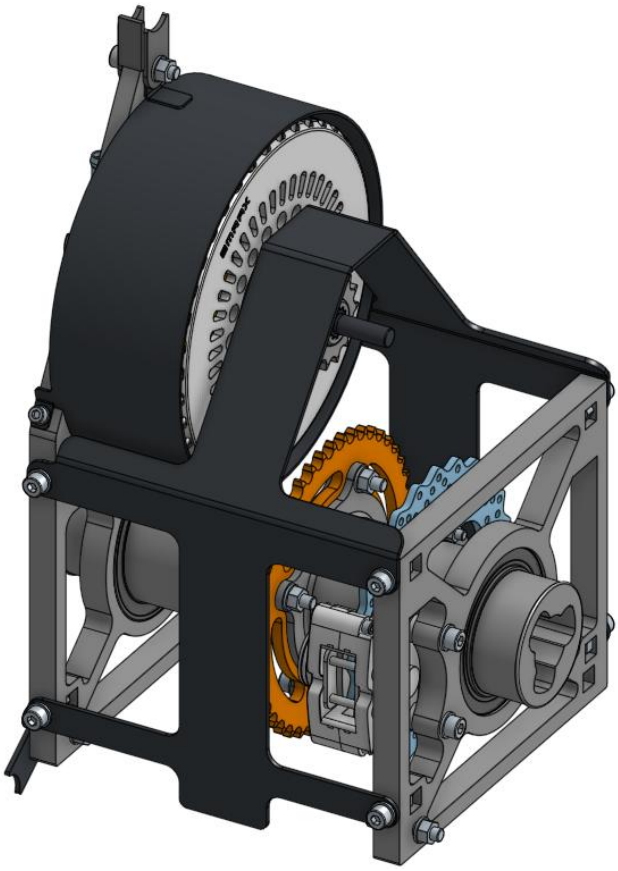


Figure 16. NU 24 Powerbox

9.1.1. Powerbox

The Powerbox is comprised of the Scatter Shield, Chain Guard, Motor Plate, and Brake Plate. This assembly is shown in Figure 17.

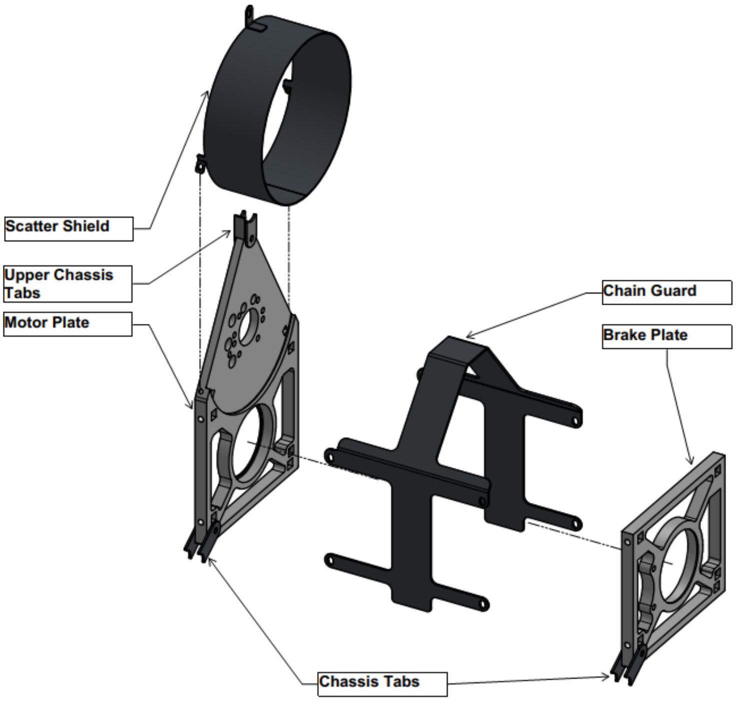


Figure 17. Powerbox Assembly

The Motor Plate and Brake plate are both made from 6061 T6 Aluminium and made in the same process. The both house the same 6916-ZZ NSK Bearing for the spool. The Brake Plate also houses the mount for the brake caliper.

Both the Scatter Shield and Chain Guards material selection and general shape is dictated by the FSAE Rules. T.5.3.2 states there must be a Scatter Shield around the motor when it rotates about its stator of minimum thickness 1 mm and of steel or 6061 T6 aluminium. T.5.2.7 states that the Chain Guard must be centred around the centre of the chain, three times the thickness of the chain, extend to the lowest point of the chain, and be of minimum thickness 2.66 mm.

9.1.2. Motor Assembly

The Motor Assembly is comprised of four main parts: the Motor, Transmission Shaft, Spacer, and 14T Sprocket. This is shown in Figure 18.

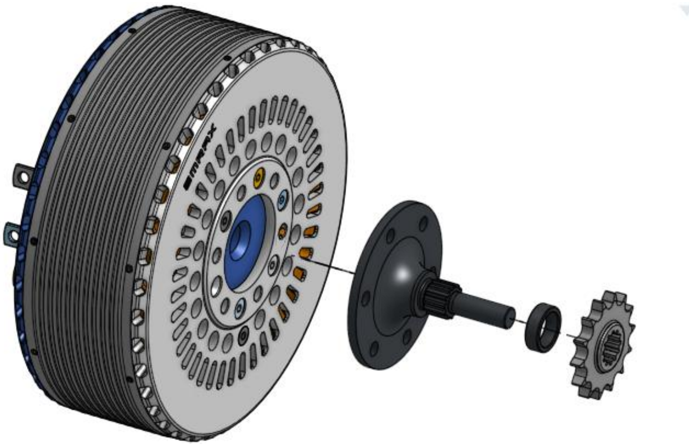


Figure 18. NU 24 Motor Assembly

The Motor used for NU 24 was the Emrax 228 which could output 230 Nm and 124 kW shown in Figure 19 [6]. This motor is AC and has three phase cables that connect to the Motor Controller.

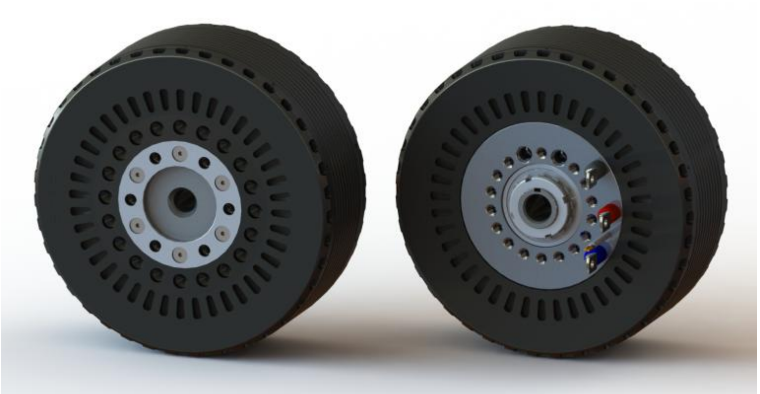


Figure 19. Image of the Emrax 228

The motor is liquid cooled and has two straight barbs which are hooked up to the Cooling System. The 228 is bolted by eight Grade 12.9, M8 × 1.25 mm socket head cap screws to the Motor Plate.

Similarly on the other side of the motor the Transmission Shaft, shown in Figure 20, was bolted to the 228 with six Grade 12.9, M8 × 1.25 mm socket head cap screws. These fasteners are also safety wired so that the assembly is positively locked, as per rule T.8.2.3 in the FSAE rules [7].

The shaft was made from 4140 Steel and gas nitrided to increase the surface hardness of the spline that had to house the 14T sprocket.

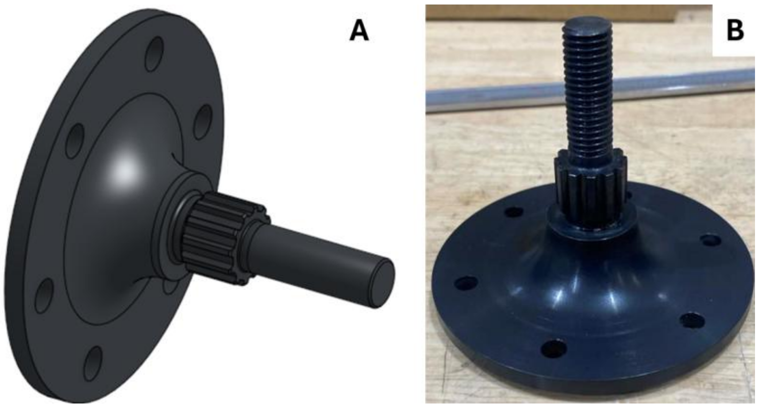


Figure 20. Transmission Shaft. CAD image (A), manufactured (B)

The Sprocket Spacer is spaces the 14 tooth (14T) sprocket, which is a bought item from a KTM 85 SX, out to the required width so the 46 tooth (46T) sprocket on the Spool are aligned.

After the 14T sprocket there is a M12 washer and M12 nyloc nut that fix it and the Sprocket Spacer to the Transmission Shaft. The completed assembly is shown in Figure 21.

Figure 21. Completed Motor Assembly with chain attached

9.1.3. Spool Assembly

The Spool Assembly is responsible for transmitting from the Motor Assembly to the driveshafts, which ultimately drive the wheels of the car. The final drive of NU 24 is locked, meaning that both rear wheels rotate at the same speed with the same torque. This is shown in Figure 22.

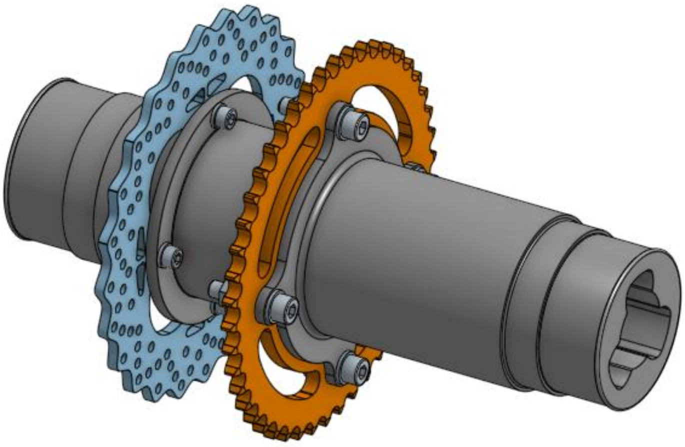


Figure 22. NU 24 Spool Assembly

The Spool is two part and bolted together at the 46T sprocket. This was done to reduce the manufacturing complexity that can often be involved with create a single part spool. It also allows for weight to be taken out of the centre part of both tripod holders. This is shown in Figure 23.

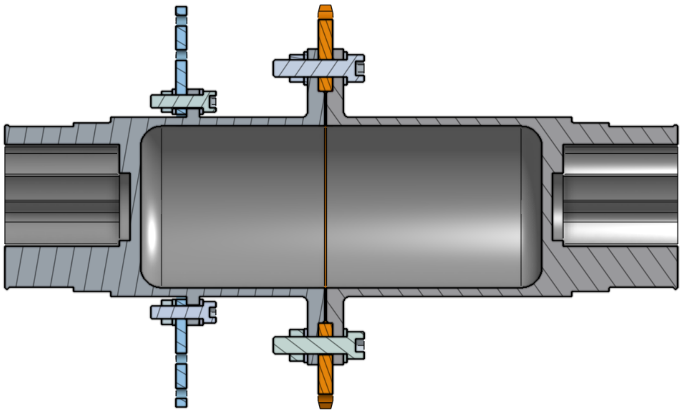


Figure 23. Section view of the Spool Assembly

The driveshafts make use of tripods to transmit torque to the driveshafts. The tripods used are RCV FSAE Lightened Tripod and are shown in Figure 24.

Figure 24. RCV FSAE Lightened Tripod [10]

In the end of each tripod holder is machined out to give the profile of the tripod and allow sufficient clearance that the rollers smoothly translate through the holder. The profile is sufficiently extended such that the driveshafts can't fall out of the spool or spindles throughout the suspension travel.

The 46T sprocket is also a bought part and from a KTM 85 SX. Unlike the 14T sprocket that is steel, this sprocket is made from 7075 Aluminium.

9.1.4. Brakes

Due to the drivetrain having a locked rear axle, NU 24 makes use single inboard brakes. A Wilwood GP200 Caliper with the Purple Pad compound are used in combination with a manufactured Steel Rotor, designed and manufactured by Kieran Burgess [11]. The rotor is bolted directly to the spool as shown in Figure 22. The caliper is bolted directly to the Brake Plate.

9.1.1. 2024 and Previous Engineers

In 2024 the Drivetrain was completed by the author and Rishi Mathuria [12]. In 2023 Jye Hollier and Rene Sturmberg were the Drivetrain Engineers [3]. The 2022 Drivetrain is vastly different to the Drivetrain’s of 2023 and 2024 and does not provide much context. This is detailed in Hollier’s report [3].

9.2. Steering

The Steering for NU 24 is comprised of the Steering Column, Steering Rack, Tie Rods, and Steering Wheel. The full assembly is discussed in more thorough detail in later in the Vehicle Dynamics report, in 4.2 NU 24 Steering Components. The full assembly is broken down in Figure 25.

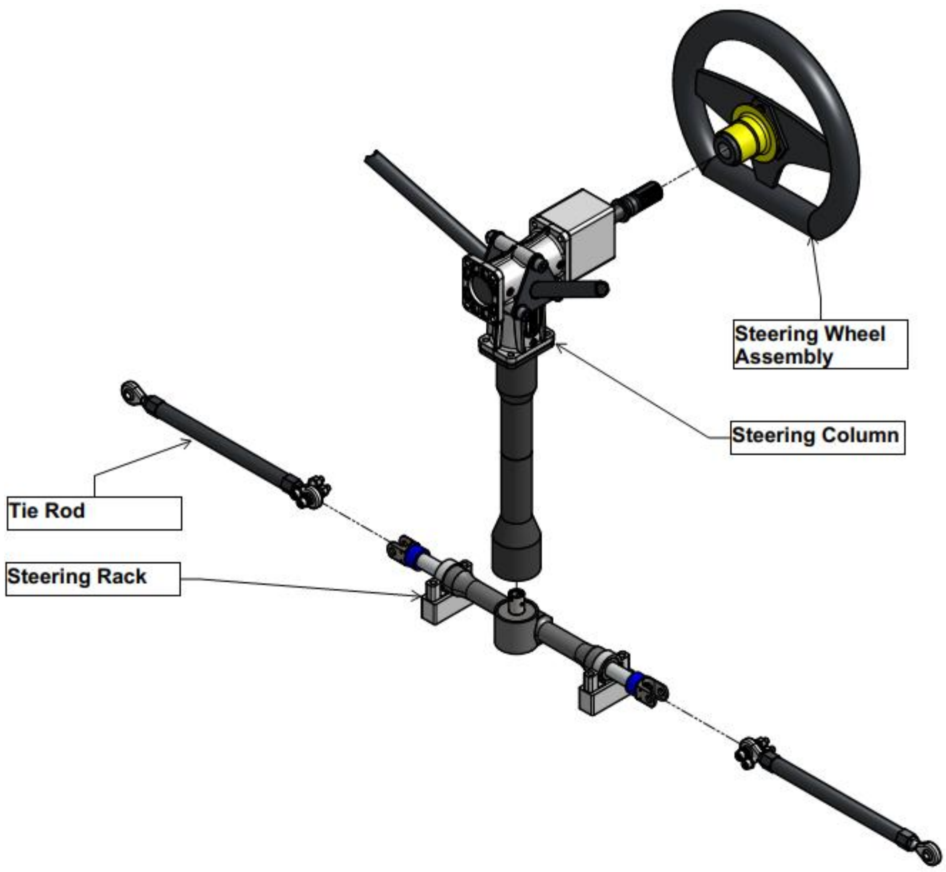


Figure 25. NU 24 Steering Assembly

9.2.1. 2024 and Previous Engineers

The Steering Engineer in 2024 was the author. In 2023 it was Drew Bender [1]. In 2020 it was designed by Matt Reggers and built by Perry McNulty and Blair McIntyre [13], [14], [15].

9.3. Suspension

The suspension for NU 24 borrows a lot of its attributes from previous years. The suspension has not undergone a mass redesign since Matthew Reggers designed it for EV.Three [13]. From EV.Three the Uprights and Spindles have been reused, with the only largescale change being the Control Arms which were manufactured in 2024, covered later in 10.4 Suspension.

The Front Right Suspension assembly is shown in Figure 26.

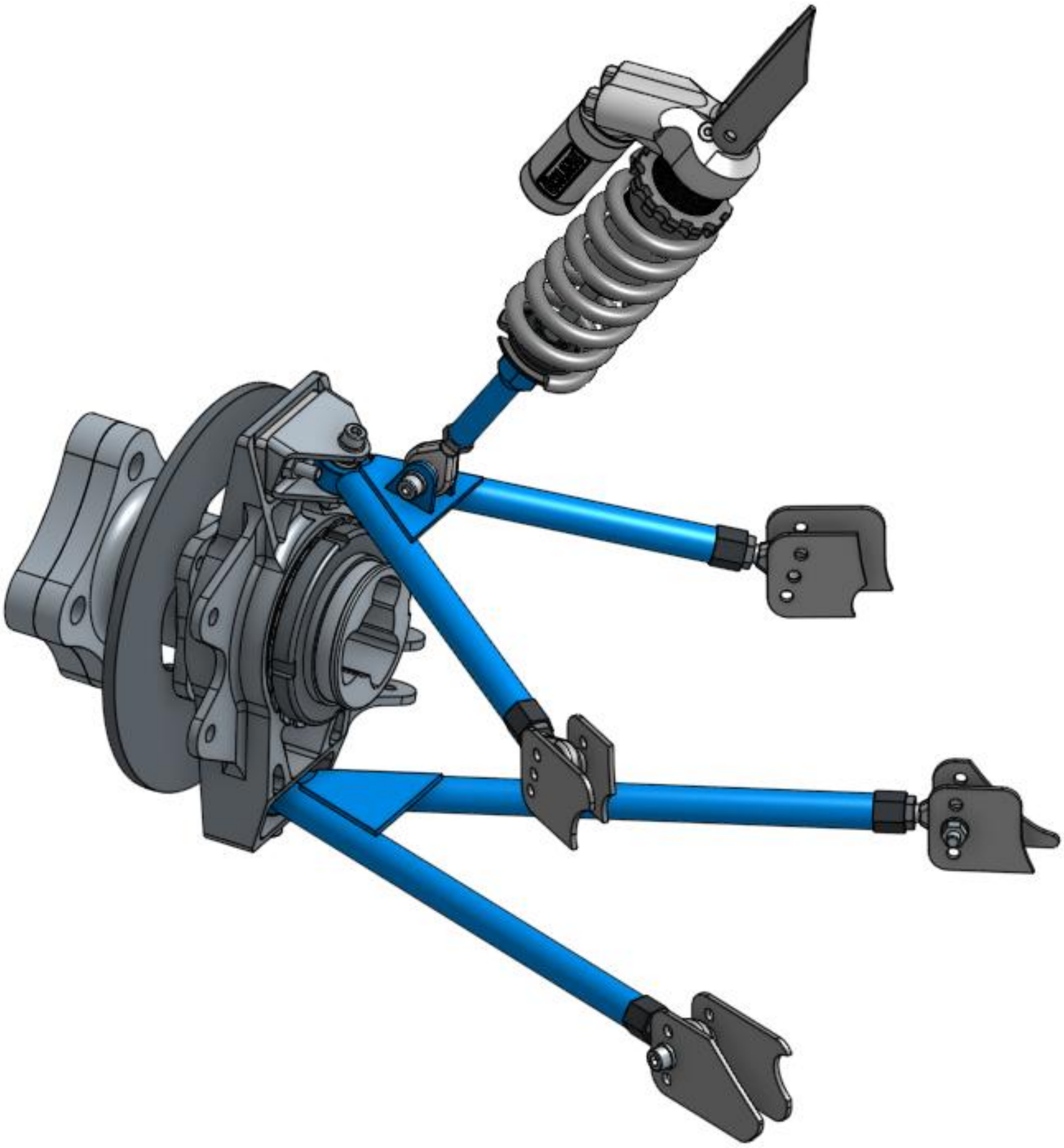


Figure 26. NU 24 Front Right Suspension Assembly

The Uprights are made from 7075-T6 Aluminium were manufactured by Newcastle Machine Shop. They house two 6814-DD NSK Deep Groove Ball Bearings. Between the two bearings is a preload spacer that maintains the correct distance between the inner race of each bearing when the locknut is tightened. The bearings require some preload such that when they experience load, the bearings are unable to move from their housing or relative to each other. It should be noted, among alumni members there is a belief the spacer does not have the appropriate clearance. Due to this, next time the bearings are removed the spacer should be measured to determine its width. The preload spacer is shown in an exploded view in Figure 27 and a section view in Figure 28.

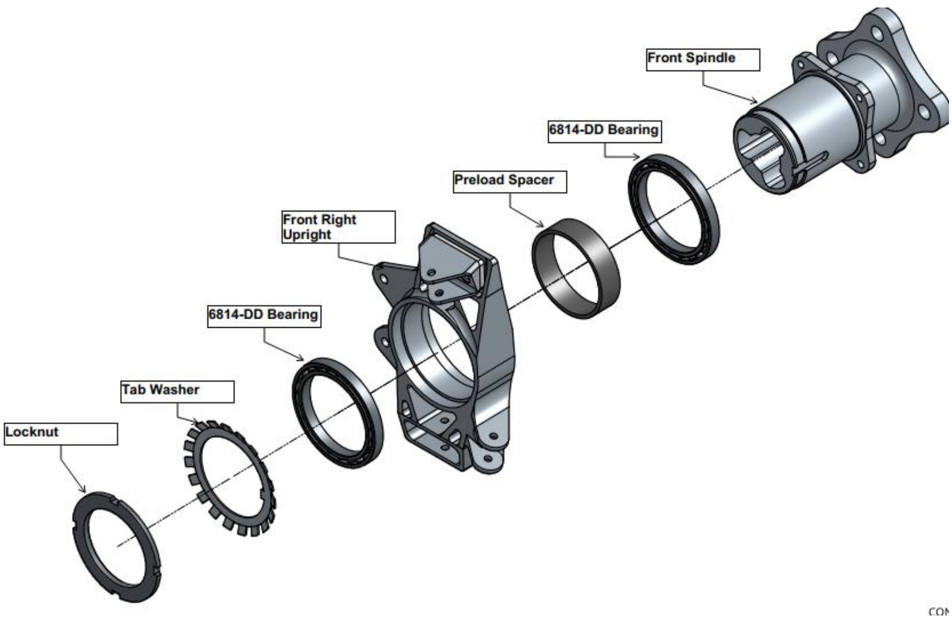


Figure 27. NU 24 Front Right Upright and Spindle Assembly

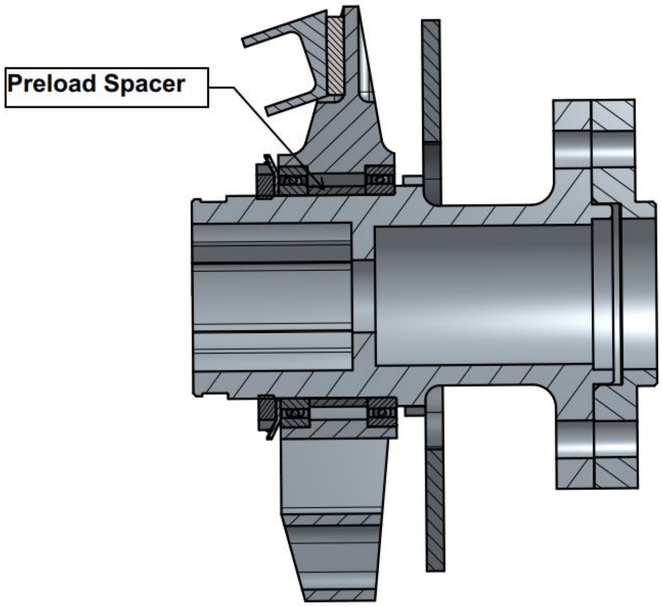


Figure 28. NU 24 Front Right Upright and Spindle Section View

The Spindles were also manufactured by Newcastle Machine shop from 6061-T6 Aluminium. The Front Spindles feature tripod housings, and these were purely put in in 2022 as future proofing, in case the team decided to revert to All Wheel Drive (AWD). The Spindles have M12 × 2 mm Wheel Studs pressed into them [15].

Both Front and Rear Uprights have a Pickup bolted into the top of the respective Upright, and the lower Pickup is machined into the Upright. Between the Upright and Upper Pickup, Camber Shims are bolted in to reduce the camber of the given corner. There are 6 mm shims and 1.6 mm shims that correspond to 0.5° and 2° of reduction respectively [16].

The Control Arms are made from 16 × 2 mm Circular Hollow Section (CHS). They are notched at one side to suit the Spherical Bearing Pocket. The other side is cut straight to allow a section of hexagonal rod to be inserted and tapped to allow the 8 mm Rod Ends to screw into the arms, with a M8 half nut to act as a locknut. The spherical bearing is a metric ABWT5V staked bearing which caused some difficulty throughout the year. This is later discussed in 10.4 Suspension.

The suspension features Ohlins TTX25 MKII coilovers. These are paired with Cane Creek springs, which at competition in 2024 were 450 lb/inch at the front and 650 lb/inch at the rear. The dampers allow for High and Low Speed Compression and Rebound Adjustment. These are shown in Figure 26 their tuning is further explained in the Vehicle Dynamics report in 6. Physical Testing.

To allow for movement in the Control Arms and Tie Rods, Stainless Steel Spacers are used to create space for the Rod Ends to move. There are five spacers of the same design but different measurements on NU 24. There are Outboard Spacers for everything that bolts to the Uprights, the Tie Rods, and the Control Arm, Inboard Spacers, for mounting the Control Arm Rod Ends to the Chassis, and the Coilover Top and Bottom Spacers which are different as one side must bolt to the Coilover and the other to the Rod End at the other side. An Outboard Suspension Spacer is shown in Figure 29.

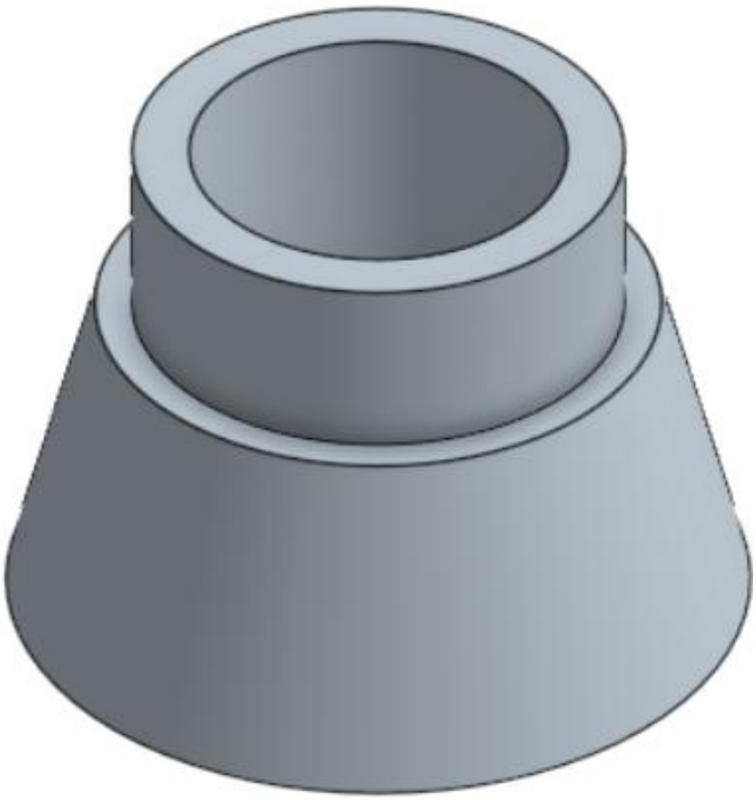


Figure 29. NU 24 Outboard Suspension Spacer

9.3.1. 2024 and Previous Engineers

The 2023 Suspension Engineer was Justin Li, and the Vehicle Dynamics Engineer was Ethan Pay [17], [16]. In 2020 it was designed by Matt Reggers and built by Perry McNulty and Blair McIntyre [13], [14], [15].

9.4. Chassis

NU 24's Chassis is comprised of 4130N Chromoly Steel tubes of CHS, Rectangular Hollow Section (RHS) and Square Hollow Section (SHS). The Chassis is notched by Canadian company VR3 Engineering and welded together by the MEWS staff. The Chassis is shown in Figure 30.

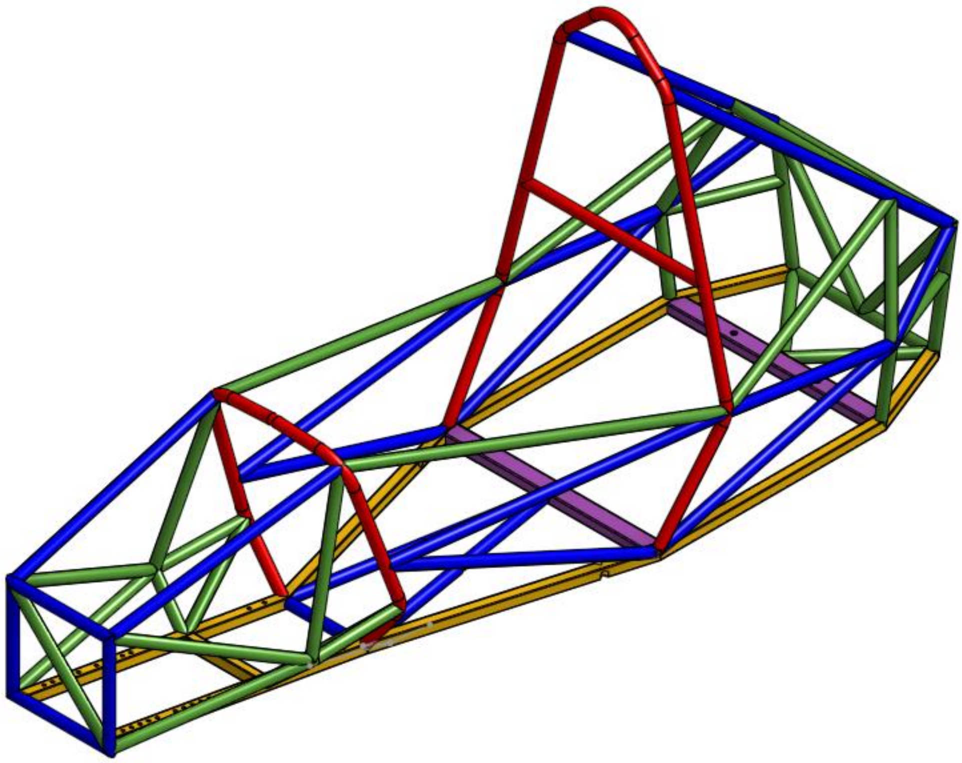


Figure 30. NU 24 Chassis

The Chassis is one of the strictest systems on the car in terms of the rules applied to it. It is required to pass the Structural Equivalency Spreadsheet (SES), which is a spreadsheet provided by FSAE, before the vehicle is allowed to be driven at competition. The SES requires that values of the Chassis' geometry are entered, and cells next to any given value will show a code which states its compliance. These codes are shown in Figure 31.

YouTube: 2019 SES Instructional Guide YouTube: 2020 ESF Document Training						
Only cells of this color can be edited. Enter all values as positive numerals.						
Drop down options can be identified by the heavy border. Delete will clear the entry.						
Each entry, each category, each tab, and the entire sheet are coded as one of the following:	BLANK	EQ	CHECK	REJECT	N/A
The status of some cells depends on entries in other cells.						

Figure 31. SES Codes

BLANK means that a cell is left empty. EQ means that the cell is compliant. CHECK means that the SES in unsure if you are compliant or not. Generally, this means a rules enquiry to SAE may be required. REJECT means that it is not compliant. N/A means that the rule does not apply to your selections / chassis. As seen in the top left of Figure 31, there are instructional videos explaining how to complete the SES.

An example of a completed SES is shown in Figure 32. It should be noted, as seen in the top left of Figure 31, that only cells of a certain colour can be edited.

EQ — Main Hoop (MH), Shoulder Harness Bar (SH)

F.5.8.1-2	The Main Hoop extends, uncut, from the lowest frame member on both sides.
F.5.6.2	All bends below the Upper SIS must have an SIS or MHBS tube within 25mm.
F.5.8.3.b	Main Hoop side view bends must be braced to an MHBS or SIS node.
F.6.5.1.a	Tube Shoulder Harness Bars must be one piece of uncut, continuous steel tub
F.6.5.1.b	Tube Shoulder Harness Bars must connect to the Main Hoop at both ends.
F.6.5.2.b	Shoulder Harness Braces must support the middle of SH bends.
F.6.5.2.b	Shoulder Harness Braces must connect back to the Main Hoop, ideally at a noc
F.6.5.2.b	The larger the SH Brace angle (>=30), the better the moment from the harness i

The MHB may act as braces for a bent Shoulder Harness Bar. See column 'F' to the right.

SH Brace Angle: https://www.fsaeonline.com/cdsweb/gra/ViewFAQ.aspx?faqnum=28

		EQ			
F.5.8	**Main Hoop (MH)**	**Minimum**	**Tube Used**		EQ
F.3.2.1.g	Example: 25mm x 2.5mm round	Size A	Round		EQ
F.3.4.1.a	Wall thickness:	2	2.413	mm	EQ
	Outer Diameter (OD):	25	25.4	mm	EQ
	Wall thickness:	2.0	2.413	mm	EQ
	Outer Diameter (OD):	25.0	25.4	mm	EQ
	Tube cross sectional area (A):	173	174	mm^2	EQ
	Tube second moment of inertia (I):	11320	11637	mm^4	EQ

		EQ			
F.6.5	**Shoulder Harness Bar (SH)**		Straight		EQ
		Minimum	**Tube Used**		EQ
F.3.2.1.k	Example: 25mm x 2.5mm round	Size A	Round		EQ
F.3.4.1.a	Wall thickness:	2	2.413	mm	EQ
	Outer Diameter (OD):	25	25.4	mm	EQ
	Wall thickness:	2.0	2.413	mm	EQ
	Outer Diameter (OD):	25.0	25.4	mm	EQ
	Tube cross sectional area (A):	173	174	mm^2	EQ
	Tube second moment of inertia (I):	11320	11637	mm^4	EQ

Shoulder Harness Bar does not require braces.

Figure 32. 2024 Completed Main Hoop SES

The SES also requires technical drawings to show differing measurements and illustrate the geometry of the car to the judges. A blank SES will show what measurements they are after, then you must replace those with drawings of your own. Completion of the SES for 2024 was completed by 2023 Chassis Engineer, Joseph Barker, and 2024 Chassis Engineer John Jones.

The Chassis underwent large changes in 2024. There was a reduction in the weight and number of members in the chassis, as well as reductions in the track width and wheelbase.

9.4.1. 2024 and Previous Engineers

In 2024 the Chassis Engineer was John Jones [18]. In 2023 it was Joseph Barker and Jye Hollier [19], [3].

9.5. Accumulator

The Accumulator is in essence the battery pack for NU 24. It stores the tractive systems electrical energy. It is made up of the Accumulator Container, Lid, Top Plate Assembly, Segments, and the Service Handle. The assembled Accumulator is shown in Figure 33 and an annotated exploded view shown in Figure 34.

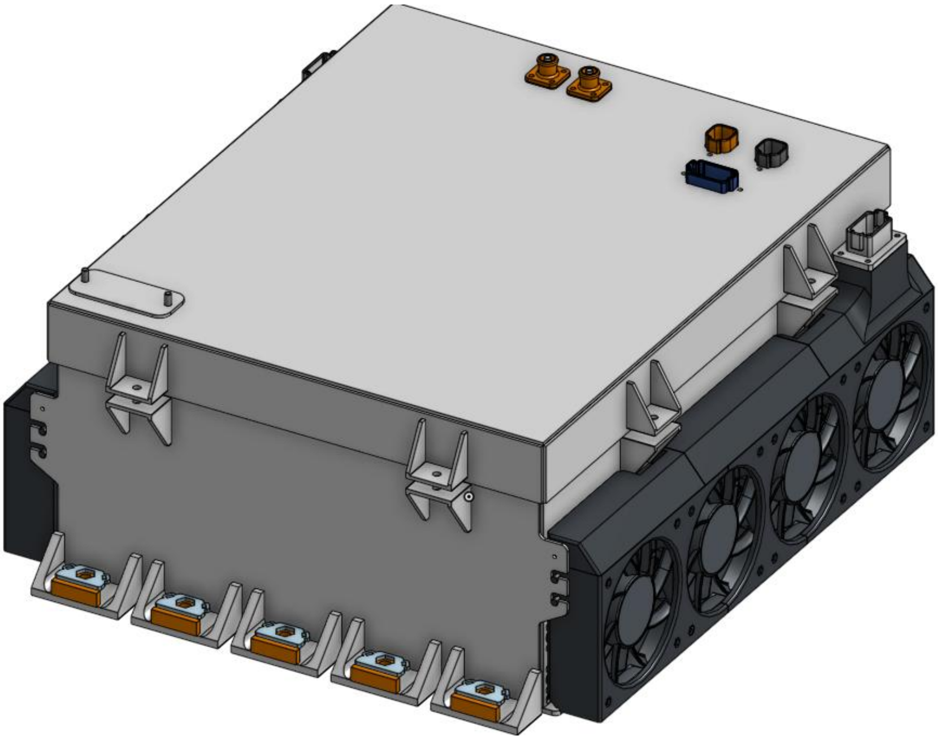


Figure 33. NU 24 Accumulator Assembly

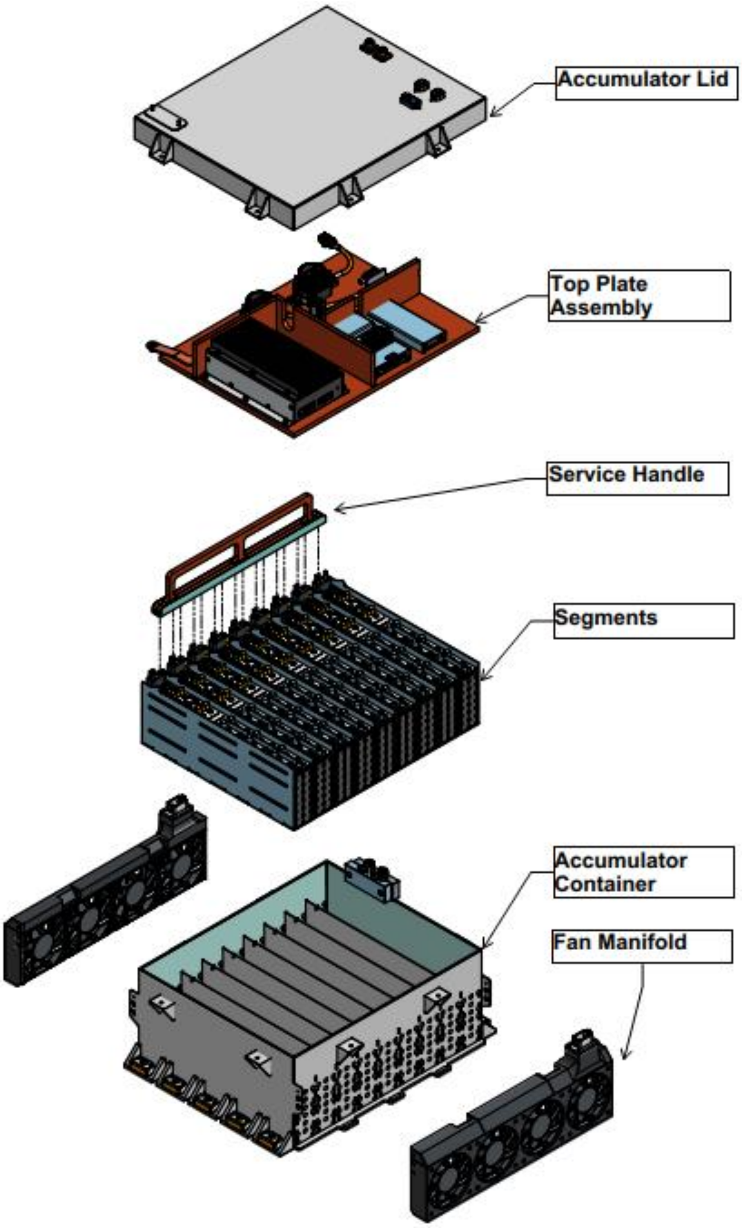


Figure 34. NU 24 Accumulator Exploded View

9.5.1. Accumulator Container and Lid

The Accumulator Container and Lid are made from 6061-T6 welded aluminium, and have minimum thickness requirements from the FSAE Rules, F.10.2 [7]. It is lined with FR-4 as an insulative material between each segment and on the inside of the Accumulator Lid, as per EV.5.2.3 [7].

The container, much like the Chassis, has an extremely strict ruleset and must pass the SES. The basics of the SES for the Chassis, as discussed in 9.4 Chassis, apply for the Accumulator section of the SES. It requires information on the Accumulator Segments, Accumulator Container, and Accumulator Mounts, both for the Chassis side and the Accumulator side.

9.5.2. Segments

There are 9 segments in the Accumulator Container. The segments are made up of Energus 18650 Battery Modules connected in series by busbars as shown in Figure 35.

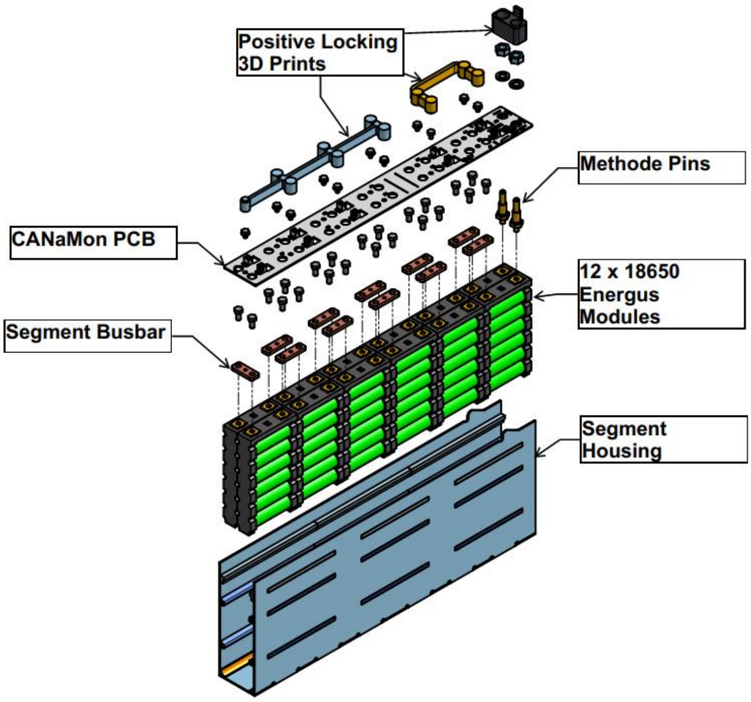


Figure 35. NU 24 Accumulator Segment Exploded View

The Modules are then placed into an FR-4 Segment housing that insulates it from the internal walls of the Accumulator Container. On top of the segment the CANaMon Print Circuit Board (PCB) is attached, which is responsible for monitoring the segment temperatures. The latest version of the CANaMon PCB was made by Jacob Bush in 2023 and more information on the PCB can be found in his report [20].

The FSAE Rules also dictate that all bolts within the Accumulator Container must be positively locked, meaning that any fasteners to have a device to resist loosening. Often for fasteners bolted into something other than a nut, they can be safety wired. This is not safe nor easy to do inside the accumulator, instead the use of 3D printed parts that lock the heads of at least two bolts together are used.

9.5.3. Service Handle (Maintenance Plug)

Every Segment, except the first and ninth, have two Methode Pins threaded into the Segment. This is so the Service Handle can be pressed in to connect all 9 Segments in series. This makes the Accumulator 'live'. Each segment has approximately 50 V and such the Accumulator can have a maximum voltage of 453.6 V. The Service Handle, referred to as the Maintenance Plug in the FSAE Rules, is what is used to connect and disconnect the Segments to allow the Accumulator to be safely worked on. An exploded view of the Service Handle is shown in Figure 36.

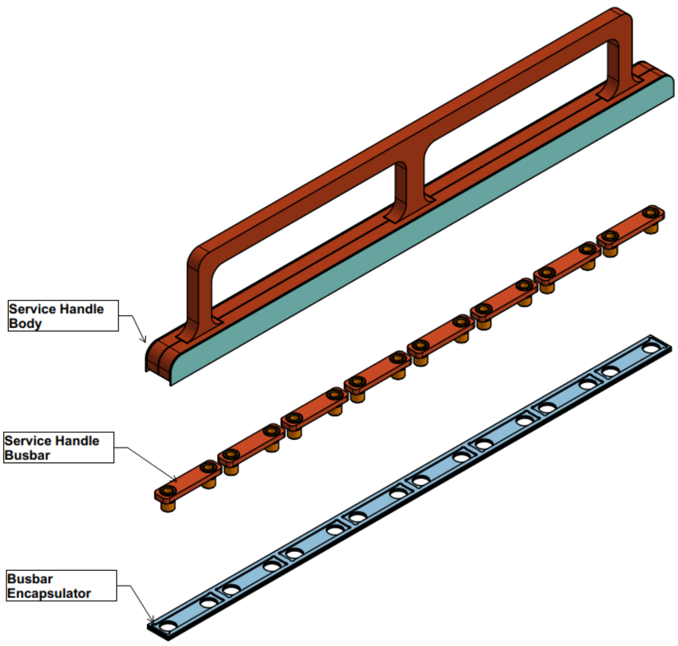


Figure 36. NU 24 Service Handle Exploded View

The Service Handle Body is made from GP0-3 and was manufactured on a CNC Router in the Architecture and Built Environment Workshop (ABEW). The Handle Body is made from 3 routed sections epoxied together.

There are 8 copper busbars that have Embedded Bud Connectors (EBC) 'Methode Buds' that are press fit into the Service Handle Busbars. They are knurled on the pressing surface and require a tight tolerance for the busbar press-fit hole as per the manufacturer's specifications. An EBC Connector is shown in Figure 37 alongside the tolerance for the busbar press-fit size as per the manufacturer's technical drawing [21].

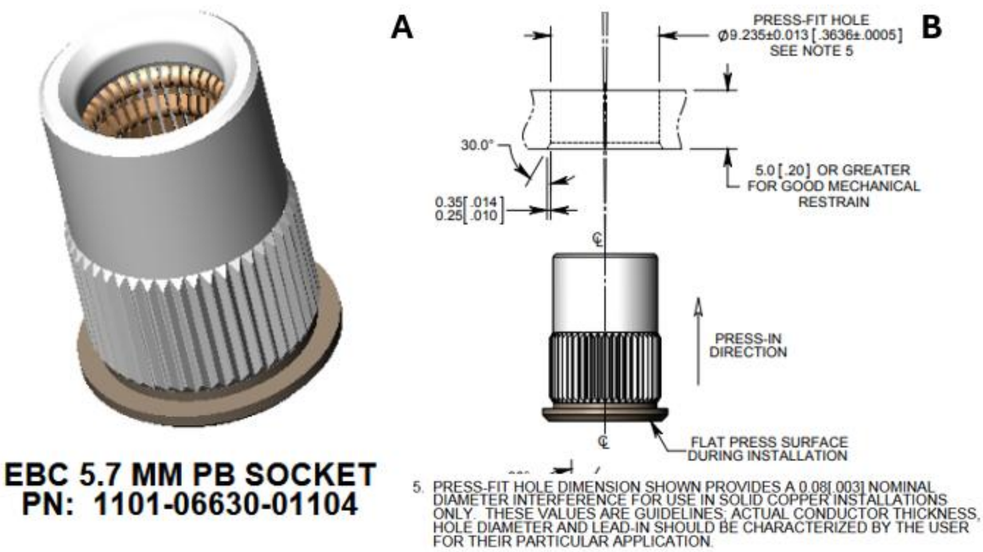


Figure 37. EBC Connector (A). Press-Fit Hole Tolerance for an EBC (B)

The Busbars are held in the Service Handle Body by the Busbar Encapsulator. This allows the Busbars to slightly move, which means the tolerance for the distance between each Segment and the tolerance between each Busbar in the Service Handle is not required to be as tight. It should be noted that the Busbars can only move laterally, and not vertically, with the allowed tolerance. A section view of the Service Handle in Figure 38 shows how the Busbars are kept in the Service Handle Body.

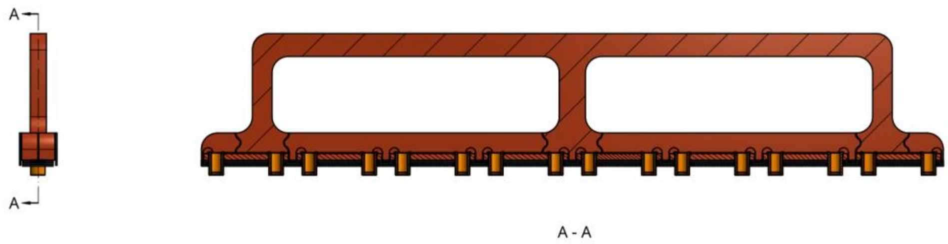


Figure 38. NU 24 Service Handle Section View

9.5.4. Top Plate Assembly

FSAE Rule EV.5.2.3 also states that above the Segments must also be covered with an insulative layer. The Top Plate covers the Segments to comply to this requirement. The Top Plate also houses majority of the electronics in the Accumulator. The Top Plate is shown in Figure 39.

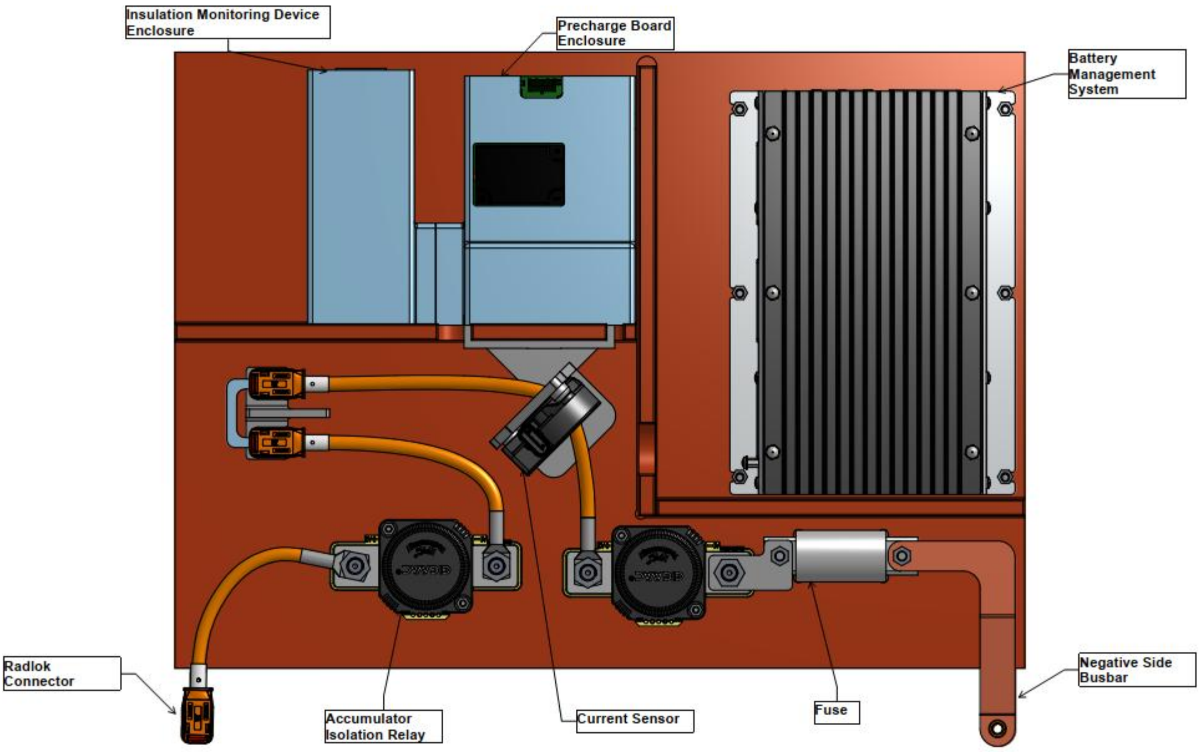


Figure 39. NU 24 Top Plate

The Accumulator Isolation Relays (AIRs) are implemented for rule compliance as per EV.5.4.1 [7]. The relays are normally open relays, meaning that unless they are actuated High Voltage

(HV) cannot be used to power the car. Also, as per rule EV.5.4.1 there is one fuse in the high current path. Housed on the Top Plate are also the Battery Management System (BMS), Insulation Monitoring Device (IMD), and Precharge PCB.

The Top Plate is also responsible for the vertical retention of each Segment with the Accumulator Lid. When the lid is placed over the Accumulator Container it rests on the Top Plate. When the lid is fastened to the container it then holds the Top Plate down, Pushing it onto the Segment Housings and the internal walls of the Accumulator Container.

9.5.5. Cooling

The Segments are not allowed to reach temperatures over 60° C for their own health, and due to the FSAE rules. Due to this two Fan Manifolds are used on either side of the Accumulator Container for cooling. One fan sucks air into the Accumulator and the other pushes air out of the Accumulator.

9.5.1. 2024 and Previous Engineers

In 2024 the Accumulator Engineer's were Kris Kerr and Daniel Iveson. In 2023 it was Jacob Searle and Michael Dalton [22], [23].

9.6. Brakes

NU 24 has two separate brake circuits, one for the front of NU 24 and one for the rear. Two outboard calipers are utilised on the front of NU 24, whereas there is one inboard caliper is used on the rear. The Front Brake Calipers are bolted to the Front Uprights and the Rotors are bolted to the Spindles. The Front Right Brake Assembly is shown in Figure 40.

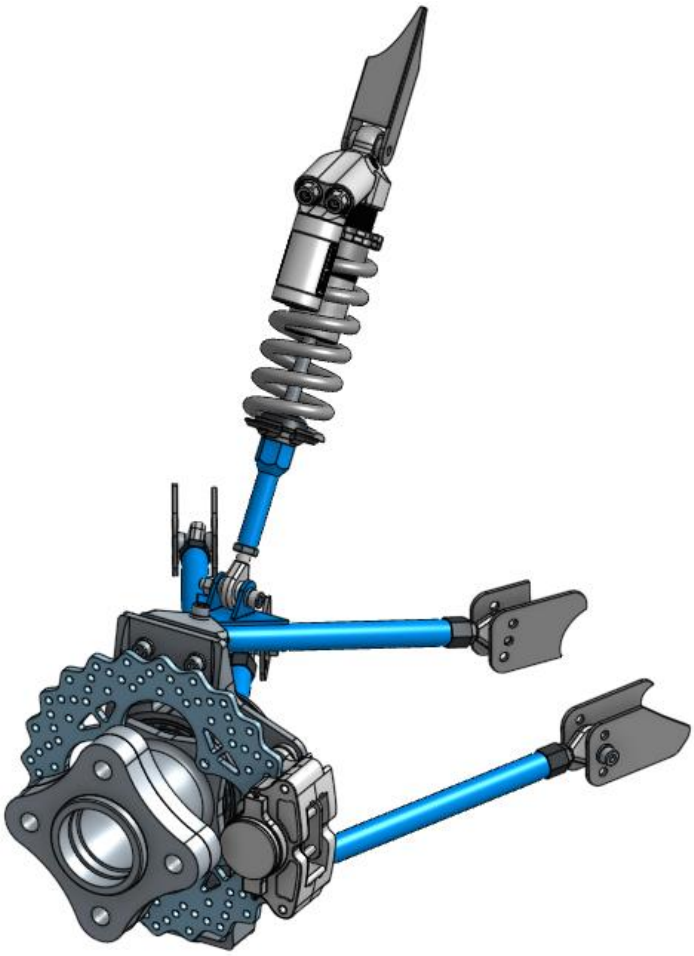


Figure 40. NU 24 Front Right Brake Assembly

The Front Calipers are also Wilwood GP200 Calipers, selected for their size. The same calipers have been used since EV.Three. The Brake Rotors were designed by Keiran Burgess from Mild Steel and uses Wilwood's Purple Pads [11].

The Brake Lines are Steel Braided AN-3 lines with basic fittings. They make use of 3 Dry-Break Disconnects that allow the Pedal Box and Powerbox to be removed from NU 24 without needing to release Brake Fluid. The disconnects are shown in Figure 41.

Figure 41. Aeroflow AN-3 Dry Break Disconnects [24]

9.6.1. 2024 and Previous Engineers

In 2023/2024 the Brakes Engineer was Keiran Burgess [11].

9.7. Cooling

NU 24 requires liquid cooling for both the Emrax 228 Motor as well as the CM200 DX Motor Controller (also referred to as the Inverter). They both have maximum temperatures specified by their manufacturers, 125° C for the Motor Controller and 120° C for the Motor [25], [26]. It should be noted that the Motor has a max coolant temperature of 50° C [25]. Due to this a cooling package including a custom PWR radiator and two Davies Craig EBP40 Electric Pumps. An 8-inch Thermo Fan that is attached to the rear of the radiator to draw additional air through the radiator. There is also a Catch Can bolted to the Radiator Support, which is required by the rules. Figure 42 shows NU 24's Cooling Assembly.

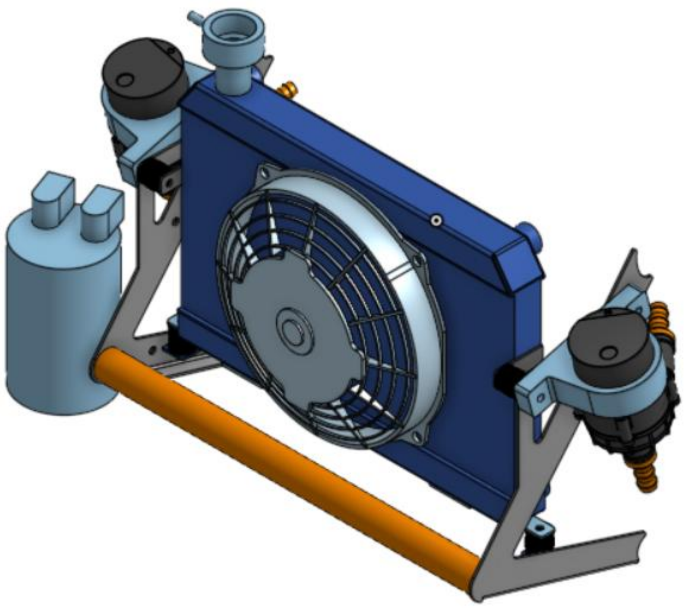


Figure 42. NU 24 Cooling Assembly

The Thermo Fan and Pumps are both powered by the Central Electronic Node (CEN) PCB.

There are two separate cooling circuits, one for the Motor and the other for the Inverter. However, the fluid is still mixed inside the Radiator. The NU 25 radiator which has already been designed and purchased, has a full split in the centre. This means there is no mixing and the circuits are split. The Motor reaches higher temperatures than the Inverter, and such with the current setup, as the circuits mix, the coolant on the Motor get cooled by the Inverter side coolant, which is in turn heated.

9.7.1. 2024 and Previous Engineers

In 2024 the Cooling Engineer was Jayden Hardinge. In 2023 it was Brock Symons [27].

9.8. Ergonomics

Ergonomics refer to the systems in the car that the driver comes into contact with. Namely these are the Head Restraint, Pedal Box, and Seat.

9.8.1. Head Restraint

The Head Restraint is a very simple assembly, however due to it being a safety device in the event of a crash it is always thoroughly checked in Technical Inspection. The Head Restraint Assembly is shown in Figure 43.

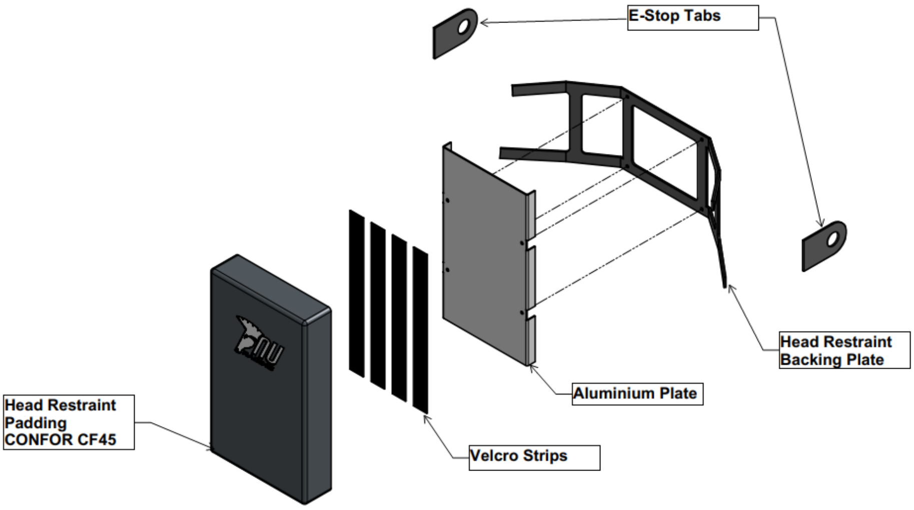


Figure 43. NU 24 Head Restraint

The role of the Head Restraint is to decrease the risk of injury of the driver's head or neck in the event of a crash. The Head Restraint Padding is a Fédération Internationale de l'Automobile (FIA) listed material called CONFOR CF45. It is listed in the FIA Technical List No 17, along with a list of businesses that sell the material [28], [29]. The padding is held in a fabric with the NU Racing logo on it, which allows Velcro Strips to be applied to it.

The position of the Head Restraint relative to the driver is extremely controlled and designed as it is always checked in Technical Inspection. In NU 24, the Head Restraint kept the same position that it had in 2023.

The FSAE rules also state that there must be one shutdown button on each side of the car “located aft of the driver’s compartment at approximately the level of the driver’s head”. For ease, two E-Stops are placed on the centre of the Head Restraint. The E-Stops are shown in Figure 44.

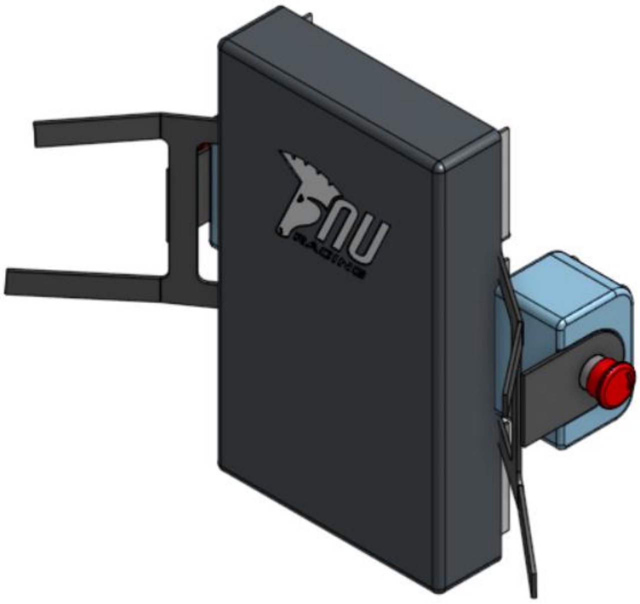


Figure 44. NU 24 Head Restraint with E-Stops

9.8.2. Pedal Box

The Pedal Box is arguably one of the most vital parts of the vehicle. It is where the Brake and Accelerator Pedals are housed. Owing to the modularity of NU 24, the pedal box is one serviceable unit that is easily removed with four bolts. The Pedal Box is shown in Figure 45 and an exploded, annotated view shown in Figure 46.

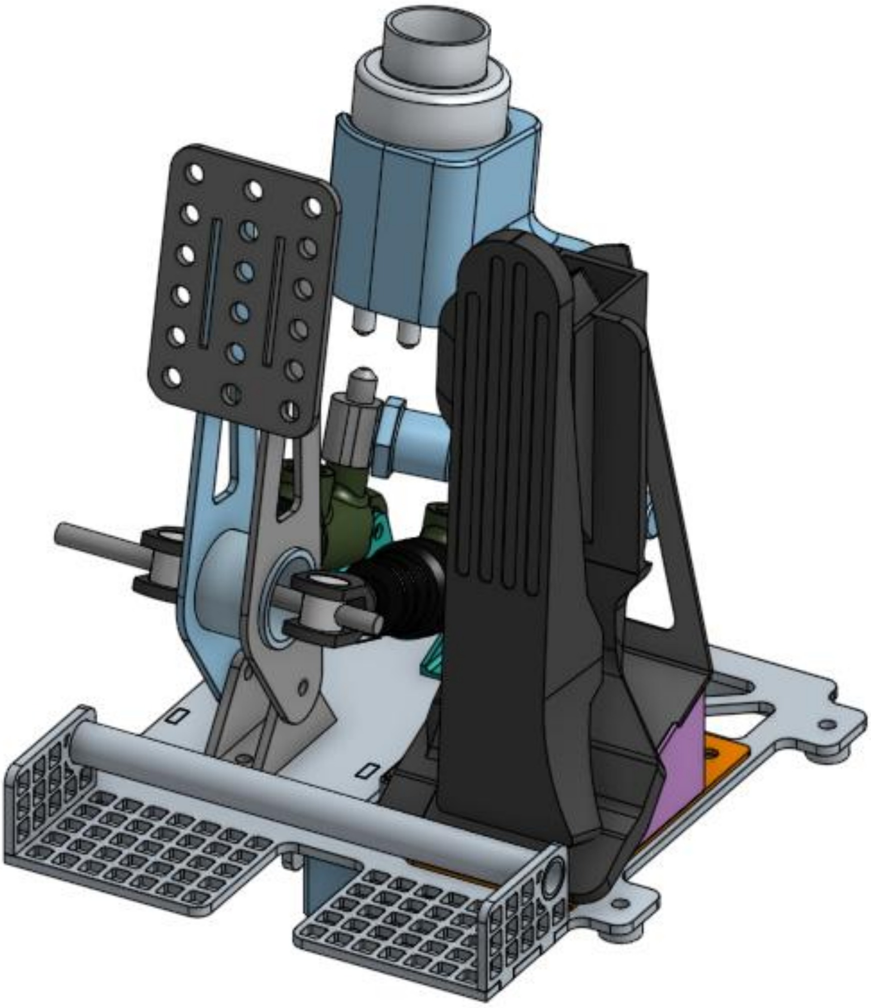


Figure 45. NU 24 Pedal Box

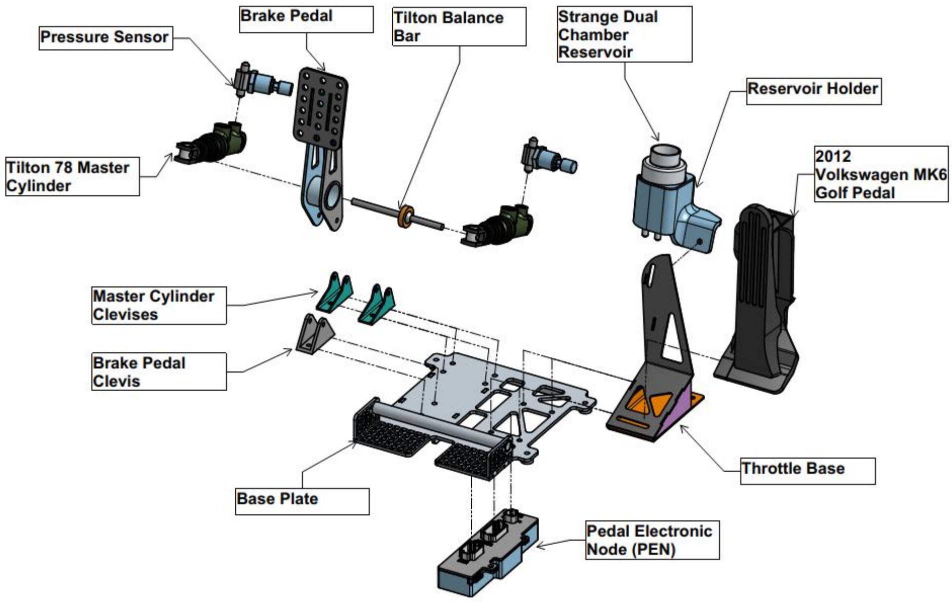


Figure 46. NU 24 Pedal Box Exploded View

NU 24's Pedal Box makes use of all of NU 23's Pedal Box except for the Base Plate, Pedal Electronic Node (PEN), and Reservoir Holder. The Base Plate was updated to suit the smaller Front Bulkhead of the Chassis. Due to the decrease in width of the Base Plate the Brake Reservoir Holder also had to be updated to suit.

9.8.2.1. Brakes

The Brakes make use of two Tilton 78 Master Cylinders with 5/8" bore that acuate the Front Brakes and the Rear Brakes on separate circuits. The Brake Balance, which is the distribution of braking force between the front and rear wheels, is manipulated by a Tilton Balance Bar. The Balance Bar is shown in Figure 47 and a diagram is shown in Figure 48.

Figure 47. Tilton Balance Bar [30]

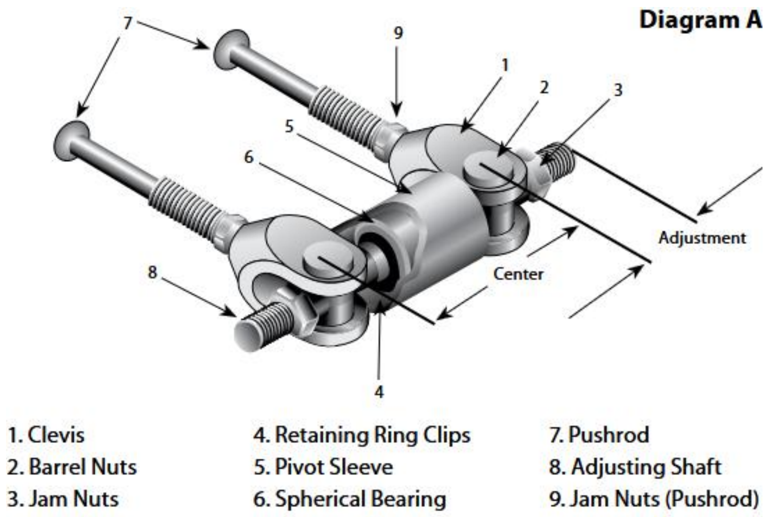


Figure 48. Diagram of Tilton's Balance Bar

The Balance Bar can be adjusted due to the Adjusting Shaft and Spherical Bearing. As the Adjusting Shaft is turned, the Spherical Bearing will move closer to one of the Pushrods. Whichever Master Cylinder the Spherical Bearing is closer to will receive more force. Figure 49 shows a Free Body Diagram that shows a Balance Bar slightly shifted to the right.

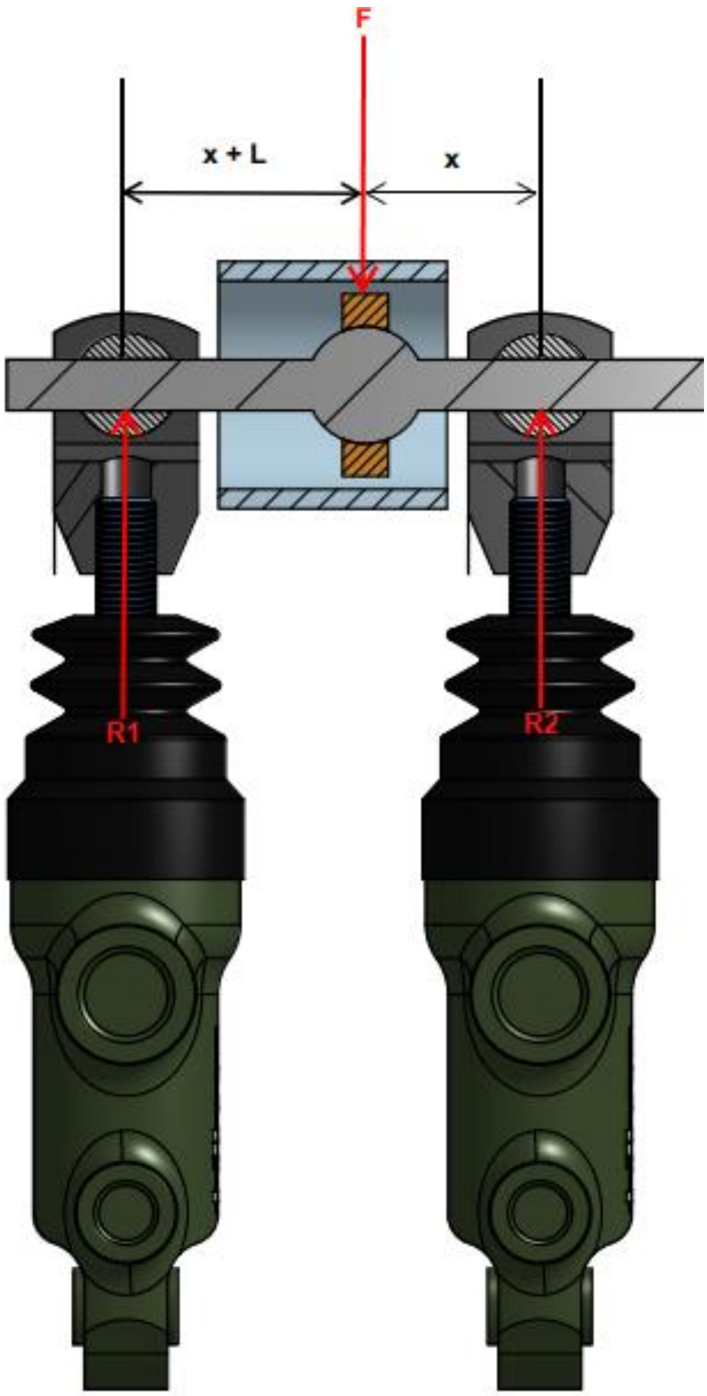


Figure 49. Brake Force Distribution from the Balance Bar

Assuming the pedal is static, for example being held in, the reaction forces at each pushrod can be calculated. Equations 1.1 and 1.2 show that for a given Pedal Force, F, the Master Cylinder Closest to the Spherical Bearing will receive the most force.

$$\sum M_{R1} = R_2(2x+L) - F(x+L) = 0$$

$$\Rightarrow R_2 = F * \frac{x+L}{2x+L} \tag{1.1}$$

$$\sum M_{r2} = F * x - R_1(2x+L) = 0$$

$$\Rightarrow R_1 = F * \frac{x}{2x+L} \tag{1.2}$$

$$\Rightarrow R_2 > R_1$$

It should also be noted that the Pivot Sleeve is welded into the Brake Pedal.

As there are two separate braking circuits which are isolated from each other, the Brake Reservoir is a dual reservoir. The reservoir is manufactured by Strange and is sold with a master cylinder with the part number B3370.

9.8.2.2. Accelerator

The Accelerator Pedal is an over the shelf (OTS) part from a 2012 MK6 Volkswagen Golf. This is because as an OEM part is has the functionality required by the FSAE Rules. The Pedal is mounted to the Accelerator Base which was designed and made by previous Chief Mechanical Engineer, Liam O'Neil [2].

9.8.1. 2024 and Previous Engineers

In 2024 the Pedal Box was made by the author. In 2023 the Pedal Box was made by Jye Hollier [3].

9.9. Aerodynamics

Following the success of NU 23's limited Aerodynamic devices, NU 24 also followed the same ideology. This was having a simple, easy to manufacture, low drag body-kit. It employed no wings or elements to produced downforce. The finalised Body Kit is shown in Figure 50

Figure 50. NU 24 Body Kit

The body-kit was manufactured in three stages. First a Foam Plug was purchased. This was then checked for large imperfections. These imperfections were filled with body filler, before being sanded back to leave a smooth finish.

Following this fibreglass moulds were made of the plug. These would be used to create the final fibreglass body-kit. Minor filling and sanding then took place before the Body Kit was test fit to the car.

The Body Kit was fixed to NU 24 through a combination of welded tabs to the Chassis and Quik Latch quick disconnects, an example of is shown in Figure 51 and Figure 52.

Figure 51. Quik Latch Connector

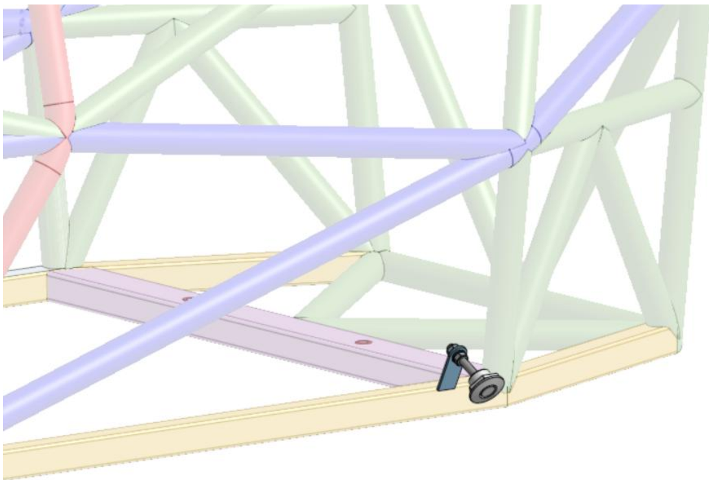


Figure 52. Example of the Body Kit Tabs

The Body Kit Tabs were welded to the car first, then the Quik Latch pins were fasted to the tabs. From this the Body Kit was placed over the Chassis and the position of each pin was marked on the inside of the Body Kit. From here a pilot hole was drilled from the inside out, before the hole for the Quik Latch connector was hole sawed from the outside in.

After this the Body Kit was sent off for painting.

9.9.1. 2024 and Previous Engineers

In 2024 the Body Kit was designed and made by Joshua Wenham. In 2023 the Aerodynamics Engineer was Mitchell Boots [31].

9.10. Low Voltage

NU 24 makes use of the 5 Nodes which are separate PCB's. Each has a certain function and all relay back the Central Electronic Node (CEN) which is also referred to as the Motherboard.

The function of each Node is discussed in Alec Chapman's report [32].

NU 24's Low Voltage Topology is shown in Figure 53.

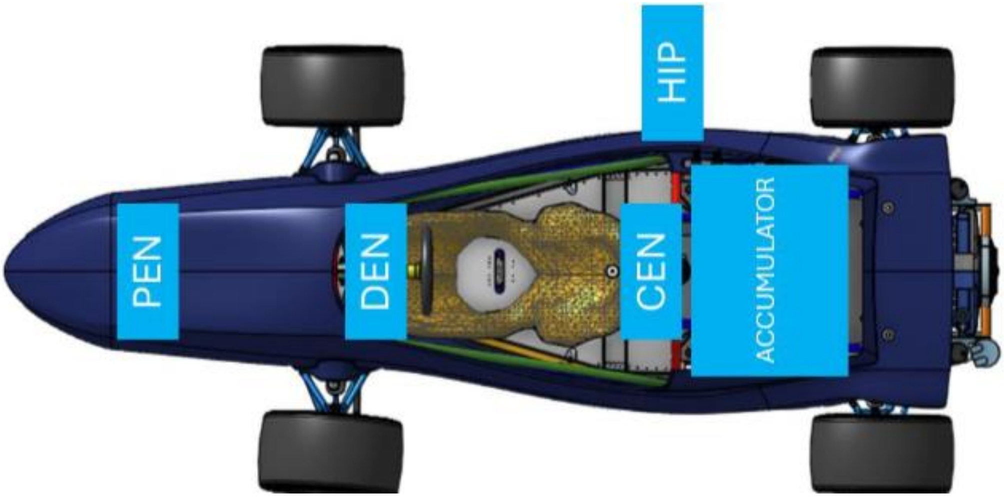


Figure 53. NU 24's Low Voltage Topology [32]

Each PCB requires an enclosure to be mounted and waterproofed for competition. Each enclosure, except the Accumulator Enclosures that are required to be UL94-V0 and have a higher glass transition temperature, are made from PETG. These are designed and printed by the Mechanical Department.

As an example, the CEN enclosure is shown in Figure 54.

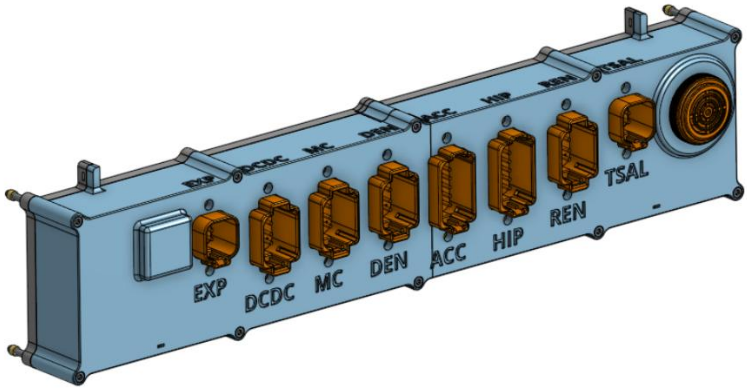


Figure 54. CEN Enclosure and PCB

10. Mechanical Lead

The Chief Mechanical Engineer in an ideal world would be mostly a management role, that spends most of their time making design decisions and reviews. However, with a small team size this cannot always be the case and the Chief Mechanical Engineer in previous years has been required to manage a large workload. This is also because the responsibility of every mechanical system or part falls to the Chief Mechanical Engineer. The author fell into this role once again and hopes dearly for the successor of the role that there are enough resources to delegate tasks effectively.

10.1. Drivetrain

Due to NU Racing's change to a build first, design second philosophy in 2024 this meant that the design for the NU 24 Drivetrain (also referred to as the Powerbox) was already designed by previous Chief Mechanical Engineer Jye Hollier [3]. This design was yet to be validated in any capacity but was not far from a finalised design. The Drivetrain Engineer for 2024 was Rishi Mathuria [12]. The following scope of work was completed by the author. Work that was completed by Mathuria is acknowledged in this report.

The initial Drivetrain design can be seen in Figure 55.

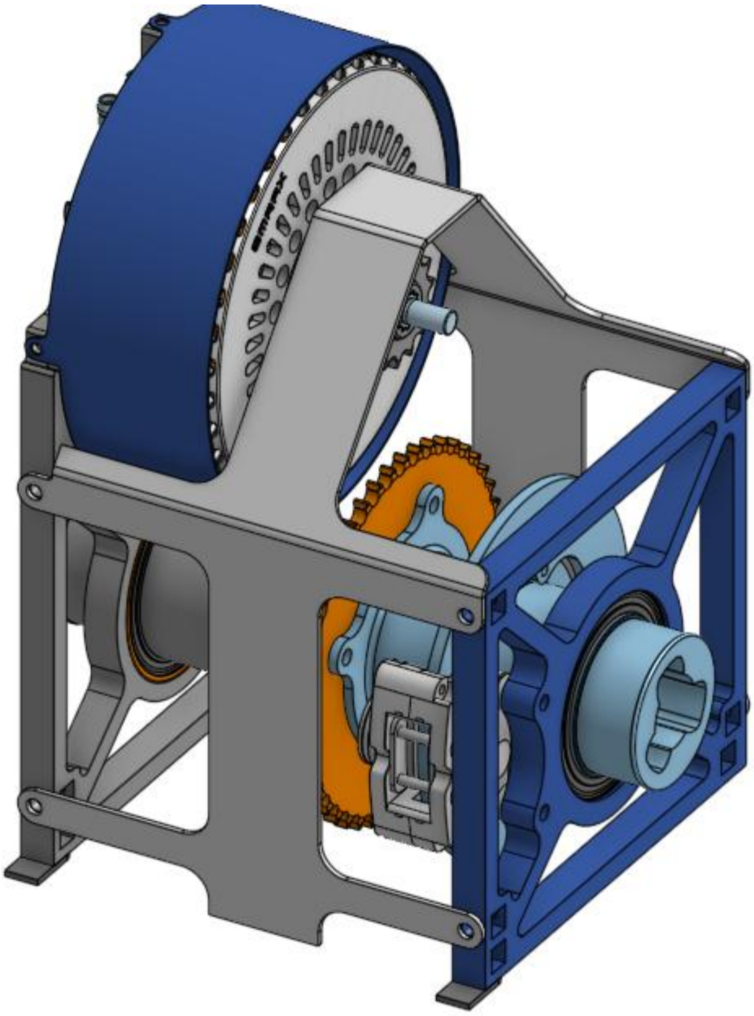


Figure 55. NU 24 Drivetrain Initial Design by Jye Hollier [3]

10.1.1. State of the Art

The forces experienced on the Drivetrain are largely due to the size of the driving sprocket and the motor torque. The maximum force from the torque is shown in Equation 3.1.

$$F_{max} = \frac{2T_{max}}{D} \qquad 3.1$$

Where T_{max} is the max motor torque and D is the pitch diameter of the driving sprocket. The pitch diameter can be found from the chain pitch and number of teeth as shown in Equation 3.2.

$$D = \frac{p * N}{\pi} \qquad 3.2$$

The chain used for the Drivetrain, for both 2024 and 2023 was a RHK Gold 428 Chain, which has a 6,600lb ≈ 29.3 kN rating. It has a pitch of 12.7 mm.

10.1.1.1. NU 23 Drivetrain

NU 23's Drivetrain featured a Emrax 188 that was capable of 100 Nm of torque and max power of 60 kW [5]. The drivetrain is shown in Figure 56.

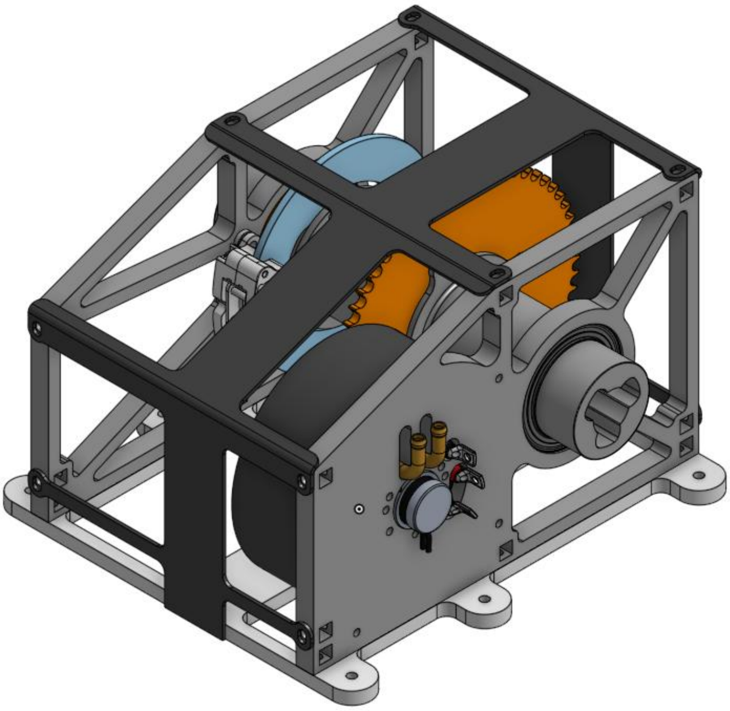


Figure 56. NU 23 Drivetrain

The final drive ratio was 11:60 and resulted in a wheel torque of 545 Nm and top speed of 91.3 km/h. It was an elegant improvement on the drivetrain of EV.Three and proved a huge success in competition. It was designed by Jye Hollier and Rene Sturmberg in 2023. Figure 57 shows the breakdown of the Drivetrain.

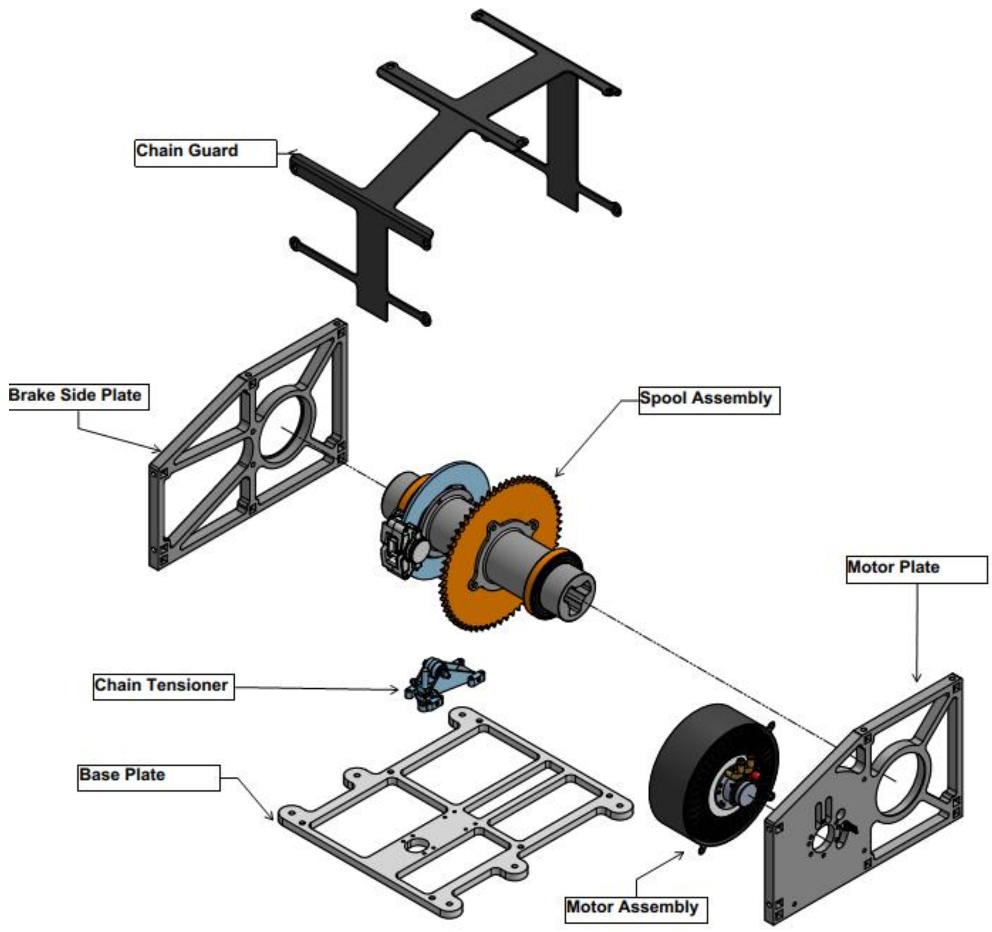


Figure 57. NU 23 Drivetrain Exploded View

As the motor torque was only 100 Nm the maximum force from the motor torque was approximately 4.5 kN.

In 2023 through testing different gear ratios, which was easy due to the adjustable chain tensioner, the ideal gear ratio was selected. Through this it was also discovered that the chain tensioner wasn’t required with the right centre to centre distance between the Motor Assembly and Spool Assembly.

NU 23’s drivetrain was both traction and speed limited. It did not have the ability to break traction off the line in acceleration runs, and once up to speed would hit the RPM imposed limit on the motor which was approximately 6500 RPM. Due to this the clear goal for 2024 was to increase the torque output from the Drivetrain.

10.1.2. Initial Design

NU 24’s initial design shown in Figure 55 borrows a lot of characteristics from NU 23’s drivetrain. It used the same methodology of keeping the drivetrain as an enclosed modular unit that could be removed from the car easily and it was made from simple to manufacture parts. The Brake Caliper mounting, Spool design, and the Chain Guard design all remained similar.

The Emrax 228 is 5.3 kg heavier than the Emrax 188, so an effort was made to minimise the weight of the assembly. This included the removal of the base plate and chain tensioner. The decision was also made to place the Motor Assembly over the Spool Assembly to help decrease the wheelbase of NU 24.

The final drive ratio of the Drivetrain, selected by Jye Hollier and Dr Alexander Gregg, was changed to offer larger wheel torque and speed. The selected gear ratio was 14:46 and corresponded to a torque output of 755 Nm and a theoretical top speed of 151.5 km/h [3].

Due to the larger motor torque and larger driving sprocket than NU 23’s design, the loading conditions for NU 24’s Powerbox had increased quite dramatically. The Drivetrain had a maximum force from the motor torque of 8.1 kN.

Due to this it was immediately apparent that the proposed design was not going to be strong enough to handle the bending moment induced on the Motor Plate by the chain tension. Jye Hollier recognised this and provided a potential solution to remedy this issue. This is shown in Figure 58.

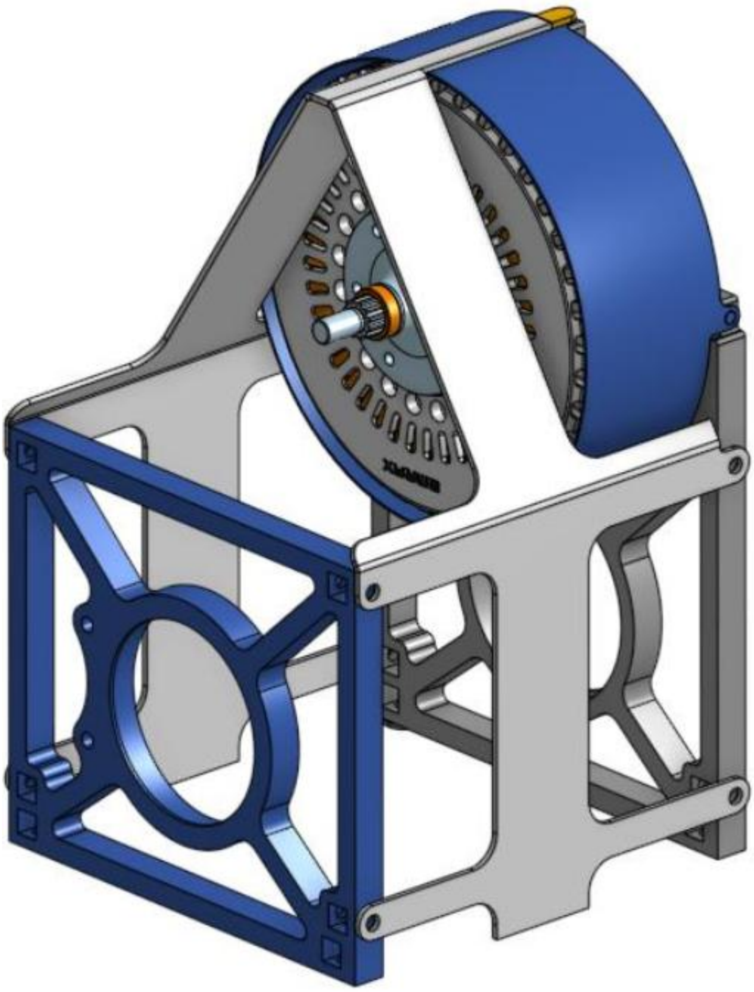


Figure 58. NU 24 Initial Design Chain Guard Support.

The idea to support the Motor Plate with the Chain Guard did make sense, however there was still doubt over the capability of the design.

10.1.3. Drivetrain V1

Initial FEA completed by Rishi Mathuria indicated that the Drivetrain could handle the stresses from the loading conditions but struggled to reduce deformation of the Motor Plate under load. To decrease this, Hollier's advice was followed and Mathuria adjusted the model to use the Chain Guard as a structural piece to increase the stiffness. The FEA from the resulting design is shown in Figure 59.

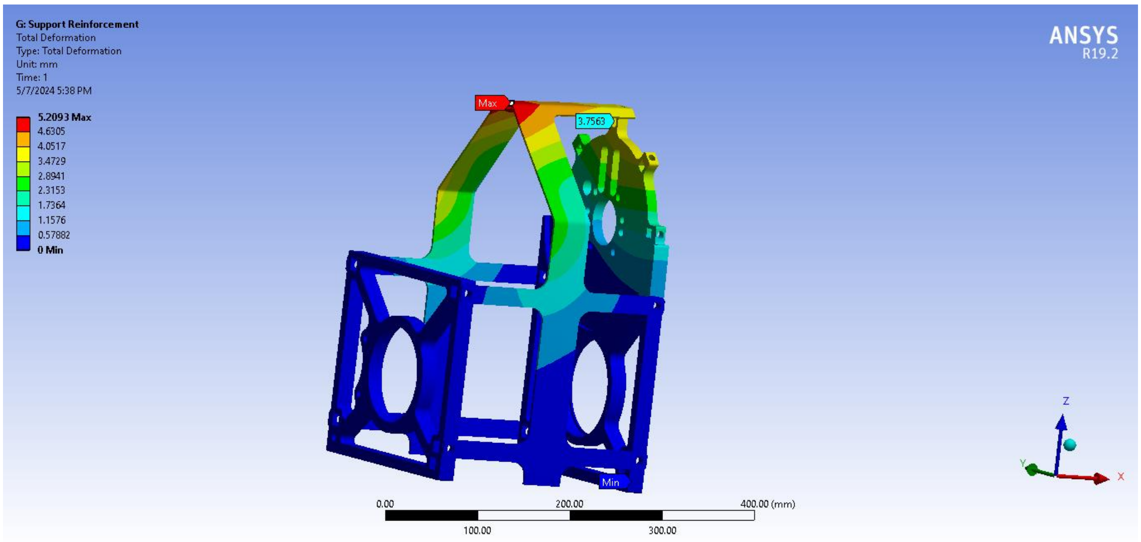


Figure 59. Drivetrain FEA conducted by Rishi Mathuria [12].

The deflection at the top of the Chain Guard and the Motor Plate was still extremely high at over 5 mm. The author had concerns of the Motor Plate bending sufficiently such that motor hit the Chain Guard, or that the Chain would be able to slip off the driving sprocket and NU 24 would lose drive.

The author asked Mathuria to extend the Brake Plate higher and bolt the Chain Guard to it. This was hoped to share the load between both plates and restrict deflection. After multiple models were created by Mathuria, the author created the model shown in Figure 60.

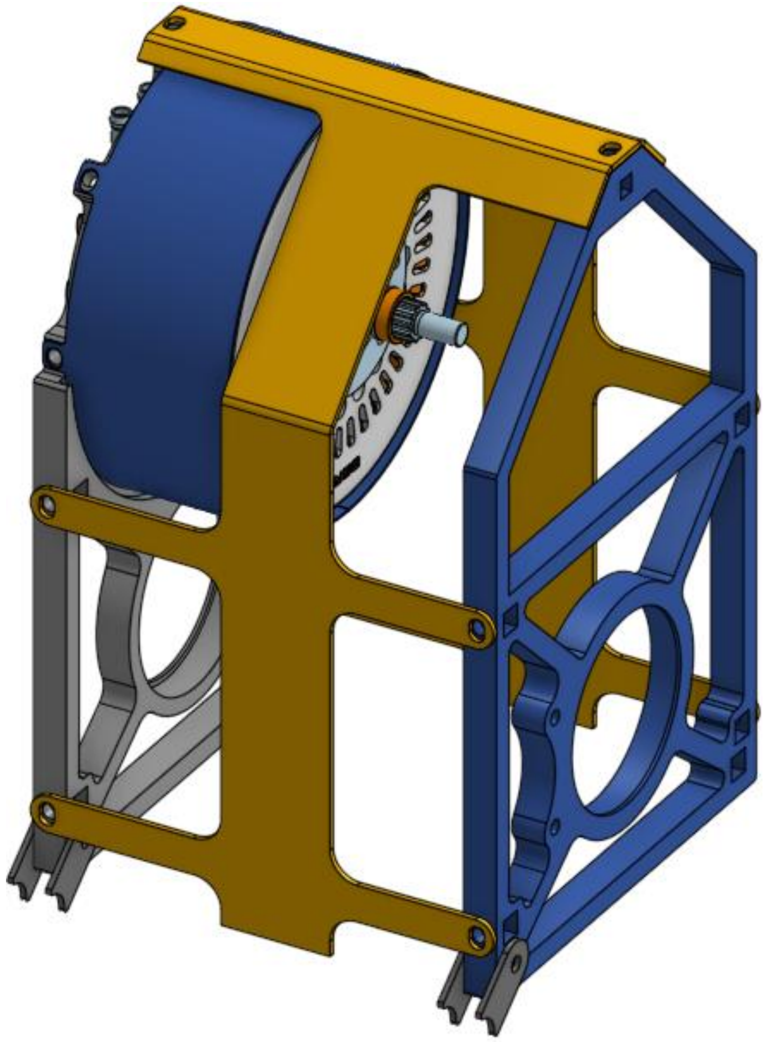


Figure 60. NU 24 Drivetrain V1

Alternate models were created that experimented with adding material in the top cavity of the Brake Plate, however this seemed to make no conceivable difference. The thickness of the outer profile had the largest effect. FEA completed by Mathuria showing the deformation of the Motor Plate is shown in Figure 61.

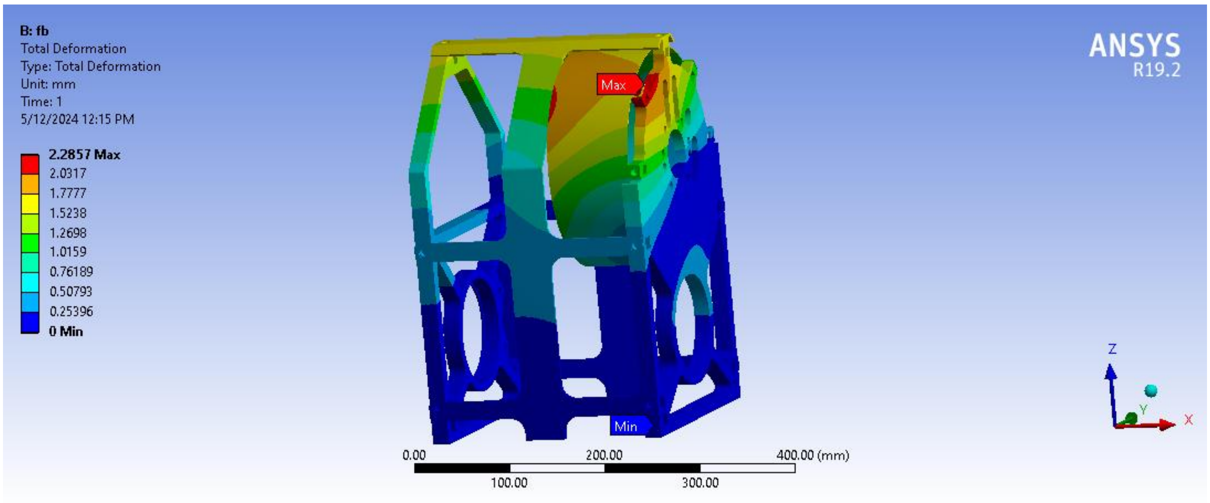


Figure 61. Total Deformation of NU 24 Drivetrain V1 [12]

There was still 2.3 mm of total deformation. The author was concerned of this and wanted to look at an alternative method of restraining the deflection of the Motor Plate. It was fast approaching the NU Racing goal of driving EV by June 30th. The author was implored by alumni and previous NU Racing Advisor Dr Alexander Gregg to trial the designed solution as a prototype. The manufacture of the Motor and Brake aluminium plates had a quick turn around and the aluminium was free from Calm Aluminium, so the decision was made to test with the current design, dubbed V1, and make another Drivetrain if required.

A piece of advice the author received from Jye Hollier was that time spent fixing known issues from a prototype is far more valuable than time spent focusing on potential issues considered during design.

An exploded view of the Drivetrain V1 is shown in Figure 62.

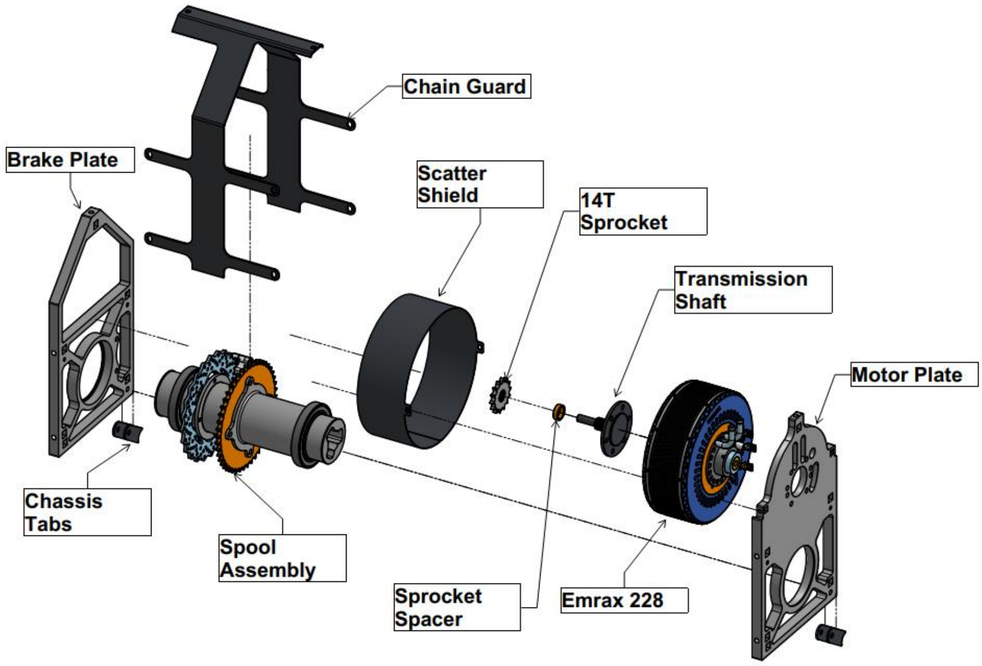


Figure 62. NU 24 Drivetrain V1 Exploded View

The material for the Motor and Brake Plate was 6061-T6 Aluminium plate of ¾” (19.05 mm) thickness. To reduce weight and ensure the plate was square it was milled down on both sides to achieve an 18 mm thickness by the Prototyping Workshop. The plate was then taken to MW on campus where it was waterjet cut. The waterjet cut plate is shown in Figure 63.

Figure 63. Waterjet Cut Motor and Brake Plate V1

A few changes were made by the author to the model before the aluminium plates were sent off to get waterjet cut. The bearing holes where the Spool Bearing is mounted was decreased in diameter. This still removed majority of the material but meant that the waterjet cutter was not close to the final bearing diameter. Before this a conversation was had between the author and a machinist from the Prototyping Workshop and they recommend removing greater that Ø15 mm from the final diameter. The author removed Ø16 mm.

Both plates make use of captive nuts to increase the serviceability of the Drivetrain. These are highlighted on the Motor Plate in Figure 64. These are used to fasten the Chain Guard and mount the Drivetrain to the Chassis. Initially these were made at 13.5 mm across the flats. The nuts used in this application are M8 x 1.25 mm and are measured at 13 mm across the flats. The captive nut holes were changed to 13 mm as the waterjet cutter is not a precise manufacturing method and removes more material that is designated by the DXFs. Due to this, when cut at 13 mm, the M8 nuts fit perfectly. It should also be noted that holes or subtractive features should be made with a smaller hole if there is any uncertainty. A smaller hole can always be bored out further.

To ensure that the base of the Drivetrain was square, 2.5 mm was added to the base of each plate prior to waterjet cutting. It should be noted that the Chassis members the Drivetrain sit on are not perfectly square and this could have been skipped, but the author decided there was no reason not to proceed with it.

The Motor Plate, Chain Guard, and Chassis Tabs were all waterjet cut following these changes.

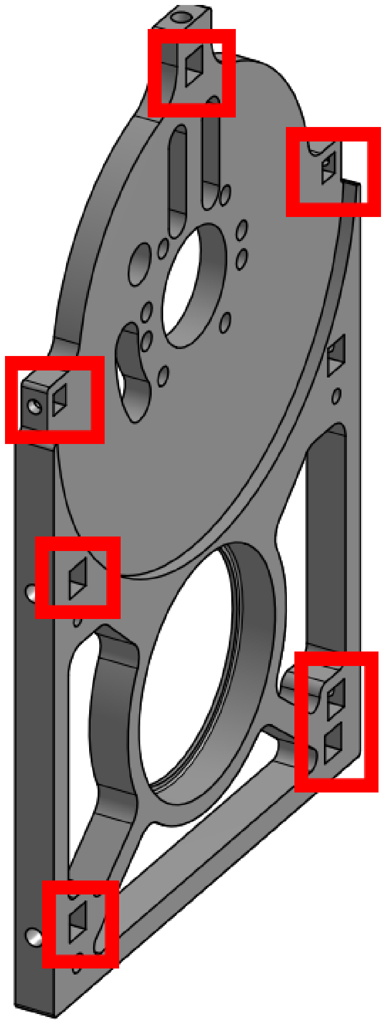


Figure 64. Drivetrain V1 Captive Nut Holes

Following the waterjet cutting of the plates, manufacturing drawings where required to submit to the Prototyping Workshop. Mathuria had supplied the first set of drawings, however they required largescale changes and additional sheets which the author completed. These are shown in 15.1 Appendix A – Drivetrain V1 Manufacturing Drawings.

The Motor and Brake Plate then required to be milled to manufacture the bearing tolerances and Motor mounting holes. The Motor Plate was manufactured flawlessly.

After the Brake Plate was fixed in the Mill and the operator was aligning the datums of the Brake Plate it was noticed that on one side the captive nut holes and the Brake Caliper mount holes were 5 mm higher than what they were meant to be. The author immediately checked the

DXF that was used for waterjet cutting assuming that a modelling error had occurred. The DXFs measured accurately and had no issues, and it was theorised that the Brake Plate had been moved by the head of the waterjet cutter during the process. During waterjet cutting it was reported that there was not enough excess material in the blank plate surrounding the profile of the Brake Plate. When waterjet cutting the material is only rested on the bed and weights are used to restrict motion. The weight can rather be placed on top of the workpiece or around it. The machinist used the Brake Plate as a practise run to ensure that the tooling for the bearing pocket was sufficient, but the piece was useless, and another one had to be manufactured. The Brake Plate is shown in Figure 65.

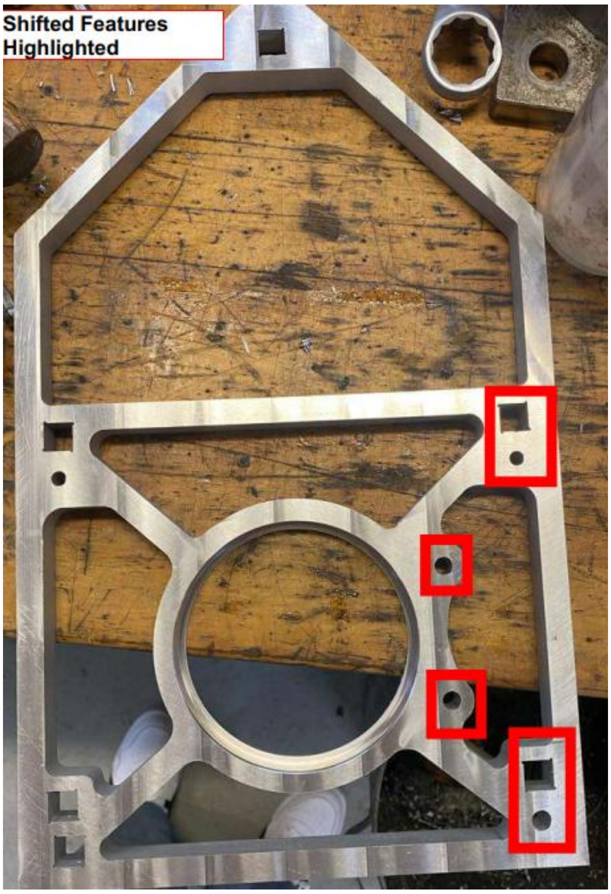


Figure 65. Drivetrain V1 Waterjet Cut Shifted Brake Plate

The method in which the MW waterjet cutter operates is that is cuts all the inner profiles first then the large outer profiles last. This is why only the highlighted features of Figure 65 are clearly shifted, whereas the outer and inner profile look unaffected.

Luckily, NU Racing had requested four plates from Calm Aluminium. This meant that another Brake Plate was immediately thinned to 18 mm then waterjet cut. The author and Jye Hollier completed the waterjet cutting, and the Brake Plate was more effectively braced. This worked and the Brake Plate manufacture was finished by the Prototyping Workshop.

Before the Drivetrain was ready for commission the Chain Guard, Scatter Shield, Spool Assembly, and Transmission Shaft needed to be manufactured.

The Chain Guard and Scatter Shield were both sent to Hancock Speedway for manufacture and returned with no issues.

The Transmission shaft followed the design of EV.Three’s however was increased in size to suit the Emrax 228 [2]. The Shaft was designed with an ‘blank’ area where the spline was required for the sprocket. This is shown in Figure 66.

Figure 66. NU 24 Transmission Shaft with 'blank' for Spline

The blank left for the spline manufacture introduces a stress concentration on the shaft. This introduces a considerable torsion and bending load on the part. To ensure that the Transmission Shaft could sustain these stresses the author did FEA and validated it through hand calculations. The FEA loading conditions are shown in Figure 67 and the results in Figure 68.

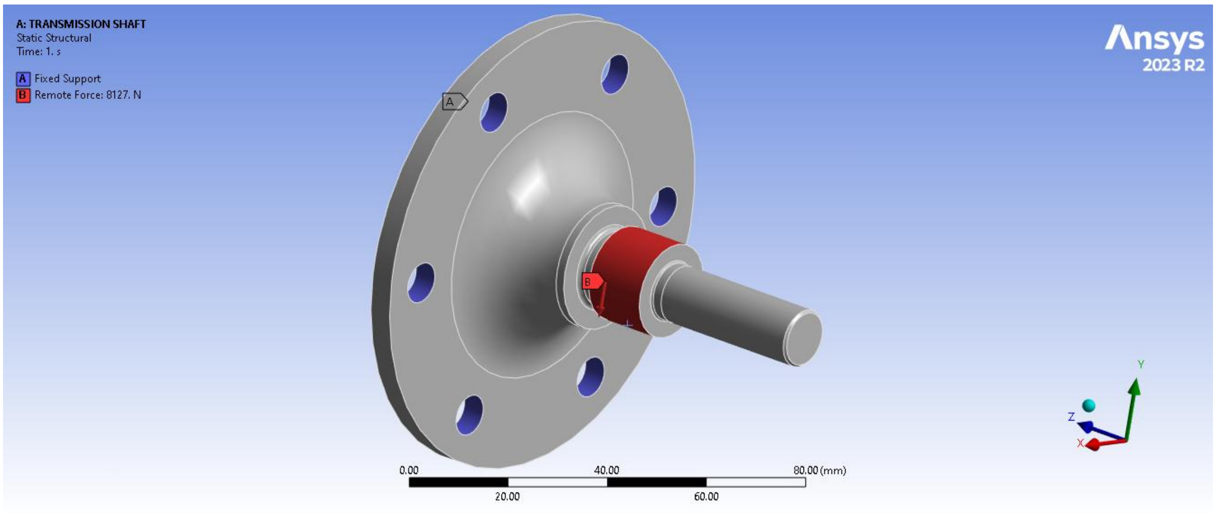


Figure 67. FEA Loading Conditions of the Transmission Shaft

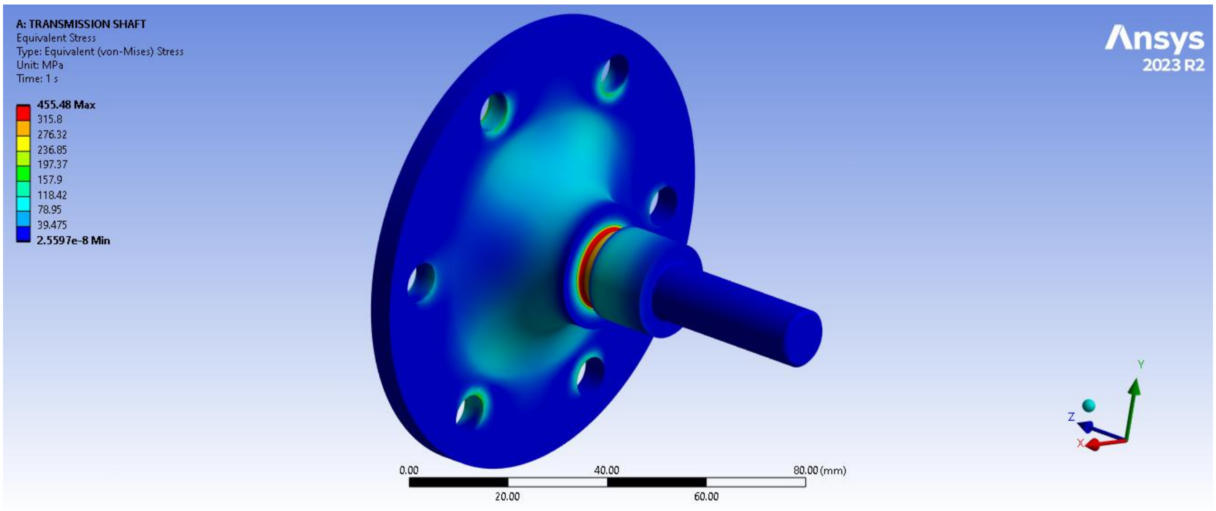


Figure 68. FEA Von Mises Stress on the Transmission Shaft

As shown in Figure 68 the maximum stress is 456 MPa.

The Transmission Shaft was designed to be made from 4140 steel from the steel racks in the Prototyping Workshop and such the exact material properties of the material where not known. When designing critical parts exact details, such as yield stress, must be retrieved from the manufacturer. As the manufacturer was not known, this was not possible. Common values of the minimum yield stress of 4140 steel are 700 MPa [33].

Hand calculations, which are shown in 15.6 Appendix F – Transmission Shaft Hand Calculations, showed that the Von Mises Stress for the Transmission Shaft was 550.94 MPa.

This is a 16% difference from the FEA. The difference was believed to be a result of the combined loading of the shaft. As this Drivetrain was considered a prototype at this stage, this was deemed acceptable by the author and manufacture proceeded.

For the spline of the Transmission shaft, as recommended by Hollier, Newcastle Gears were approached and asked about the job, if the spline manufacture was possible with the designed part and what other details they required. Newcastle Gears said the design was great and they had the spline details from when EV.Three's Transmission Shaft was made. The author Newcastle Gears with the 14T Sprocket to ensure the fit of the sprocket onto the spline.

The Transmission Shaft was manufactured by the Prototyping Workshop then supplied to Newcastle Gears to cut the spline.

Due to the increased motor torque the author had concerns about the wear on the spline from the 14T sprocket. Due to this it seemed reasonable to get the Transmission Shaft case hardened. Upon consulting Newcastle Gears it was learned that 4140 steel cannot be gas hardened and gas nitriding was suggested instead.

Gas nitriding is a process where nitrogen gases, typically ammonia, are diffused onto the surface of a ferrous metal [34]. It increases the hardness and durability of the surface of the metal and does not impact the properties of the core [35].

The author decided gas nitriding the part made sense. Newcastle Gears had other parts being heat treated and were kind enough to send the Transmission Shaft with those, at no extra cost to NU Racing.

The final Transmission Shaft can be seen in Figure 69.

Figure 69. NU 24 Transmission Shaft following Gas Nitriding

The Spool Assembly only had small changes from the initial design which is shown in Figure 70.

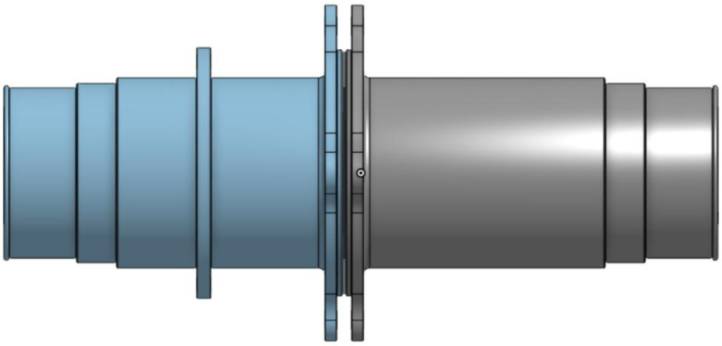


Figure 70. NU 24 Spool Initial Design. (LHS Brake Side Tripod Housing, RHS Drive Side Tripod Housing)

The only design change was to increase the manufacturability of each side of the Spool. Both sides had small lips to make it easier to retain the CV Boots used to hold grease inside the tripod housings. The only issue it created is for the Drive Side Tripod Housing, the left housing in Figure 70. During machining a tool change would have been required on the lathe due to the angle of the lip. This angle was reduced to allow a right-handed tool to be used for the entire process. Upon conversation with a machinist from the Prototyping Workshop, an angle of 65 degrees was used. This is shown in Figure 71.

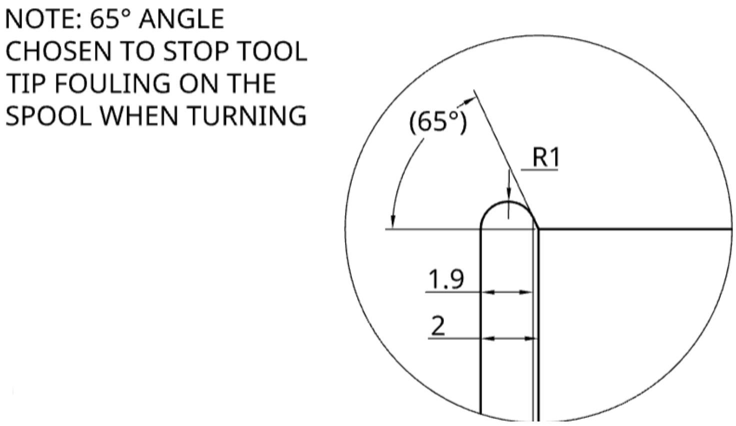


Figure 71. Spool CV Boot Lip Dimensions

Both Tripod Housings were manufactured from 6061-T6 Ø152.4 mm Round Bar and are shown in Figure 72.

Figure 72. Manufactured Drive Side Tripod Housing (left) and Drive Side Tripod Housing (right)

Once the Spool was manufactured, the Drivetrain was fully assembled prior to weldment of the Chassis Tabs. This is shown in Figure 73.

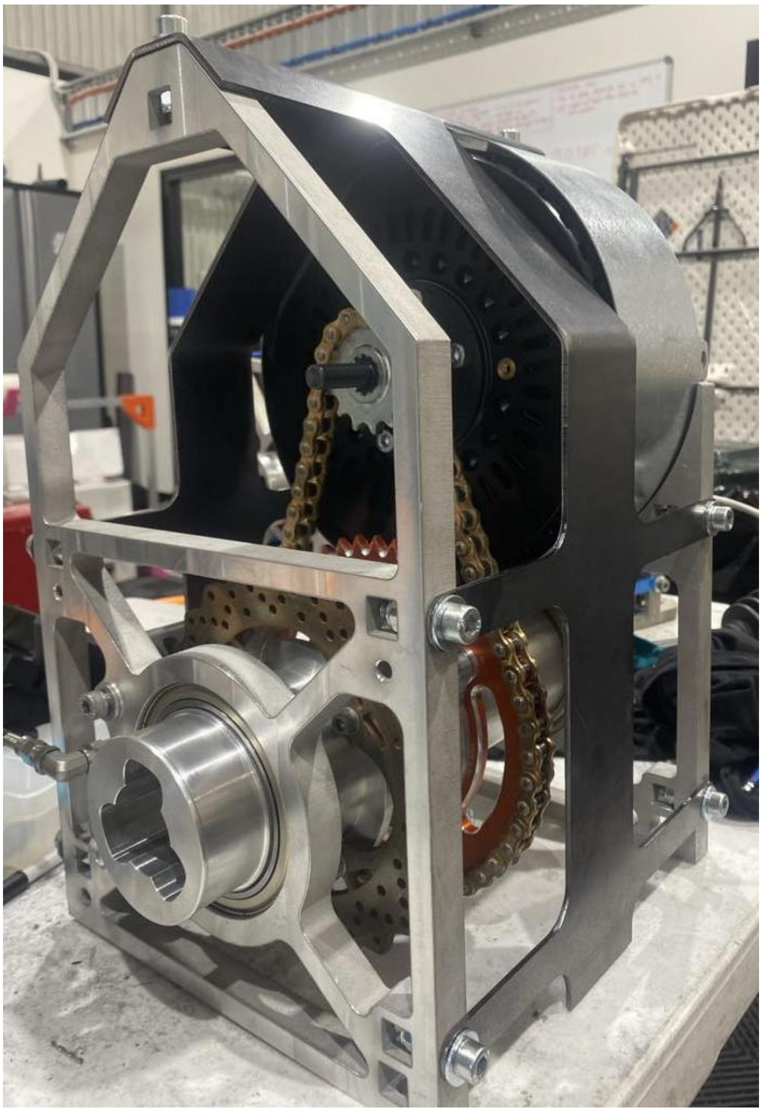


Figure 73. NU 24 Drivetrain V1 Assembled

The Drivetrain was assembled with no issues, and the centre-to-centre distance from the Transmission Shaft to the Spool allowed the correct chain tension. The Drivetrain was immediately disassembled to remove the Motor Assembly to allow the Powerbox to be used to weld the Chassis Tabs in situ. This is shown in Figure 74.

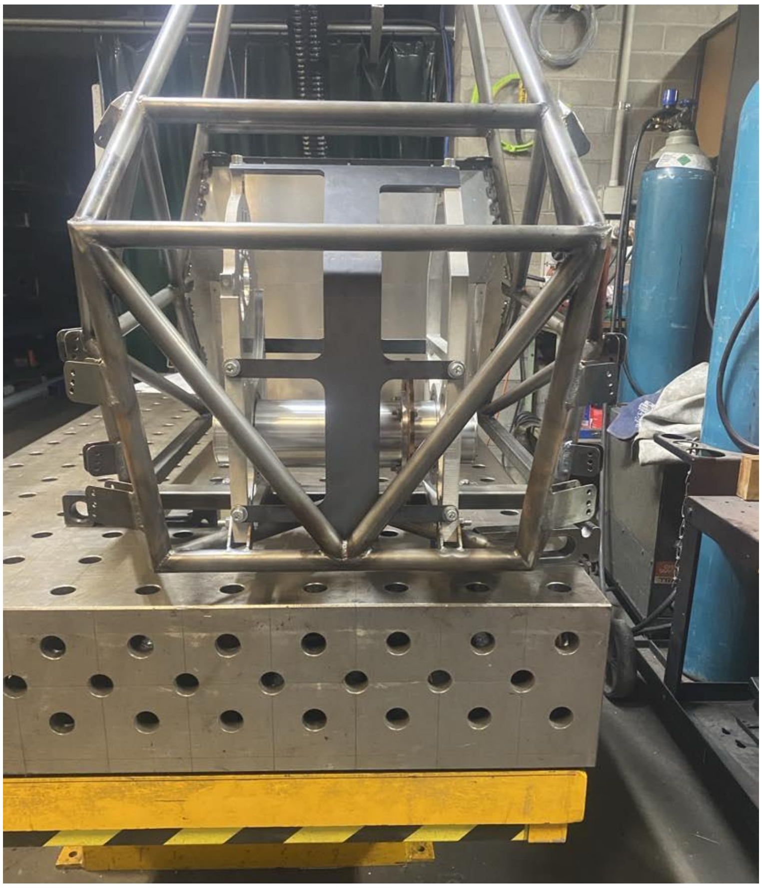


Figure 74. Drivetrain Tab Weldment

10.1.3.1. Drivetrain V1 Performance and Evaluation

The Drivetrain was used for NU 24's first drive was on the 13th of July at the ICT Carpark on campus, two weeks after the June 30th driving goal. The Motor torque was limited and increased at intervals after the team was satisfied. The maximum torque request from the Motor Controller was 160 Nm and the speed limiter was set at 3000 RPM. There were no issues with the Drivetrain at this time, however it was only 70% of the maximum torque so no lessons were truly learnt.

Another track day was not booked until August 3rd where the Motor Controller faulted and ceased operation. NU 24 did not drive again until October 28th again due to this issue. This was three months of lost testing time and left the team with 5 weeks until competition to complete thorough testing and tuning of NU 24.

Once the Motor Controller broke, and it was unknown how much testing time would be available, the author decided that there would not be enough testing time to ensure that the first Drivetrain iteration would be able to handle full torque and instructed Mathuria to change the design to utilise an additional Chassis Tab, instead of the Chain Guard and Brake Plate, to prevent deflection of the Motor Plate. This marked the end of the Drivetrain V1.

Due to the time it took Drivetrain V2 to be commissioned, as discussed in 10.1.4 Drivetrain V2, Drivetrain V1 was used for six track days throughout three weeks prior to competition.

As the main concern was the 228 hitting the Chain Guard the author measured the original distance between the Chain Guard and the Motor face and taped a piece of cardboard overhanging the edge of the Chain Guard. The Motor Plate was only suspected to return close to or at its original position after a high torque application. Because the only way to see the deformation was whilst the car was driving this was used such that if the cardboard had noticeably hit or rubbed against the Motor it would be visible. A GoPro was also attached to the chassis member above the Drivetrain, however during running due to vibrations nothing could be clearly seen in the footage. This is shown in Figure 75.

Figure 75. Motor Plate Deflection Check

On October 28th NU 24's first shakedown was an endurance style drive that lasted 15 minutes. The driver slowly increased speed and accelerator usage. Throughout the drive no issues were apparent. In the pits it was evident that the Motor had moved closer to the Chain Guard and the cardboard was deteriorated. This is shown in Figure 76.

Figure 76. Motor and Chain Guard Interference Check

Due to this the author requested that the torque was limited to 180 Nm. This was kept for the rest of the track day. For the next track day, the torque was limited to 140 Nm to ensure that the Motor Plate would not see excessive load as the car was 'going through the paces', doing mainly endurance testing as there were many electrical issues the car was dealing with.

It was kept this way until November 11^{th} where Autocross, Acceleration, and Skid Pad training and testing begun. The torque was only increased to 160 Nm, which equated to 526 Nm of wheel torque.

On the November 14^{th} track day there was a large banging noise that was heard from NU 24 during the same part of the track consistently, where there was a dip in the track. During Autocross training.

Due to the mounting of NU 24's Accumulator the mounting bolts where the lowest point of the Chassis. The height of the head of the M8 Socket Head Cap Screw was 8 mm lower than the Primary Structure. This is shown in Figure 77.

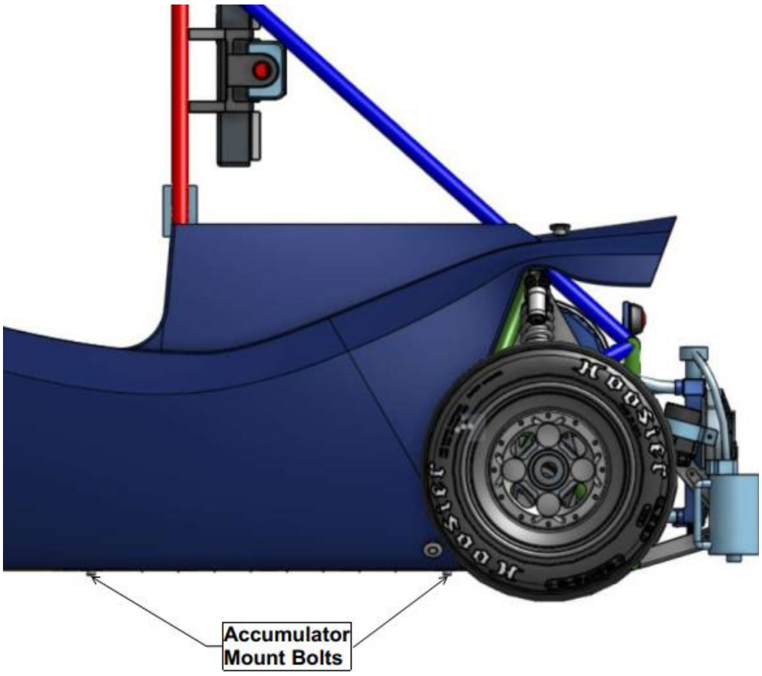


Figure 77. Accumulator Mount Bolt Position

As the noise was heard in the same spot every time it was assumed that the Accumulator Bolts were hitting the ground. When the bolts were inspected there was only one bolt that had clearly hit the ground and not the others. The ride height of the vehicle was increased and driver sent out again. The same noise was heard again in the same spot. Immediately the driver was called in and the author inspected the vehicle. There was no more wear on the Accumulator Bolts. Instead, the author saw that the Motor had hit the Chain Guard as there were score marks on both parts. Immediately the torque was limited to 140 Nm and the issue ceased. This meant that the Drivetrain was only able to output 460 Nm of wheel torque, which was considerably less that NU 23's 545 Nm.

Upon disassembly of the Drivetrain, it was noted that the Spool Assembly, in particular the Tripod Housings were significantly bruised as a result of the higher torque. It is believed this bruising happened during the few runs at full motor torque. This is shown in Figure 78.

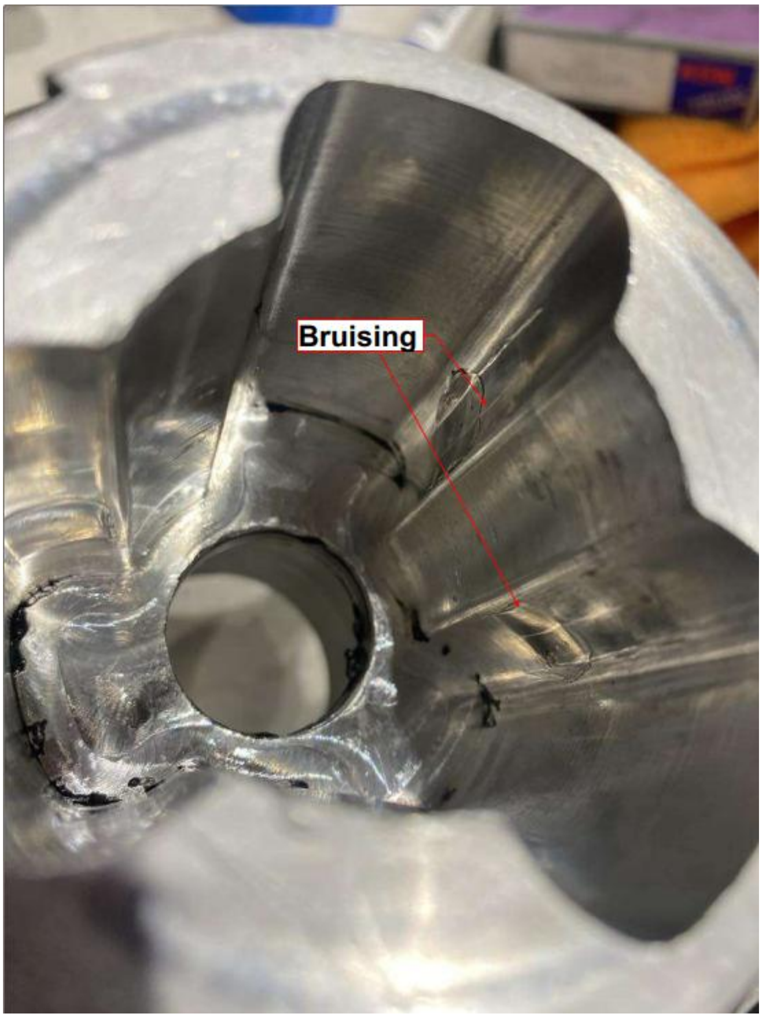


Figure 78. Tripod Housing Bruising

This was not a huge surprise as the Tripod Housing's were made from 6061-T6 Aluminium, typical Brinell Hardness value of 95 [36], and the Tripods are made from a 4340 steel, minimum Brinell Hardness value of 248 [37]. The hardness difference between the two meant that the Tripod Housings were always going to deform first, which was known. However, difficulty arose when removing the Driveshafts from the housings. Due to the bruising there were raised edges above where the Tripods were seated, meaning they could not slide out as required. This made disassembly difficult. Two of the Tripods had to be pulled out of the Tripod

Housings at different parts of the year. This was not as big an issue in the Spindles as the fit for the Tripods was a lot looser than the Tripod Housings. This meant that there wasn't as much material displaced by the bruising. To reassemble the Driveshaft and the Tripod Housings the inside of each Tripod Housing was sanded down with varying grits of wet and dry sandpaper to remove the raised edges. This allowed the Tripods to be fully inserted into Tripod Housings as they were intended.

It should be noted that initial fit for the Tripods was a beautiful precision fit. This may not be ideal due to this bruising and if the part is manufactured again the tolerance around the Tripod should be investigated and perhaps increased.

Circlips are used on either side of the Tripod on the Driveshafts to stop the Driveshaft falling out. The last time the circlips were replaced, rather in 2023 or 2022, they were changed with the wrong thickness circlip, which meant that the Tripod could free itself off the driveshaft and remain stuck in the Tripod Housing. These were replaced with correctly sized circlips.

10.1.4. Drivetrain V2

In retrospect, with the limited resources, the author should have immediately commenced manufacture on the Drivetrain V2, however was convinced to not rush into manufacturing without giving the Mechatronic Department time to solve the issue. The hope was that the Motor Controller could be fixed and Drivetrain V1 would still have time to be fully tested. This was not the case and at the start of October the author advised Mathuria that the Drivetrain V2, shown in Figure 79, needed to be prepared for manufacture as time before competition was too close.

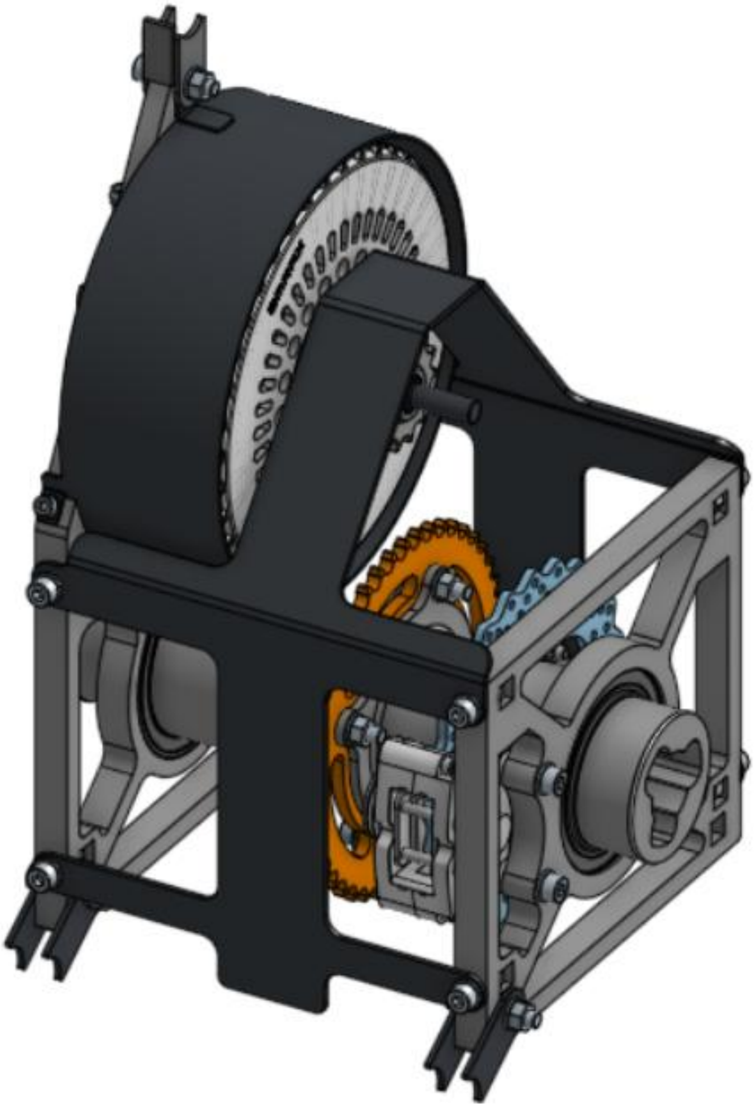


Figure 79. NU 24 Drivetrain V2

Due to the limited time to manufacture the author imposed the following constraints on the design:

- Must utilise the Spool Assembly, Chassis Tabs, and Transmission Shaft.
- It must be possible to use Drivetrain V1 with the new Motor Plate Chassis Tabs.
- The same gear ratio and centre-to-centre distance must be used.
- The Brake Plate must be reused, with the top half removed.

Mathuria completed the design and FEA whilst small changes were made by the author. The design only required a new Motor Plate, Chain Guard, and Scatter Shield. The FEA showed improvement over V1, however did completely fix the issue. The initial design choice to not support both sides of the 228 had proven a huge design flaw. The author made the decision to not completely redesign and manufacture the entire Drivetrain as this was not feasible before competition. The FEA had suggested that the Upper Chassis Tab would restrict the top of the Motor Plate deforming, but it would deform in line with the tight side chain tension force. This is shown in Figure 80.

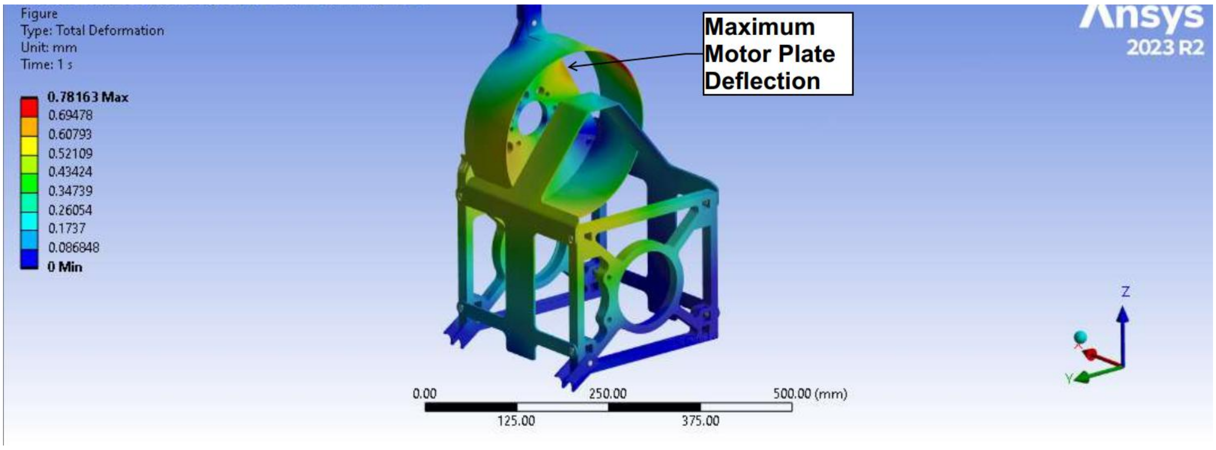


Figure 80. Drivetrain V2 FEA Deformation

This was not ideal, but with limited time, the author made the hard call to stop development and begin manufacture as the timeline towards competition was tight as it was.

During the same period the author was preparing the Chassis to be powder coated. This meant that every tab and bracket that was going to be welded onto the Chassis had to be complete. In an ideal world the Drivetrain would be assembled and placed in the Chassis and the tabs tacked in place prior to full welding. As the new Motor Plate was not completed the author made a jig to allow the weldment of the Upper Drivetrain Chassis Tabs. The 3D printed jig, shown in Figure 81, made use of the Chassis Members to give the weldment position of one of the tabs. It was cable tied to the appropriate members and one tab was tacked in place. The jig left allowed either tab to be welded first depending on the preference of the machinist. As the jig was only PETG as much space from the weld area of the tab was given to limit the melting of the jig onto the part, leading to its horrible appearance. Following the initial tab the spacing between the tabs, which was given a larger tolerance as there was the chance the jig did not perfectly align the tabs, was given in the drawings and a spacer was used and bolted between the tabs to give the desired distance.

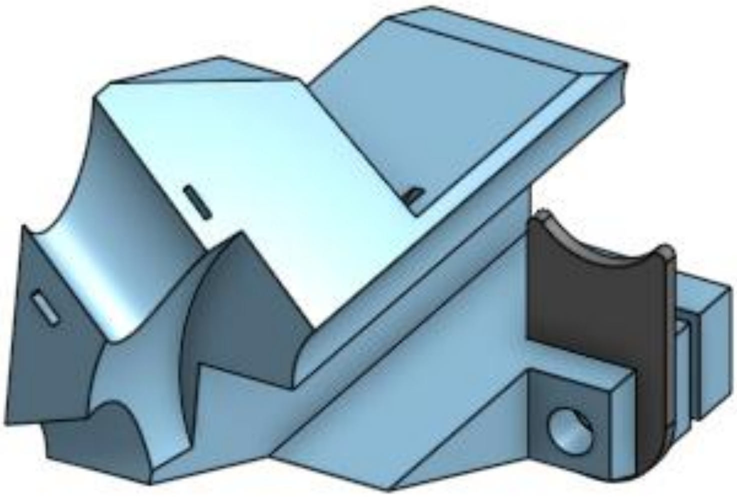


Figure 81. Drivetrain V2 Chassis Tab Jig

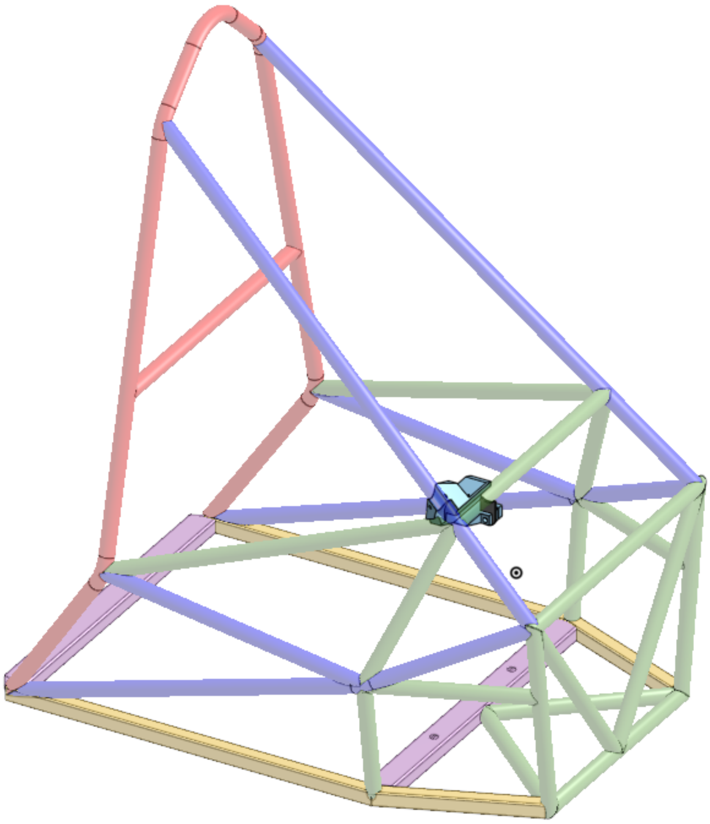


Figure 82. Drivetrain V2 Chassis Tab Jig Position

The new Chain Guard and Scatter Shield were ordered from Hancock Speedway alongside a few other parts on October 23rd. They were made with no issues and picked up on October 31st.

The main delay that halted the commission of Drivetrain V2 was securing the ¾” (19.05 mm) 6061-T6 plate from Calm Aluminium and the milling of the Motor Details and critical features by the Prototyping Workshop. This process took from October 17th to 24th October for the arrival of the aluminium plate. The plate was then thinned to 18 mm. The plate was waterjet cut on November 1st by the author. The plate was supplied on November 4th to the Prototyping Workshop and returned on November 20th.The work required in completing the Motor Plate is approximately two days, from prior experience and from the machinist’s estimate. The Motor Plate was nearly complete after one day’s work, its state shown in Figure 83, which shows it in the CNC Mill.

Figure 83. Drivetrain V2 Motor Plate in the CNC Mill

However, the machinist responsible for the job had gotten ill and the job was forced to wait. It was the recommendation from other machinists that the workpiece was left to be completed by the recovering machinist, as they might have done things in a different order or method. Someone taking over would increase the risk of them making an error that could destroy the near complete Motor Plate.

Due to this the new Drivetrain was delayed by over two weeks, missing 5 track days where it could have been tested, and delivered on November 20th, only 13 days until the team left for competition. This further limited slim testing time and caused great concern. It was assembled that night and drove the next day.

10.1.4.1. Drivetrain V2 Performance and Evaluation

On November 21st the second iteration Drivetrain was tested throughout Acceleration runs as during a standing start is when the tyres provide the maximum resistance and as the 228 can provide full torque instantly.

The Drivetrain was not able to handle the full torque from the 228. The banging noise that was heard from Drivetrain V1 was heard again under full torque runs. The Upper Chassis Tab had fulfilled its purpose and stopped the top of the Motor Plate deforming. Instead, due to the direction of the chain tension force was causing the plate to twist and the forward side of the Motor Plate deformed enough to hit the Chain Guard again. This was what the FEA had highlighted. This was frustrating and a blow to the team.

A torque limit was imposed. The limit was tested and ended up at 180 Nm. This provided 592 Nm of wheel torque and meant that only 78% of the 228's torque capacity was used. This was less than ideal and meant that NU 24 had failed one of its goals of being traction limited. It should be noted however the Drivetrain still allowed higher top speeds, so was still an improvement over NU 23.

The Drivetrain underwent no more changes before competition, outside of new sprockets and a new chain.

The Drivetrain performed well at competition, passing Technical Inspection comfortably and nearly gifted NU Racing a podium in Acceleration recording a fastest time of 3.9397 seconds. This was 0.511 faster than NU 23 and a huge achievement.

A noise was reported from the Spool Bearing on the Motor Plate in the Drivetrain that resembled the bearing walking issues in NU 23 [3]. This noise was only heard a few times and was not addressed. This did not affect performance. This should be further investigated to find the true cause. This was not an issue with Drivetrain V1 which did over 200 km of testing. It is believed that it is rather the interference between the bearing and the Drive Side Tripod, or the bearing tolerance in the Motor Plate was slightly oversized and the bearing, having a harder surface, had worn down the tolerance of the plate and was slightly shifting. The likelihood of it being the Drive Side Tripod Housing is higher as it is the only part in the interfacing parts that was not replaced from Drivetrain V1.

10.2. Pedal Box

10.2.1. Introduction

An overview of the Pedal Box and its associated components can be found in 9.8.2 Pedal Box and seen in Figure 46.

For any given braking event the brake pressure is a result of the Brake Pedal Ratio, Brake Pedal Force, Master Cylinder bore size, and the number of Master Cylinders.

The pedal ratio describes the mechanical advantage of the Brake Pedal over the Master Cylinders. Figure 84 shows a diagram of the measurements required to find the pedal ratio. For the given image the pedal ratio is A divided by B.

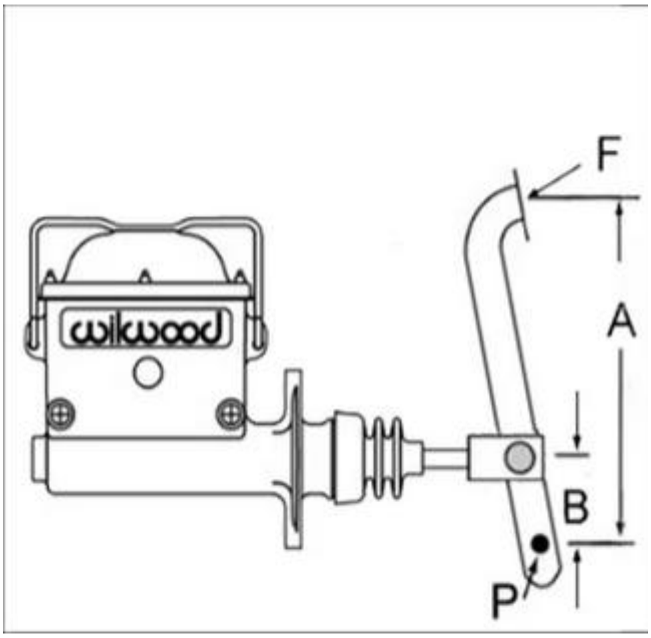


Figure 84. Pedal Ratio Diagram [38]

For NU 23's Brake Pedal the Pedal Ratio is approximately 3.9. This means that whatever force is placed on the Brake Pedal, the force on the Master Cylinders is 3.9 times that force. This can be evaluated using simple moment sums.

The bore size of a Master Cylinder dictates the pressure generated for a certain force. As pressure is force divided by area, the area of the bore dictates this pressure. A smaller bore will produce more pressure for the same brake force than a larger bore.

10.2.2. Initial Design and Pedal Box V1

NU 24's Pedal Box was initially designed by the Chief Mechatronic Engineer Alec Chapman and is shown in Figure 85.

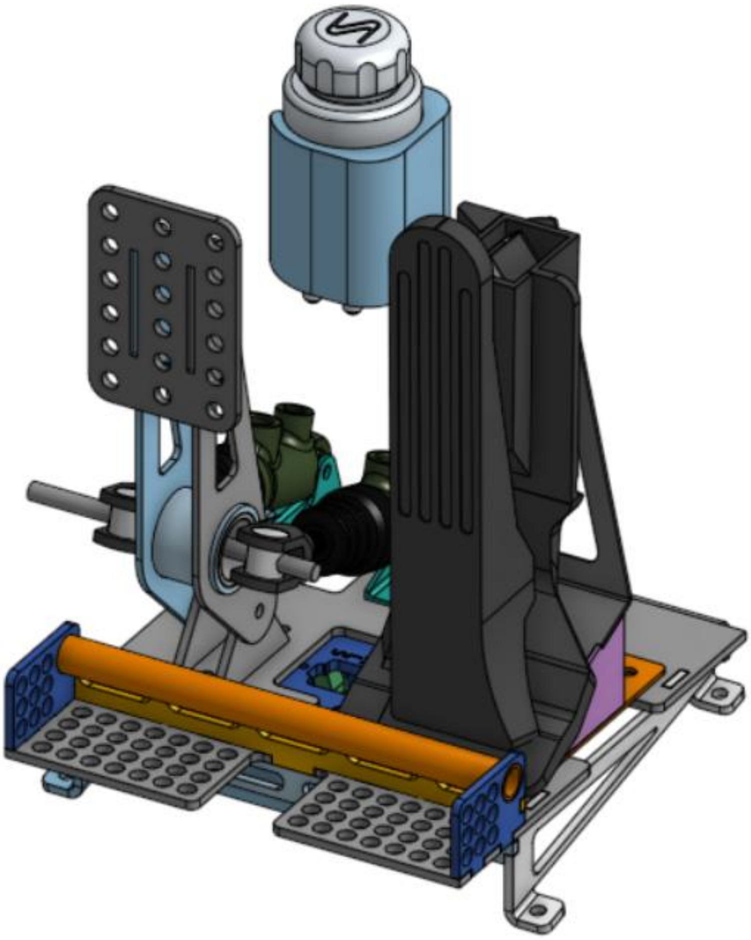


Figure 85. NU 24 Pedal Box V1

The scope for this Pedal Box was as follows:

- Reuse as many components from NU 23 as possible
- Keep the same pedal ratio as NU 23 ~ 3.9
- Fit in the smaller front bulkhead due to Chassis changes
- House the PEN in the smaller front bulkhead

This version accomplished all its goals in a conceptual sense but would have had severe stiffness issues. The area Brake Pedal Clevis and Master Cylinder, the area that takes all the braking load from the driver, was ill supported.

Due to the change of the Chassis to include a 10° lift from the Front Hoop forward [19], Chapman wanted the Pedal Box to remain parallel with the ground. This was to allow the pedal faces to stay at an angle that was comfortable for the drivers' ankles. This is shown in Figure 86.

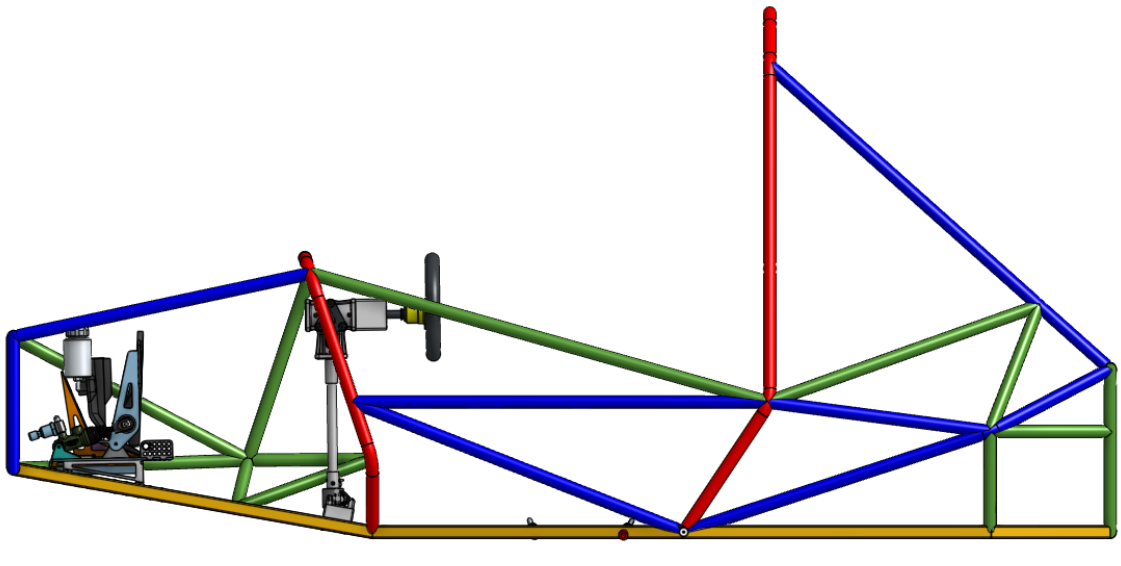


Figure 86. Pedal Box V1 with Vertical Stands

Following this the Chief Engineer Joshua Wenham updated the Pedal Box design to include a stiffening brace underneath the Brake Pedal and Master Cylinder. This was then handed to

Keiran Burgess who was tasked with removing weight and completing FEA. This was completed before the author became the Chief Mechanical Engineer in early 2024.

Due to the base of the Accumulator Container being made from 4.06 mm (5/32”) 6061-T6 Aluminium from which there was spare, the author decided to use this as the material for the base plate. 6061-T6 is hard to bend and is prone to snapping as it is bent. The author changed the design to remove bends from the Base Plate and Vertical Stands, instead makings separate parts that could be welded. The final design is shown in Figure 87.

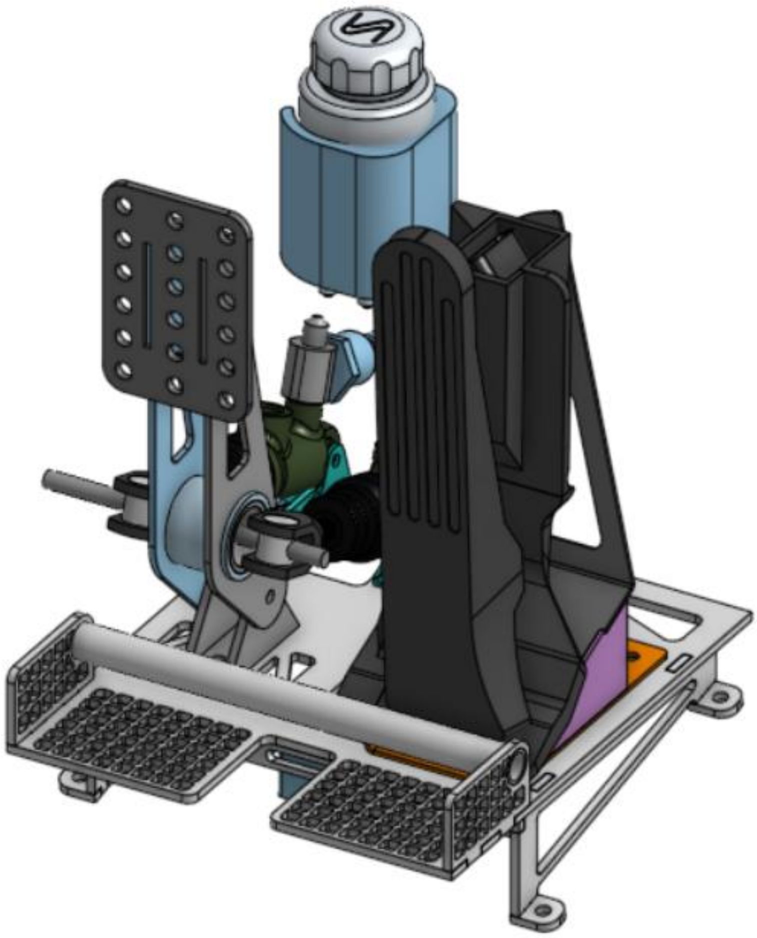


Figure 87. NU 24 Pedal Box V1 Revised

The manufacturing drawings were prepared by John Jones before the Base Plate and associated parts were waterjet cut by the author. It was sent to the Prototyping Workshop for weldment.

The Pedal Box was the assembled using components from NU 23's Pedal Box and bolted to the car.

10.2.2.1. Pedal Box V1 Performance and Evaluation

Several notes came back from the machinist who completed the job:

- There was limited space to weld between the Feet and Vertical Stands
- The weight saving at the footrest made it hard to avoid welding blowout at the:
    - Foot Stop Tube
    - Tube Stop Plate

With the vertical stands and raised Pedal Box some drivers could not fit in the car. Because the footrest was raised it meant that it brought their legs up higher. This was not an issue until attempting to steer, where the drivers' legs would interfere with their hands and Steering Wheel. Due to this it became evident another iteration of the Pedal Box was required.

After this it was also discovered that the Pedal Box had plastically deformed under braking, which extremely bad as NU 24 was not driven in a demanding fashion in its first drive. This is shown in Figure 88. This meant the validation of the Base Plate's performance was not done to a high standard.

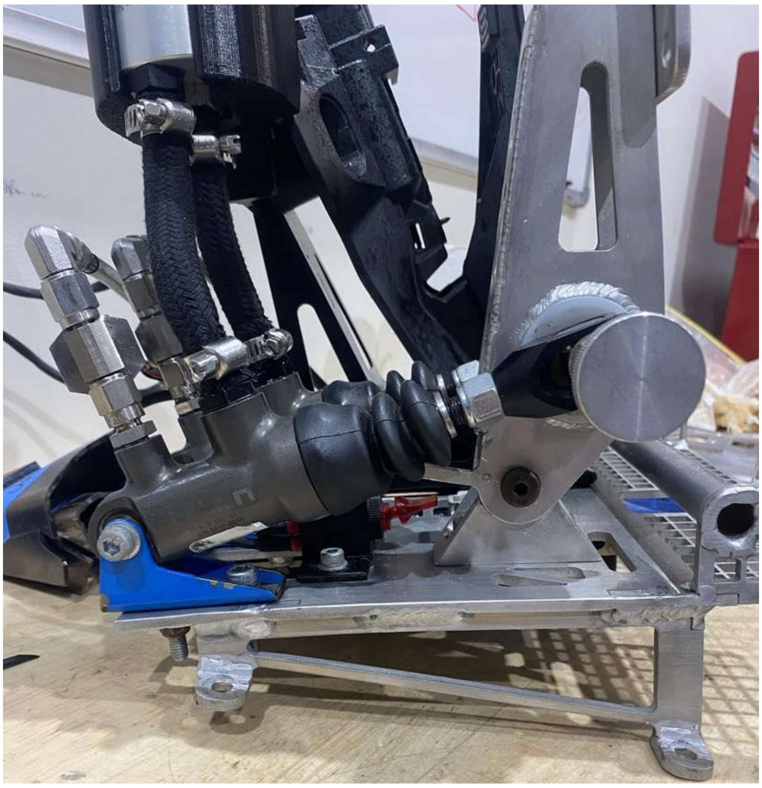


Figure 88. Deformation of Pedal Box V1

This was caused by the weight reduction in the Base Plate and its stiffeners. This is shown in Figure 89 and Figure 90.

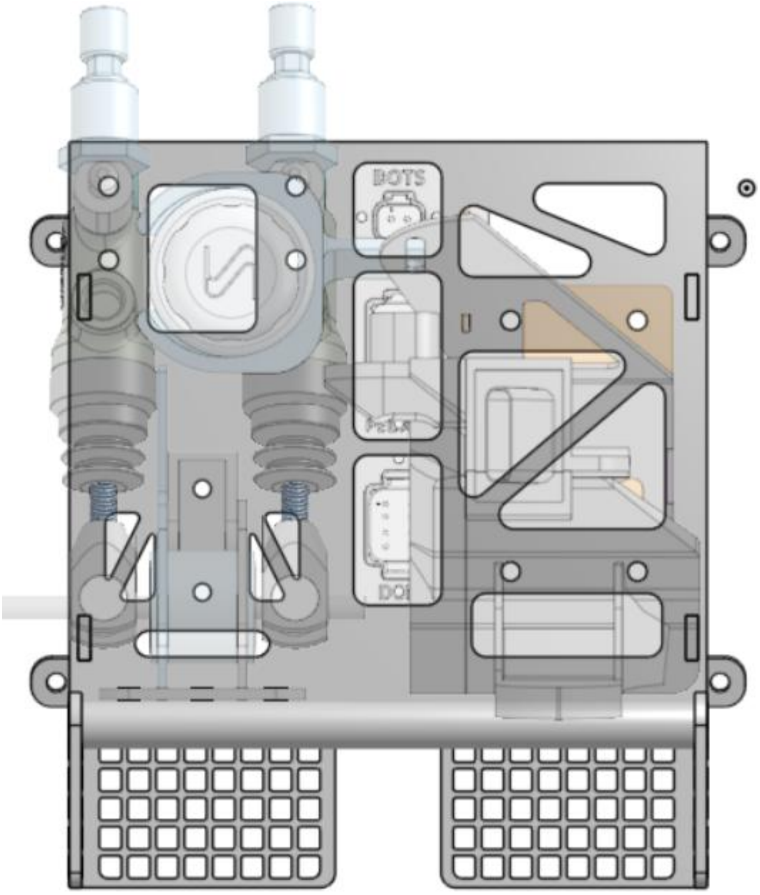


Figure 89. Base Plate Weight Reduction

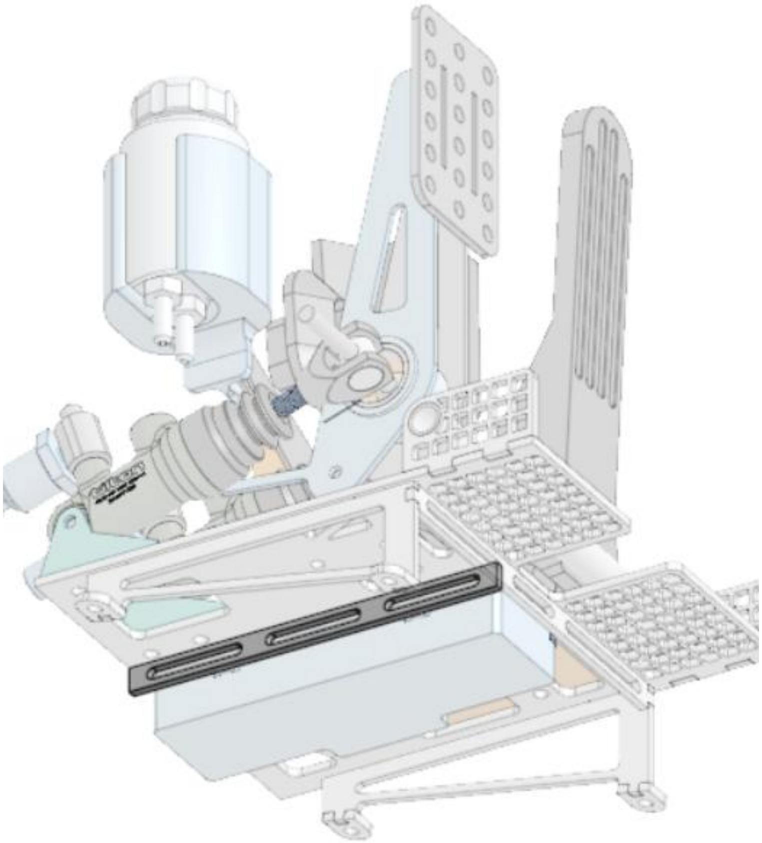


Figure 90. Pedal Box V1 Stiffening Brace

The reaction forces from the Brake Pedal Clevis and Master Cylinder Mount Clevises are directly applied to the Base Plate, and by removing material near them it allowed more deflection. It was also observed that the stiffening brace had deformed at the rear, buckling about the hole generated for weight saving.

10.2.3. Pedal Box V2

The author begun designing a new Pedal Box immediately. This was before the Motor Controller Failure, so the author made this top priority so more drivers could fit in the vehicle to increase driving time. The scope for the new iteration was as follows:

- Increase strength and stiffness
- Change footrest position to increase clearance between driver's legs and the Steering Wheel
- Reuse all components from the first iteration – only a new Base Plate

- PEN must stay in the same spot

The FSAE Rules state that the Pedal Box and associated components must be able to handle 2000 N of force, however, did not require this as a design criterion. The Brake Pedal had to be able to take the maximum force from any official when sitting in the car. To test what load the Brake Pedal and Pedal Box took, the author sat two drivers in the car. Once they had tightened their harness, they pressed a scale that was placed between the Brake Pedal and the driver's foot. This gave a representation of what maximum force could be exerted, and what load was generally used. It should be noted that there are Brake Pressure Sensors, but this was done as a sanity check instead of blindly following the sensors. The setup is shown in Figure 91.

Figure 91. Brake Pedal Force Test

The results showed that one driver was able to do 70 kg of force, whilst the other could do 80 kg of force. MoTeC data from the 2023 competition was evaluated to find the highest brake pressure during an Autocross run. From the pressure, knowing the bore size of the Master Cylinders (5/8"), number of master cylinders, and pedal ratio the total Brake Pedal Force could be approximated. In 2023, Alec Chapman achieved a brake pressure of 948 psi. This equated to an approximate Brake Pedal force of 68 kg, which was close to what the two drivers had recorded with the scale setup and gave good context to the author. The calculations for this are shown in 15.2 Appendix B – Brake Force Calculations.

It was decided by the author that these values would be considered to design the Pedal Box, but it should be made to survive 2000 N.

To increase the room available for the driver, the Vertical Stands were removed the design, replaced instead by spacers such that the PEN still fit underneath the Pedal Box, shown in Figure 92. They raised the Pedal Box by 8 mm and were welded to the Base Plate.

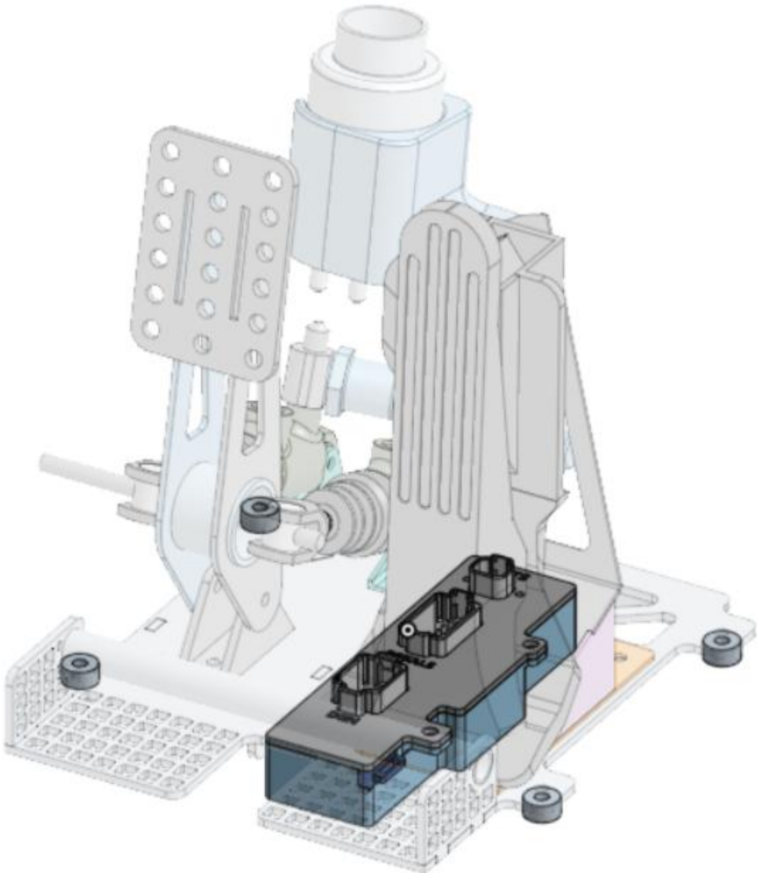


Figure 92. Pedal Box V2 Spacers

To increase the stiffness and strength of the Pedal Box, the weight reduction around the Brake Pedal Clevis and Master Cylinder Clevis and in the stiffening brace was removed.

As the major goal for this iteration was to increase driver space, the Base Plate was 3D printed to verify driver fitment. Once printed, all components were bolted to the Base Plate, and it was placed in NU 24. This is shown in Figure 93.

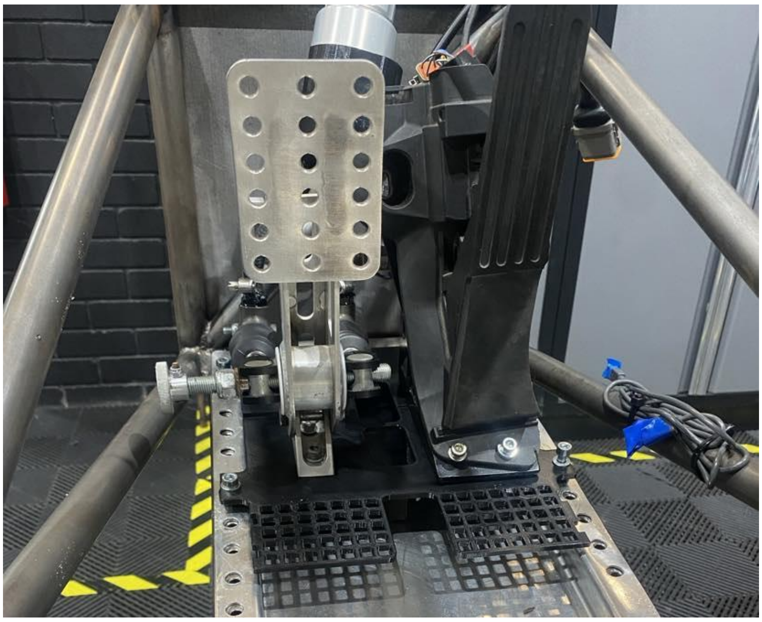


Figure 93. 3D Printed Base Plate

The same drivers who had issues with fitment tested were placed in NU 24. The removal of the Vertical Stands had given enough room to stop the fitment issues. However, with the Pedal Box now sitting at 10°, the Brake Pedal position needed to be adjusted. The Master Cylinder Clevises bolted to the Balance Bar, shown in Figure 94, were wound all the way in, which made the pedals perpendicular to the ground and improved driver comfortability. The Accelerator Pedal position could not be altered without changing the mount. The author got driver feedback for its position and no issues were advised. The Accelerator Pedal position did not change.

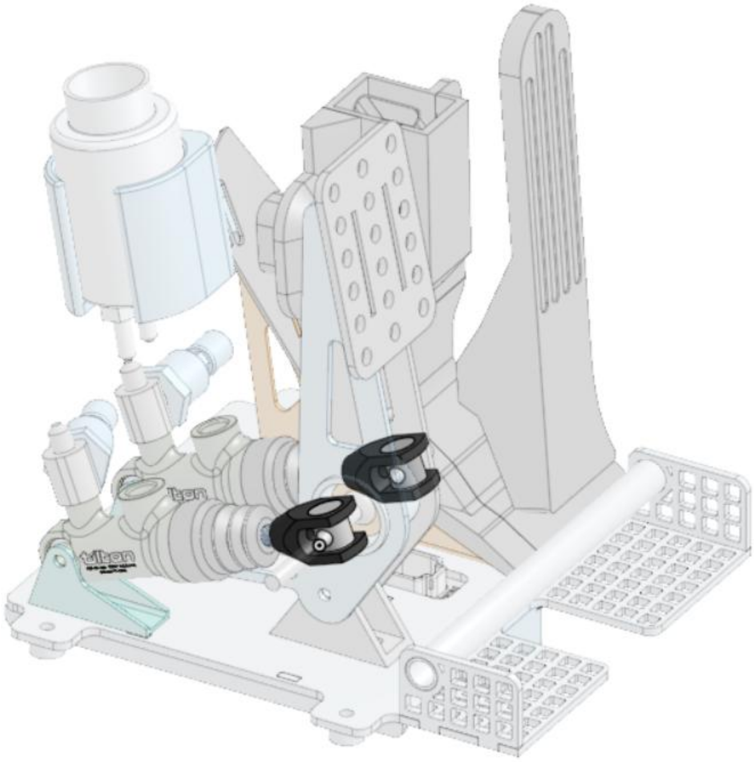


Figure 94. Master Cylinder Clevis

The author added two stiffening braces to the Base Plate, and created slots for them so sit in to assist weldment. To remedy weld blowout issues from the first iteration, a larger area between weldment positions at the Footrest Side Plate and Base Plate, and Footrest to the Footrest Tube were given. In retrospect not enough area was given.

The author completed FEA on the Pedal box to verify its integrity. To replicate the force transfer between the Brake Pedal and the Master Cylinder Mount Clevises a revolute joint, as shown in Figure 95, between the bore for the balance bar and the clevises.

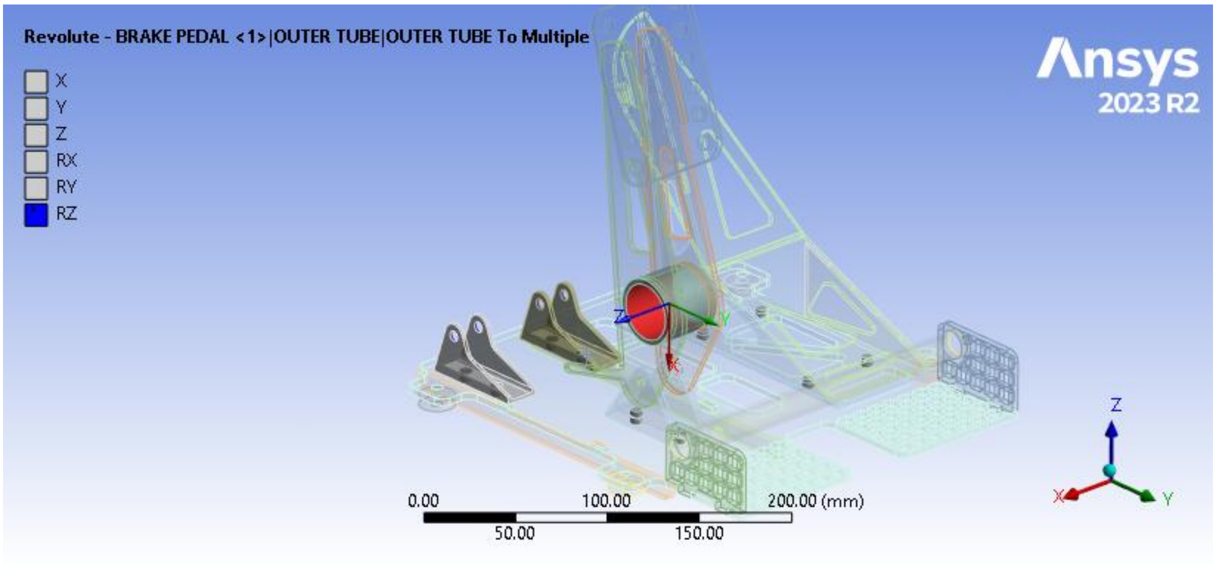


Figure 95. Revolute Joint Pedal Box V2 FEA

To allow the Brake Pedal to pivot on the Brake Pedal Clevis another revolute joint was used.

The deformation and stress results for an applied force of 2000 N are shown in Figure 96 and Figure 97.

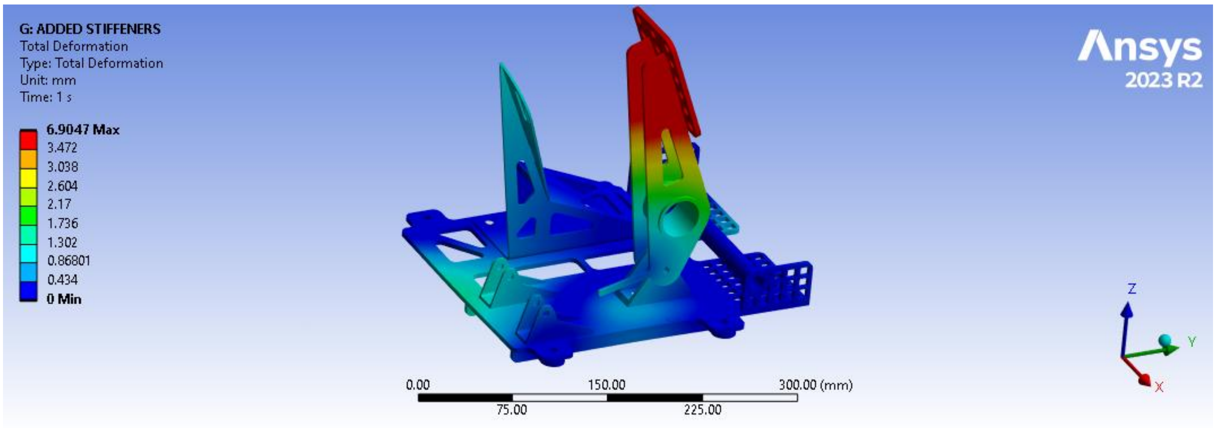


Figure 96. Pedal Box V2 Deformation

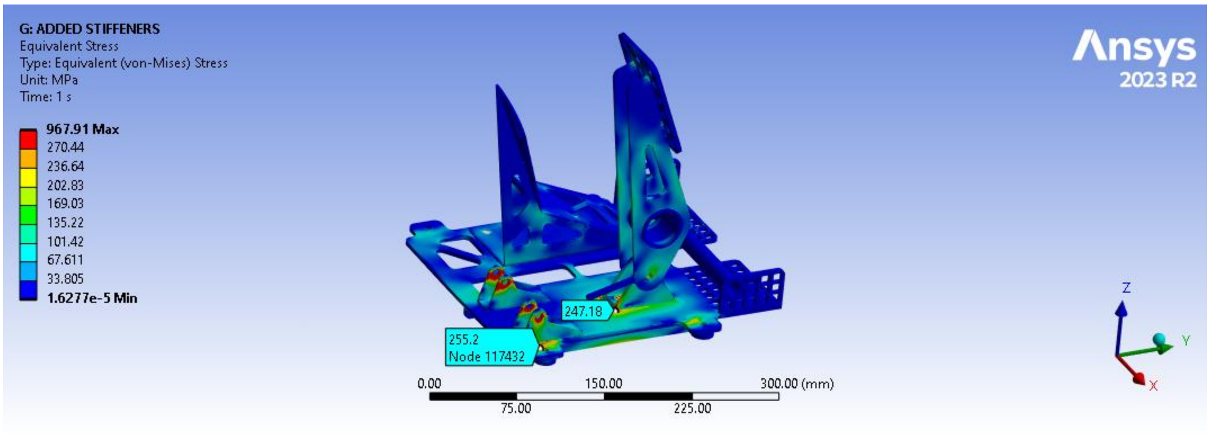


Figure 97. Pedal Box V2 Stress

Figure 97 shows that the weakest parts of the assembly were the pre-existing Master Cylinder Mount Clevises. As they had been used effectively for two years this was deemed acceptable. It showed that the Base Plate, at 2000 N would not plastically deform, with a max stress of approximately 260 MPa.

The deformation shown in Figure 96 showed that this iteration would deform at this load, but at expected loads, such as 700 N shown in Figure 98, it would only deform slightly.

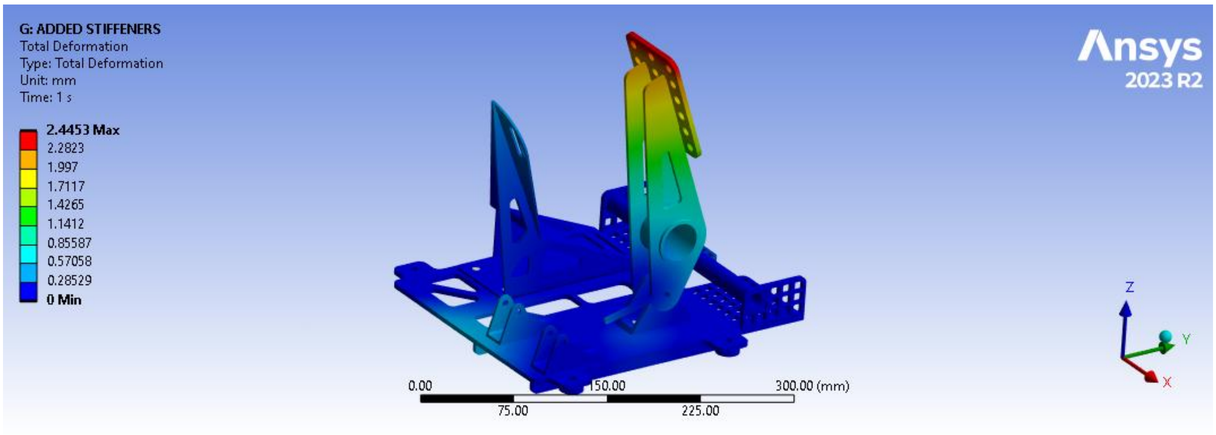


Figure 98. Pedal Box V2 Deformation under 700 N

The author made full manufacturing drawings, shown in 15.3 Appendix C –Base Plate Manufacturing Drawings.

The Base Plate an associated parts were then waterjet cut. During this process, automatic compensation was not turned on. Automatic compensation on a waterjet cutter accounts for the thickness of the waterjet and applies this to the supplied DXF. This makes the waterjet cut half the thickness of the jet from any point and ensures parts come out at the correct size. Therefore, all of the features on the Base Plate were slightly oversized. This did not make a large difference for the application of the assembly but increase the difficulty of weldment. The decrease in area between welds made weld blowout more prevalent for the machinist.

The Pedal Box was the assembled with no issues.

10.2.3.1. Pedal Box V2 Performance and Evaluation

The second iteration of the part accomplished its goals and was stronger, stiffer, and allowed more accessibility for drivers. It was however noted at competition that the Base Plate flexed under extremely hard braking (an official holding the Front Hoop and applying maximum force), but did not plastically deform. This was seen in Mechanical Inspection.

The stiffening braces added to the Base Plate were stitch welded at 25-60, meaning there were 25 mm welds spaced 60 mm apart. In retrospect, larger stitches and smaller spacing would have been preferred to assist the flexing. Increasing the height of the stiffening braces also would have been thoroughly effective.

The areas that the deflection occurred was in the same positions as the FEA had shown in Figure 96 just in higher magnitudes. Upon reflection of the FEA setup, the stiffening braces were scoped as fully bonded to the Base Plate. This would have increased the effectiveness of the braces in the simulation and given unrealistic results. Another error could have been not making the Brake Pedal angle, relative to the Base Plate, represent full Master Cylinder Stroke. This would change the braking force vector direction and ultimately the results.

Despite the flexing in inspection, this was never noted by any driver, including the author. The flexing never occurred to the same magnitude under usual braking loads and was not noted during brake bleeding. Despite this it should be addressed to ensure no issues throughout Mechanical Inspection in 2025.

10.3. Chassis

The author had no impact on the initial design nor the manufacture of NU 24's Chassis. The design was completed by Joseph Barker, then ordered by Joshua Wenham, and manufactured by John Jones. All three assisted in completing the SES.

On November 13th, less than three weeks before the team left for competition, Team Leader Timothy Kerr received the email shown in Figure 99.

Dear Timothy
Your SES has been reviewed and one area of rules non-compliance has been identified. In the rear impact section of the Tube Chassis tab, it is stipulated that the rear impact structure must be fully triangulated back to the SIS. There is a section at the rear of the vehicle in side view which is not triangulated.

Without understanding the positioning of your driveline components, you might consider how you can effectively brace this area, with reference to the guidance images in cell columns EK to EZ. You might add another diagonal in the rear rectangular open box from the upper rearmost node down to the bottom node where the other diagonal joins to the bottom member at the vertical and running from the upper SIS. Alternatively, possibly add a second diagonal across the forward rectangular box, running down to the bottom of the MRH, effectively creating an 'X' brace.

Regards,

FSAE-A Rules Committee

Formula SAE-A
5-8 December 2024
Society of Automotive Engineers – Australasia
+61 403 267 166 | formulasae@sae-a.com.au

Figure 99. NU 24 Chassis Non-Compliance Email

The email, that was shared with the Leadership Team on November 14th, midway through a Sydney Motorsport Park (SMSP) track day, states that the area highlighted in Figure 100 was not fully triangulated from the Rear Impact Structure (RIS) and was non-compliant. This square area was where the Driveshafts passed through the Chassis to the Rear Spindles. It should be noted that the last three NU Racing Chassis; NU24, NU 23, and EV.Three. featured this same square area for the driveshafts.

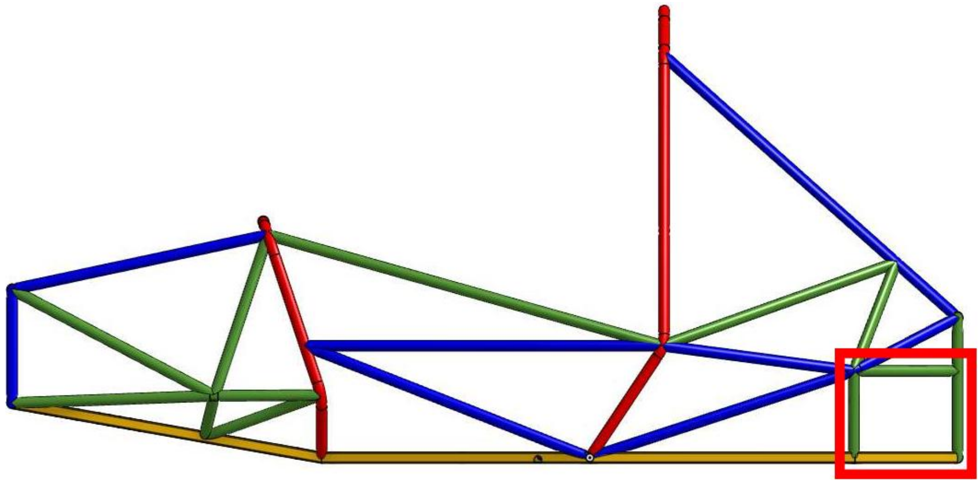


Figure 100. Non-Triangulated Section NU 24 Chassis

This was a huge blow, especially considering the author was getting the Drivetrain V2 manufactured at the same time.

Due to the Driveshaft orientation two members per side were required to clear the Driveshafts and be compliant. The author noted quickly that due to the placement of the Suspension pickups there was only one orientation that would ease manufacturing time on the Prototyping Workshop. Joshua Wenham modelled additional members in this orientation shown in Figure 101. This orientation meant that the Driveshaft clearance to the new members under full compression of the Suspension had to be verified.

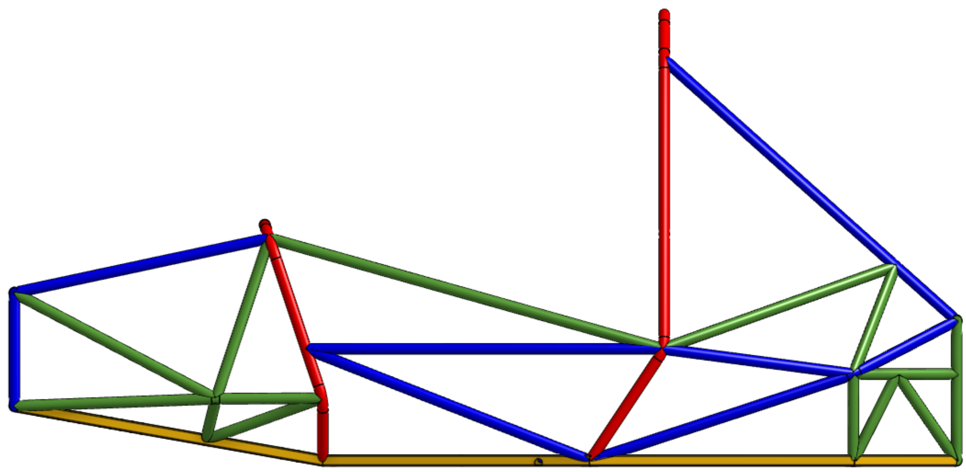


Figure 101. NU 24 Chassis with Additional RIS Members

The author then 3D printed the members and placed them in the Chassis to ensure the Driveshafts would have sufficient clearance, by removing the spring from the coilover and moving through the full wheel travel. These are shown in Figure 102. After multiple test prints and small changes to the position of the node where the two members meet the design was complete.

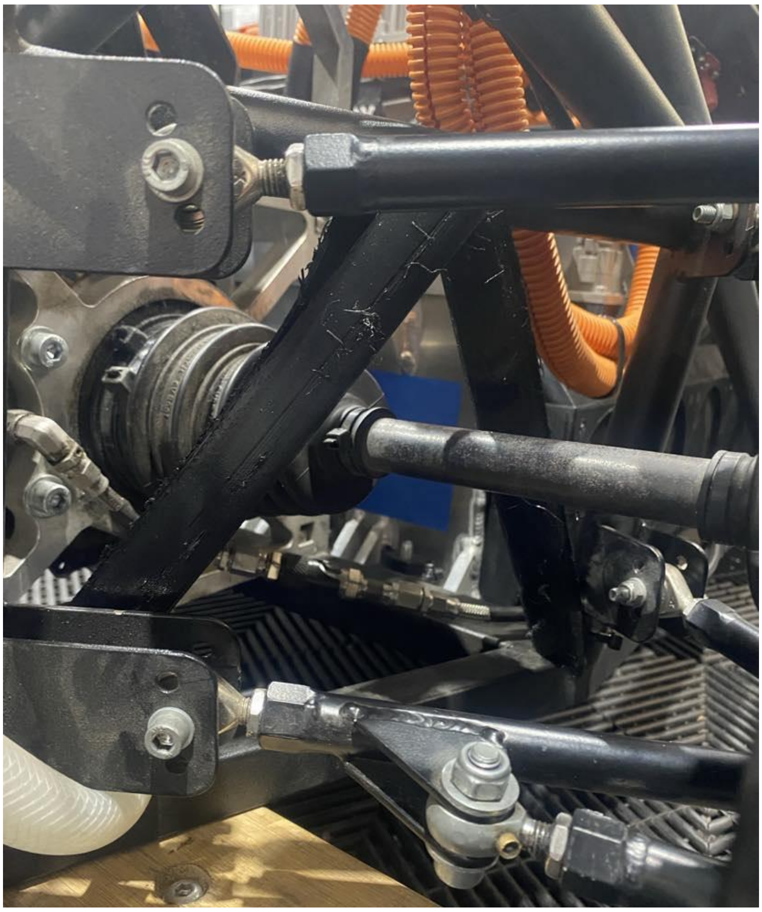


Figure 102. 3D Printed RIS Members

The author then created manufacturing drawings to allow the tubes to be notched and welded. These are shown in 15.4 Appendix D – RIS Chassis Member Manufacturing Drawings.

Following consultation with the Prototyping Workshop on Friday 15th November the following timeline was created:

- The author would finalise the design and drawings and send them before Monday 18th November
- The machinist would notch the four new members that day (Monday)
- NU Racing would complete its planned track day that day (Monday)
- After the track day NU 24 would be stripped (Monday)
- The Chassis would be provided to the Prototyping Workshop and placed on the welding bench at 7:00 am the next day (Tuesday)
- The suspension pickups would be altered, powder coat removed from the welding area, and members welded (Tuesday / Wednesday)
- Chassis returned to NU Racing (Wednesday afternoon)
- NU 24 put back together, including new Drivetrain V2 (Wednesday night)
- NU Racing track day (Thursday)

This timeline worked and the NU 24 was driven on Thursday, exactly one week since the team learnt of the issue. This is completely due to the hard work and assistance of the Prototyping Workshop and their assistance cannot be thanked enough. Through this NU 24 had a compliant Chassis heading to competition.

10.4. Suspension

NU 24's Suspension was designed by Justin Li and manufactured by Keiran Burgess [17], [11]. Their reports detail their contributions to the system.

The Suspension is given a brief overview in 9.3 Suspension.

The author was responsible for changes to the design and some aspects of manufacture. These included the redesign and commission of the Control Arm jigs, manufacture of extra Extension Rods, and a major change to the Spherical Bearing Pocket.

10.4.1. Control Arm Manufacturing Jigs

For NU 24 the major change for the Suspension system, not including the largescale Chassis changes, was the manufacture of new Control Arms (or A-Arms). The Front Right Control Arms are shown in Figure 103.

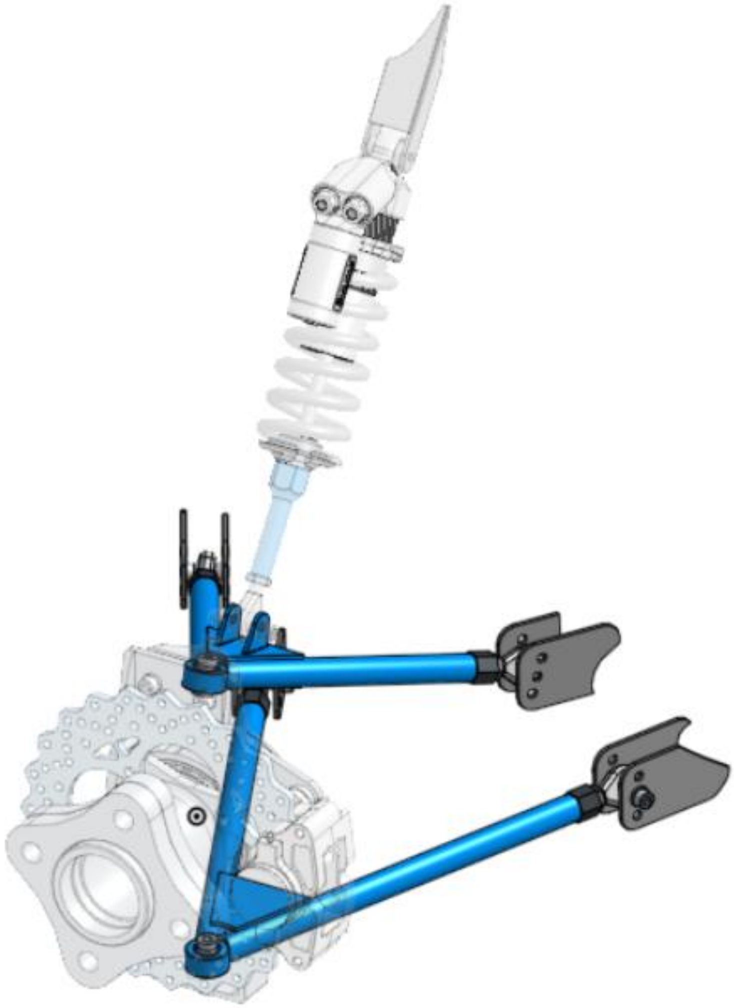


Figure 103. NU 24 Front Right Control Arms

Each Control Arm has a different internal angle, that corresponds to the different locations of the Suspension Pickups on the Chassis. Due to this manufacturing the Control Arms takes care as there are 16 different tubes that need to be cut, notched, then welded to the correct angle.

To aid in the weldment, a jig was made to represent each angle of every Control Arm. Initially this was designed and manufactured by the 2024 Suspension Engineer, Andrew Thomas. This is shown in Figure 104.

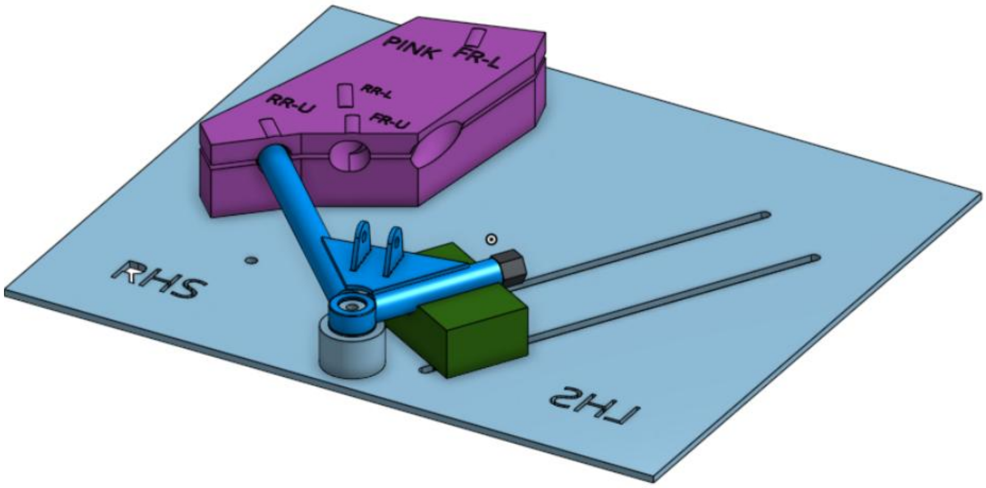


Figure 104. Control Arm Jig V1

A plate was used to hold each Control Arm and 3D printed jigs to allow for the correct angle to be applied to the Control Arm before it was tack welded, before fully welded. The RHS of Figure 104 shows that one side of the jig did not need to be changed for each angle and was allowed to slide for each Control Arm length. The LHS jigs changed angle for every Control Arm configuration. As the LHS and RHS suspension of any car is mirrored along the centreline, the jigs assembly was mirrored, and the base plate was flipped to weld the other side Control Arms.

The plate used to hold the jigs was manufactured correctly. However, one the jigs he provided to the Prototyping Workshop had the incorrect naming on the jig, meaning that the wrong tubes would have been welded at the wrong angle. Due to the attention to detail of the machinist in the Prototyping Workshop this was noticed, and the author was notified by Lachlan Barrell, the Professional Engineer.

Upon inspection by the author, it was further noted that most of the jigs did not line up with the desired angles of the Control Arms. The original intention was to simply fix the jigs and reprint them for the Prototyping Workshop. However, the modelling method utilised to create the jigs made editing near impossible. Therefore, the author remade every jig to ensure the Control Arms were manufactured correctly.

The machinists have access to the NU Racing Onshape which was incredibly useful for this job. It allowed the machinists to reference the Onshape Assembly to ensure the right tubes were being welded together. To increase the usability of the Control Arm Jig Assembly for the machinists, the author used Assembly Configurations in Onshape. This is shown in Figure 105.

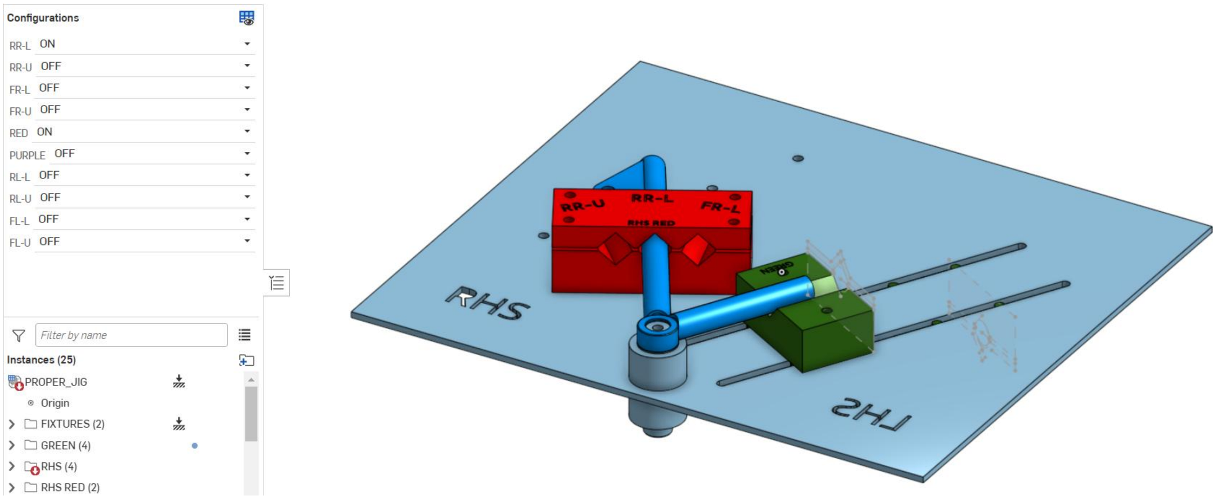


Figure 105. Control Arm Jig Assembly Configuration

The top left of Figure 105 allowed the user to turn on or turn off a configuration of the assembly to show selected Control Arms and the associated jig. This meant that the machinist did not have to look in the model tree and manually hide and show items.

The jigs were given to the Prototyping Workshop, and the Control Arms were welded with no issues.

10.4.2. Coilover Extension Rods

The Extension Rods bolt to the end of each coilover and have a M8 Rod End threaded into them to mount to the Upper Control Arm of each corner of the car. The Front Right Coilover Extension Rod is shown in Figure 106.

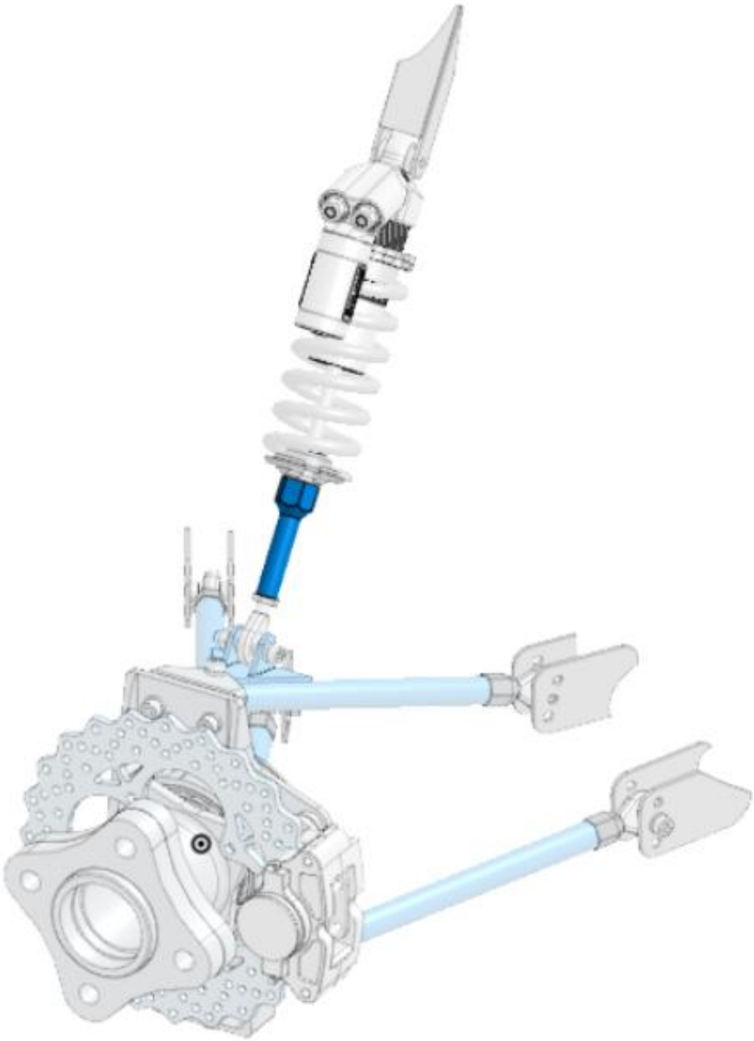


Figure 106. Front Right Coilover Extension Rod

The length of the Extension Rods controls the ride height of the Chassis. This is because their length increases or decreases the distance between the Upper Control Arm and the Coilover Chassis Pickup, pushing or pulling the Upright towards the Chassis.

The initial model for the Extension Rods designed to make the car statically sit approximately 50 mm off the ground. After they were manufactured by Keiran Burgess, the car sat at approximately 32 mm off the ground.

One of the goals for NU 24 was to have the car as low as possible (while compliant). FSAE Rule V.3.1.1 states that a minimum wheel travel of 50 mm with the driver seated is required.

This is in rebound and jounce (compression) [7]. The Australasian Rules Addendum later added that minimum 25 mm of this travel must be in jounce. Therefore, the car only had to be 25 mm off the ground theoretically. During initial testing the author manufactured different length Extension Rods to influence the ride height of NU 24. The original ones, a set 10 mm longer, and another set 20 mm longer. This changed the ride height approximately 7.5 mm each due to the Motion Ratio of the Front and Rear Control Arms, which is discussed in further detail in 2.11 Motion Ratio in the Vehicle Dynamics section of this report.

When manufacturing Extension Tubes, determining the length of the extension tubes to develop a certain ride height often requires a prototype set to see where the ride height sits. This can drive the design decisions (i.e. the length) of a new set. This is why the initial Extension Rods were not changed from Li’s initial design, before the author adjusted their length to change the ride height.

10.4.3. Spherical Bearing Issues

To allow the full range of motion of the Suspension system (rebound, jounce, and steering) spherical bearings are used. They multi-directional movement, and due to this are perfect for the Control Arms. They are shown in Figure 107.

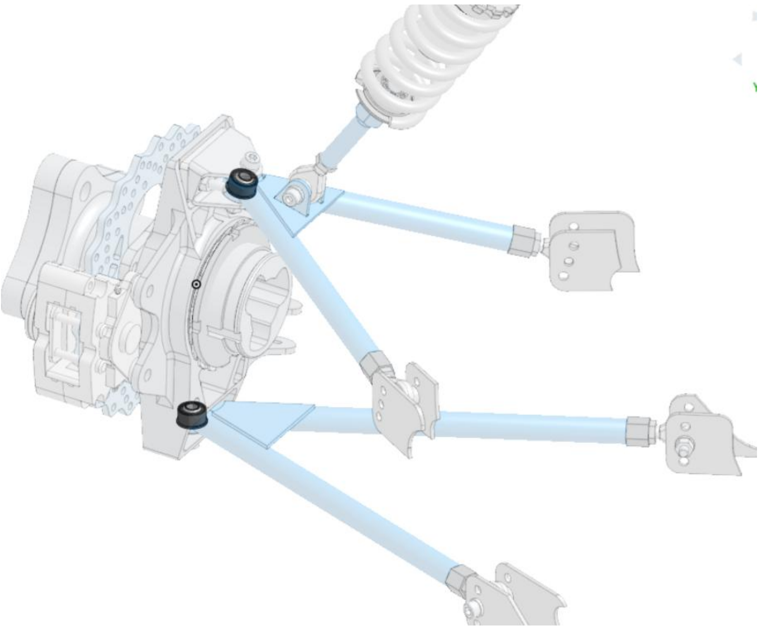


Figure 107. NU 24 Spherical Bearings

The spherical bearings used for NU 24 are ABWT5V Bearings. These are cheaper and more readily available than other spherical bearings ($30 / unit and stocked in Australia). They were purchased as a recommendation from the Prototyping Workshop [17]. After Li had designed the Spherical Housings (where the spherical bearings are pressed into the Control Arm), Joshua Wenham changed the design to include a circlip to assist in retaining the spherical bearing.

The ABWT5V is a staked bearing. They have a V groove in the top of the bearing shown in Figure 108. This V groove is designed to allow a staking tool pressed into this groove. It then deforms the outermost part of the bearing, which is made from a softer material, expanding it into the bearing pocket creating an interference fit. An example of a staking tool is shown in Figure 109.

Figure 108. ABWT5V Spherical Bearing

Figure 109. Example Staking Tool

The design intention of these bearings was never to purchase a staking tool and instead use a heavy push fit tolerance to press them in like a normal bearing. Due to the softer outer shell of the ABWT5V bearings when they were pressed into the Spherical Housing they deformed, as they are designed to, and would not press in squarely. The Prototyping Workshop encouraged the author and Joshua Wenham to source different bearings.

Spherical Bearings are expensive and hard to source in Australia, the ABWT5V being one of the exceptions to this. Due to this and curiosity the author decided that instead of searching for new bearings, at least one of the Spherical Housings should have the heavy push fit tolerance changed to an interference fit or slightly under and the bearing pressed in with Bearing Retaining Compound (Loctite). The Spherical Housings already had been changed to include circlips to retain the bearings and limit axial movement, so this seemed like a simple solution.

After a trial run, the Prototyping Workshop pushed in the ABWT5V bearings with no large radial movements. After this the Control Arms were welded to the associated Spherical Housings and the Control Arms were completed.

Throughout the year there were no issues with the Spherical Housings or the ABWT5V bearings. The Prototyping Workshop recommends not using the ABWT5V bearings, however if there is no clear alternative (i.e. cost or lead time for another set of bearings is too high) the author does not see an issue with using the bearings again. However, care must be taken as this did cause delays in the manufacturing process. A simple solution should just be purchasing the staking tool and using the bearings as the manufacturer recommends.

10.4.4. Suspension Clearnce Issues

Once the Control Arms were manufactured and the Suspension Pickups were welded to NU 24, which was oversaw by John Jones, it was immediately noticed by the machinist that the support plates on the Lower Front Control Arms were interfering with the Uprights, meaning that the car could not steer correctly. The machinist grinded the support plate down to allow the Upright to move without hitting the Lower Control Arm. This is shown in Figure 110.

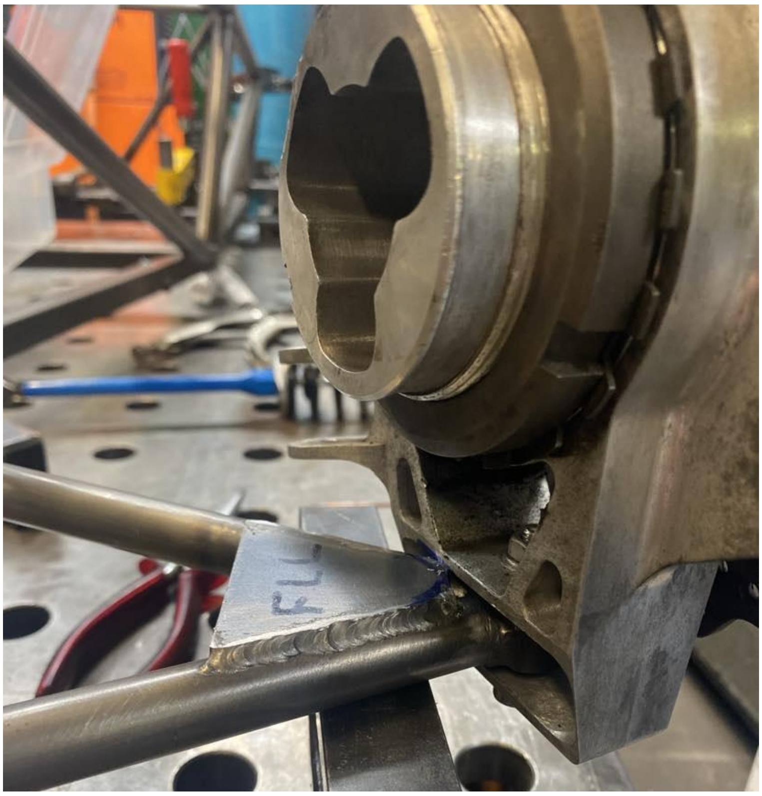


Figure 110. Lower Control Arm and Upright Interference

As discussed in 10.4.3 the Spherical Housings were changed to accommodate the inclusion of a ¾" circlip. Due to this change and the position of the Control Arm Support Plates, even after grinding, wear was noticed on the Upper and Lower Front Control Arms from interference with the Upright.

This is the result of the Control Arm design never being properly constrained in Onshape to allow full rotation of the Uprights and compression of the Coilover to simulate the movement of the Control Arms and check for clearance issues. Another solution would have been to validate the design through 3D printed prototypes of the Control Arms to check clearance issues. It cannot be understated how important validation of designs are, as this issue would have been immediately remedied.

10.4.5. Upright Bearing Failure

On November 18th, the final SMSP track day before the Chassis would go to the Prototyping Workshop, as mentioned in 10.3, NU 24 suffered a bearing failure. The outer bearing of the Rear Left Upright had collapsed during Skid Pad training. This is shown in Figure 111.

Figure 111. Rear Left Upright Collapsed Bearing

Prior to the collapse a noise was heard from the Rear Right Upright briefly by a driver. Upon inspection nothing seemed to be the issue, and the author made the call to keep driving with the intention of pulling the Upright assembly apart later that night, as the Chassis was being disassembled that night to prepare the Chassis for welding. After a few minutes of driving an ringing scattering noise was heard and NU 24 returned to the pits where it was very clear that the bearing had failed.

This was no surprise when considering the life of the bearing. The had not been changed since 2022 and most FSAE tracks designed by NU Racing and at competition are clockwise tracks. This means that the LHS of the car is loaded much more frequently than the RHS (turning right increases the wheel load on the left).

The Bearings are 6814-DD NSK Deep Groove Ball Bearings. The author was able to source six replacement bearings, two for the Rear Left Upright and four spares for competition, by Wednesday 20th November. Two new bearings were immediately installed into the Upright, however due to issues with the Uprights initial manufacture the bearing tolerance was looser than ideal, so the author ensured Bearing Compound Retainer was used [15].

During competition a similar noise that was heard from the Rear Left Upright before the failure was heard on the Front Right Upright. This prompted the replacement of all Front Wheel Bearings (four total, two per Upright) after Acceleration on Saturday of competition.

10.5. Body Kit Tabs

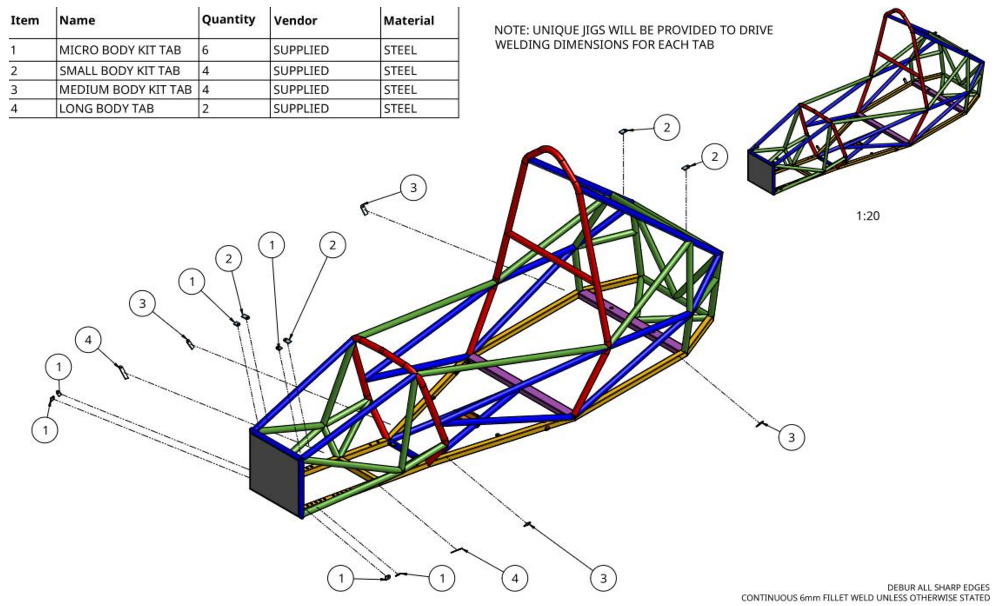
The Body Kit is mounted to the Chassis through a series of welded tabs and Quik Latch quick disconnects as described in 9.9. 2024 Chief Engineer Joshua Wenham was responsible for the design and manufacture of the Body Kit.

Towards the end of the year, as the author was preparing the Chassis for powder coating, which also meant finalising the Chassis design and manufacture for the year. As a part of this the Body Kit Tabs, which the male side of the Quik Latch quick disconnects would be fastened to, needed to be welded to the car.

As Wenham was in the final steps of the Body Kit manufacture, the author offered to get the tabs manufactured and welded, pending Wenham would just model them where he wanted them. The tabs were modelled, and the author began the process of getting them manufactured.

Once the number of tabs and their length were known the author got the tabs laser cut at Hancock Speedway.

As the position of the tabs, shown in Figure 112, were arbitrary and not easily measurable the author made separate jigs for each jig on one side of the car, before mirroring them for the other side. The jigs used Chassis nodes or Suspension Pickups to give the position of the tabs. Examples of the two types of jigs are shown in Figure 113 and Figure 114 respectively. It should be noted that there are no real benefits to either style.



Item	Name	Quantity	Vendor	Material
1	MICRO BODY KIT TAB	6	SUPPLIED	STEEL
2	SMALL BODY KIT TAB	4	SUPPLIED	STEEL
3	MEDIUM BODY KIT TAB	4	SUPPLIED	STEEL
4	LONG BODY TAB	2	SUPPLIED	STEEL

Figure 112. Position of the Body Kit Tabs

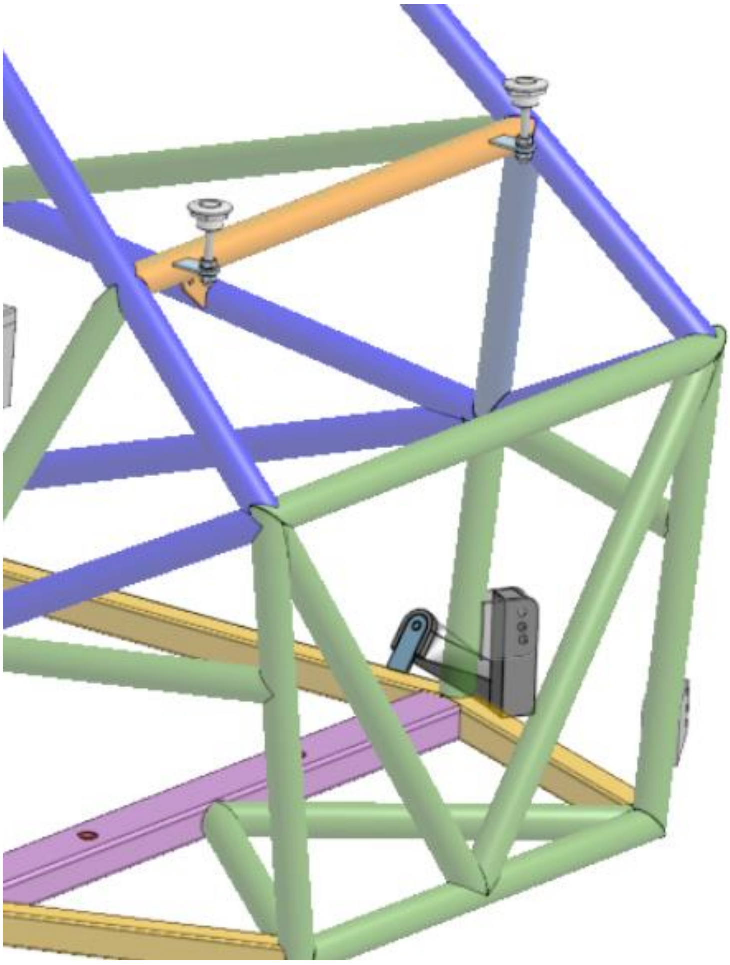


Figure 113. Body Kit Tab Jig - Suspension Pickup Example

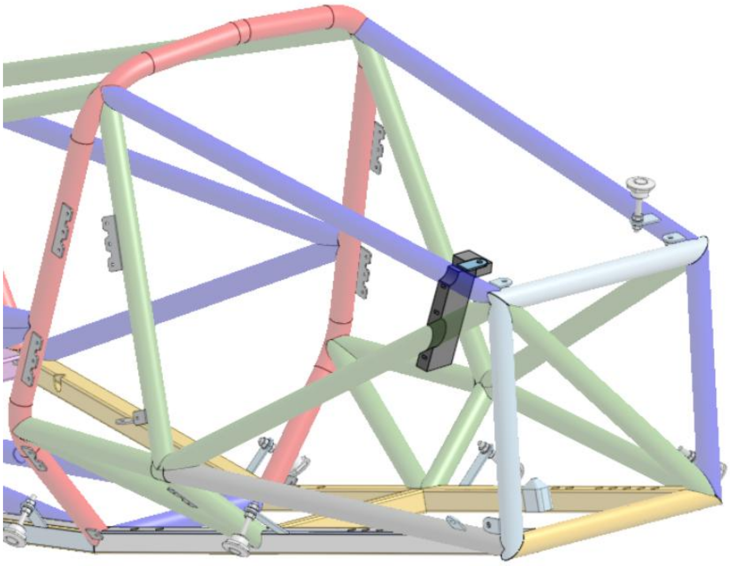


Figure 114. Body Kit Tab Jig – Chassis Node Example

There were 16 total tabs welded to the Chassis. As every jig was different, after consultation with the Prototyping Workshop it was decided that author would fasten each jig to the Chassis then place the tab in before the machinist would tack weld it in place. This process went smoothly, and every Body Kit tab was welded to the Chassis without issue.

10.6. Head Restraint

10.6.1. Initial Design

As described in 9.8.1 Head Restraint the parts and assembly of the Head Restraint is quite simple. NU 24's Head Restraint followed closely from NU 23's with the only goal of being lighter. An initial Head Restraint Design was completed by Chief Engineer, Joshua Wenham, then given to Keiran Burgess to reduce weight. It reused the Head Restraint Padding and E-Stop Enclosures from NU 23. This design is shown in Figure 115.

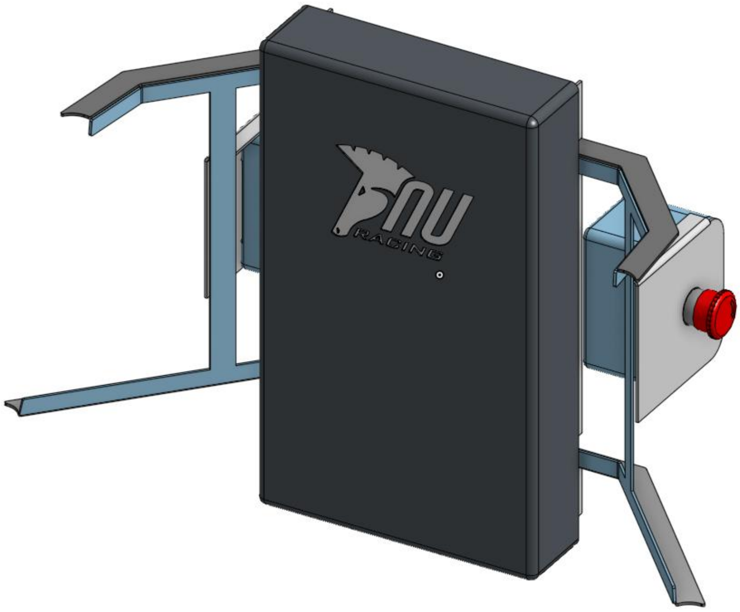


Figure 115. Initial Head Restraint Design

In the FSAE Rules it is required the Head Restraint must be able to withstand 900 N longitudinally and 300 N vertically or laterally [7]. This design was attempting to optimise the weight for the 900 N by including welded stiffeners on the top and bottom of the part. It should be noted this design was compliant.

This increased part count, manufacturing complexity (due to the additional welding), and weight. This design weighed 0.9 kg.

10.6.2. Revised Design

The author redesigned the Head Restraint with scope as follows:

- Increase manufacturability
- Reduce part count
- Reduce weight

The author's design is shown in Figure 116. An exploded view is shown in 9.8.1 Head Restraint, Figure 43.

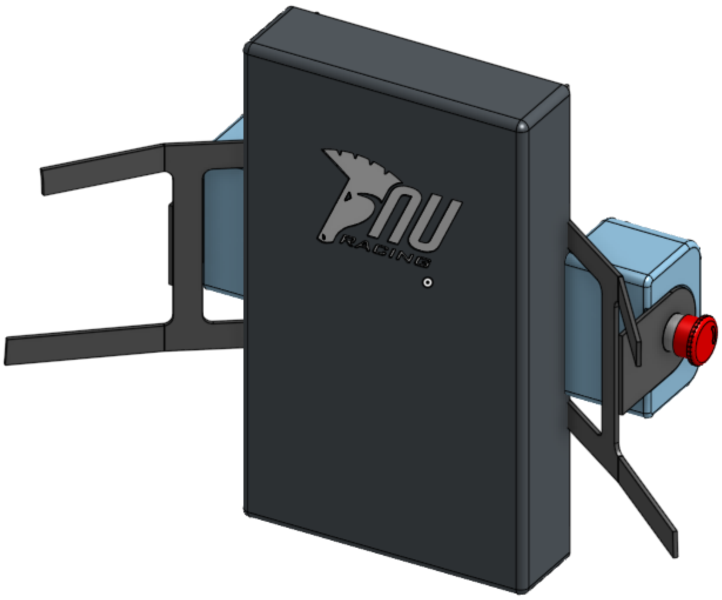


Figure 116. NU 24 Head Restraint

The Head Restraint reduced part count and increase manufacturability. The 2.5 mm steel backing plate was now single piece, barring the weldment of the E-Stop tabs due to the bend angle. This reduced the manufacturing time and effort. The solution weighed 0.77 kgs.

To prove the Head Restraint could survive the load specified by the FSAE Rules, FEA was completed and the results shown in Figure 117. It should be noted there were small peaks of 600 MPa stress shown in Figure 118. Due to their small size and likelihood of causing failure, the author made the call that these were acceptable.

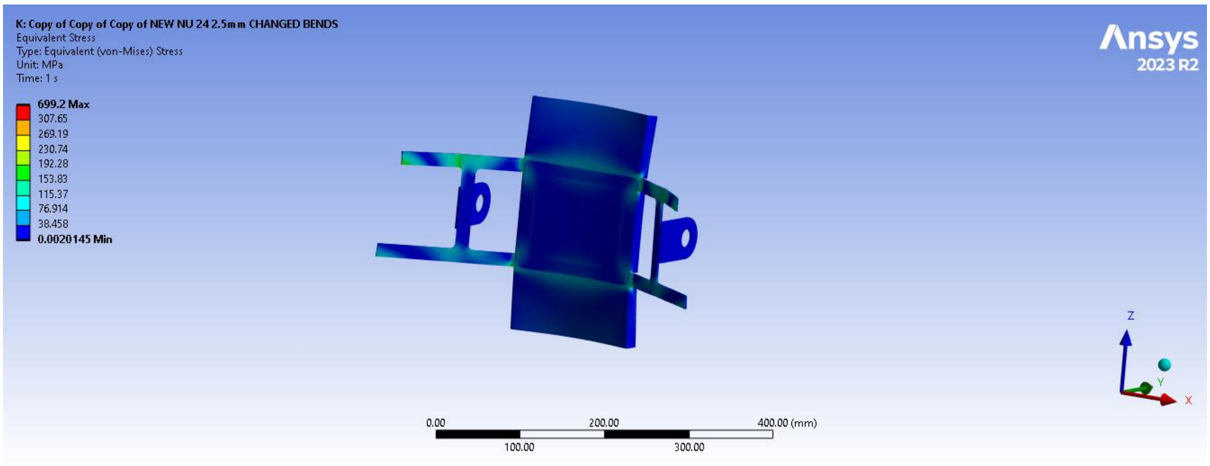


Figure 117. Head Restraint FEA

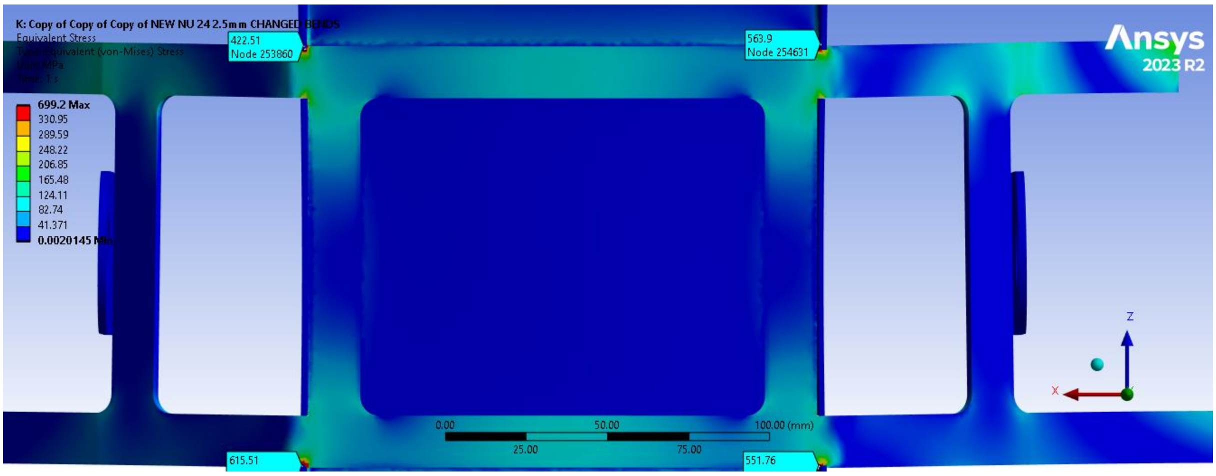


Figure 118. Head Restraint Stress Concentrations

This does not consider the weld pullout stress.

The author created manufacturing drawings for the Head Restraint, shown in 15.5 Appendix E – Head Restraint Manufacturing Drawings.

The Head Restraint and Aluminium Plate were sent to Hancock Speedway and manufactured with no issues.

To tack weld the E-Stop tabs to the steel backing plate, before full welding, the author made 3D printed jigs which slotted into the backing plate. The RHS jig is shown in Figure 119.

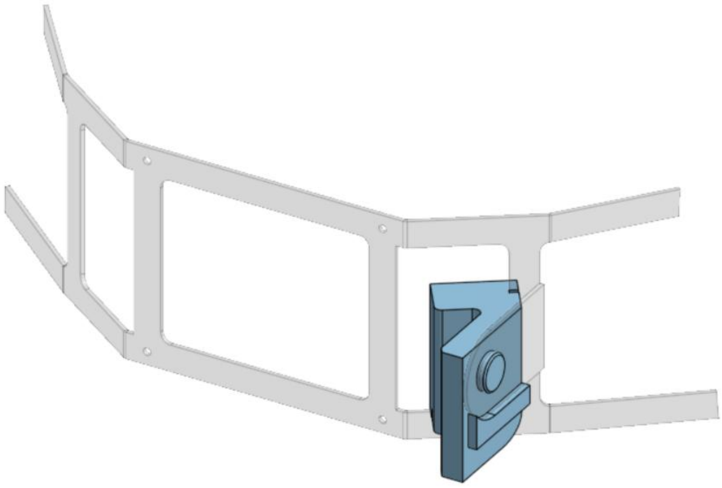


Figure 119. E-Stop Weldment Jig

The author made sure to increase distance from the PETG jig to the welding area to limit melting due to the heat. The Head Restraint was welded with no issues.

10.6.2.1. Head Restraint Performance and Evaluation

The Head Restraint passed Mechanical Inspection and performed as intended at competition. The position of the Head Restraint Padding begun to cause concern throughout the back end of 2024. Due to using the position of the Head Restraint from NU 23, no critical analysis was put into the position for NU 24. Depending on the driver, some people drove NU 24 with their head leaning forward. This can be seen in Figure 120.

Figure 120. Driver Head Position

The FSAE Rules state that the driver's helmet must be no less than 25 mm away from the padding in their normal driving position. Certain drivers, especially taller drivers, have the tendency to sit more upright and closer to the padding, whereas smaller drivers do not. The tallest driver when seated, always had their helmet close to the padding.

For NU 25 it is suggested that the tallest driver is sat in NU 24 as a reference and the helmets distance from the padding is measured. From this, the ideal position of the Head Restraint can be found. If the padding suits the tallest driver, rule T.2.8.5 states that different thickness padding maybe used for different drivers. The CONFOR CF45M padding used in 2024 is the minimum thickness dictates by the rules (38 mm), therefore thicker padding may be purchased to ease this issue. At a minimum the Head Restraint must move forward by some degree.

10.7. Brake Test Issues

In 2023, NU 23 passed the Brake Test with relative ease, only needing one attempt. The Brake System in NU 24 was the exact same, except for new Rotors designed by Keiran Burgess and the brake fluid was changed from DOT 3 to DOT 4 by the author. It was expected that NU 24 would pass this with ease. Due to the slew of changes in the weeks before competition the Brake Test was never practised.

What was not considered was that in 2023 tyres were allowed to be changed between events and this was stopped in 2024. NU 23 completed the Brake Test with used front tyres.

Due to rule changes NU 24 had to complete the Brake Test with the tyres it intended to compete with, brand new Hoosier LC0 Tyres. The rules stated that any tyre pressure was allowed if it was underneath the maximum dictated on the tyre sidewall. The initial pressure was 25 psi.

The author drove in the Brake Test and NU 24 struggled to lock the brakes. After a few attempts the NU 24 went back to the pits, the brakes lines were bled and the pads checked for glazing as there was thought to be an issue. Nothing was found and NU 24 went back out.

NU 24 then attempted the Brake Test twice more, before the tyre pressures were bumped up to 38 psi, however this done with a Makita Battery Air Compressor and was never checked with a Tyre Gauge by the officials. The actual pressure was 32 psi. The author was able to lock all four wheels, however the officials wanted it to be redone. The next run the author had locked all four wheels again. The vehicle was passed, however there were conversations about whether they would make us attempt the test again. This did not occur.

The maximum brake pressure, shown in Figure 121, was 1248 psi in the Rear Brake Lines and 1174 in the Front Brake Lines at 1.5 g of deceleration. This is equated to 89 kg of force applied on the Brake Pedal, shown in 15.2 Appendix B – Brake Force Calculations.

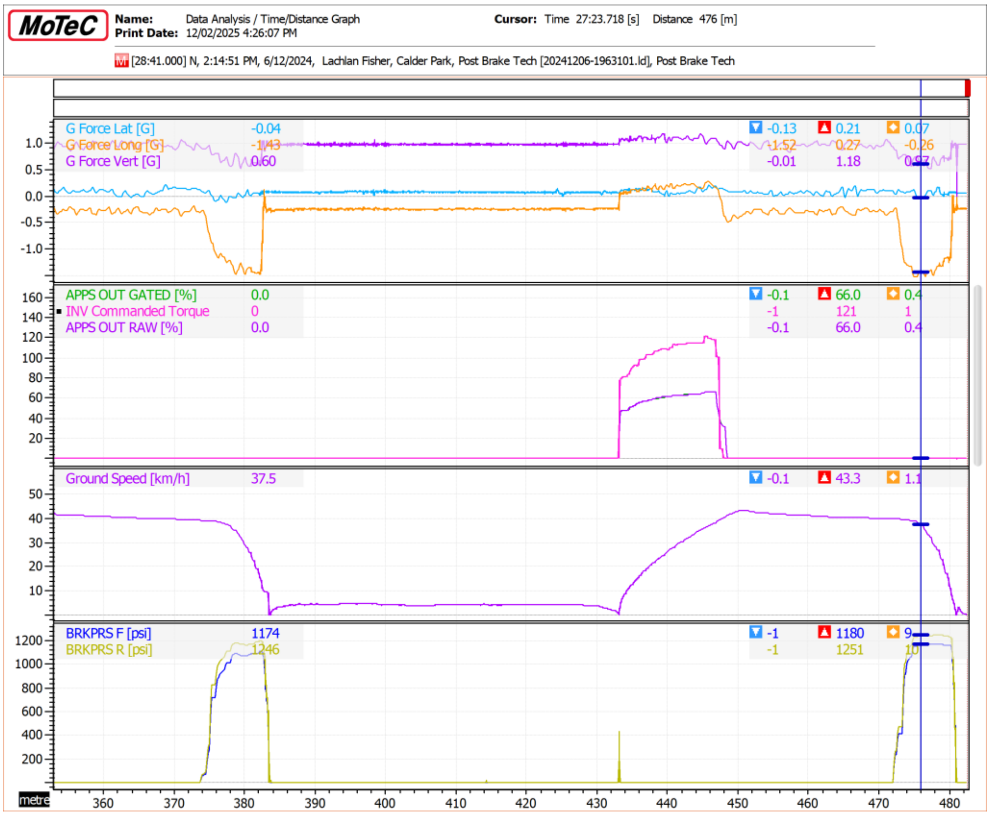


Figure 121. Brake Pressure and Longitudinal G-Force from the Brake Test

At this pressure the Brake Torque applied to each wheel should have been 256 Nm. The Braking Force was calculated to be approximately 1260 N to each front wheel and 630 N to each rear wheel. These calculations are shown in 15.2 Appendix B – Brake Force Calculations.

Weight is transferred to the front wheels under braking. This is described by Equation 5.1 where μ is the tyre friction coefficient, h is the height of the CoG, W is the vehicle weight, a is the longitudinal acceleration of the vehicle under braking, w_b is the wheelbase and g is acceleration due to gravity.

$$W_T = \frac{\mu h W a}{w_b g} \tag{5.1}$$

Ideally the friction coefficient and the Tractive Force from the tyre under braking could be found from the TTC data, where it is simply the weight on the tyre divided by the braking or driving force. This however was not possible, as the Round 8 of the Tyre Test, which is where our tyre data is stored, did not record drive or brake torque as explained in Figure 122. Due to this the required braking force, derived from the Tractive Force of the tyres, cannot be gathered from this.

9. TEST COMMENTS

A few important comments on the Round 8 tests:

All 10 inch tire testing went very smoothly. This data was collected using an offset adapter. The spindle on the Calspan Tire Research Facility test machine cannot descend low enough for the 10 inch tires to touch the roadway without an adapter. Because the adapter cannot transmit drive/brake torques, all 10 inch tire data is free-rolling only.

Figure 122. TTC Round 8 Test Comments

Another issue noticed post-competition was that the Brake Rotors did not fully contact the pads at the outer edge. This reduces the effective radius of the braking torque. This is shown in Figure 123.

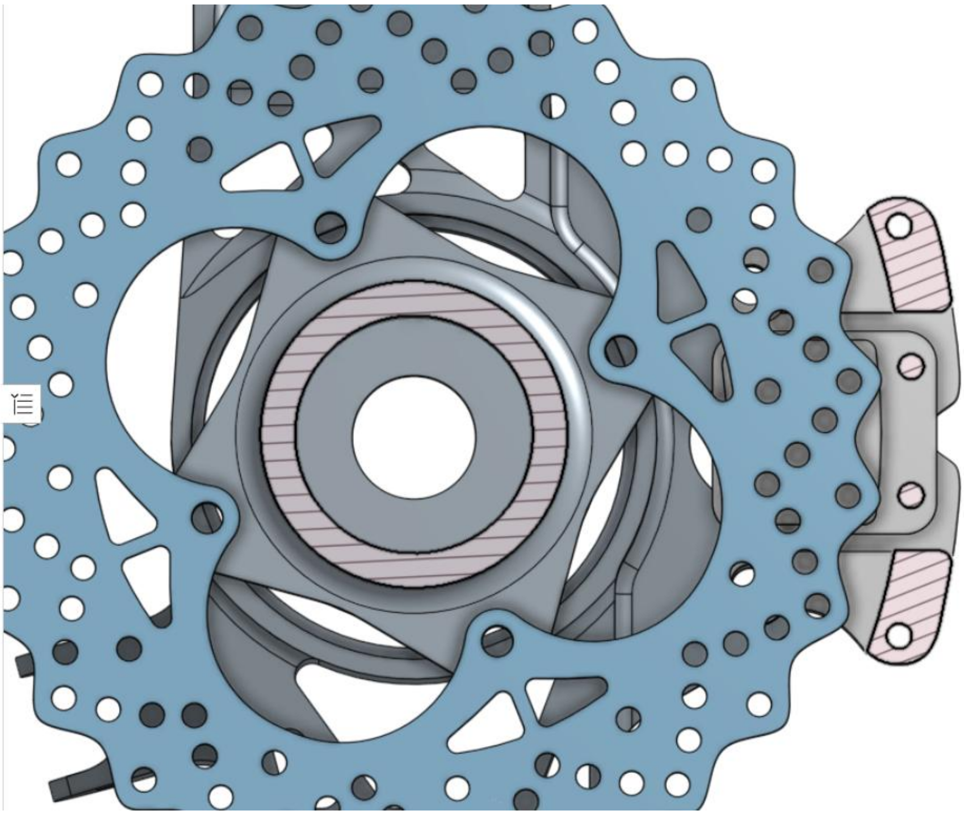


Figure 123. Brake Rotors Not Making Full Pad Contact

10.7.1. Recommendations

The lack of Braking Torque was alarming and must be addressed in 2025. The easiest solution would be to purchase the BP-28 Brake Pads from Wilwood. These were never purchased for NU 24 as there were budget restrictions. They provide a higher coefficient of friction across all heat ranges (0.4 compared to the Purple Pads 0.28 at 100° F). This is shown in Figure 124 and Figure 125.

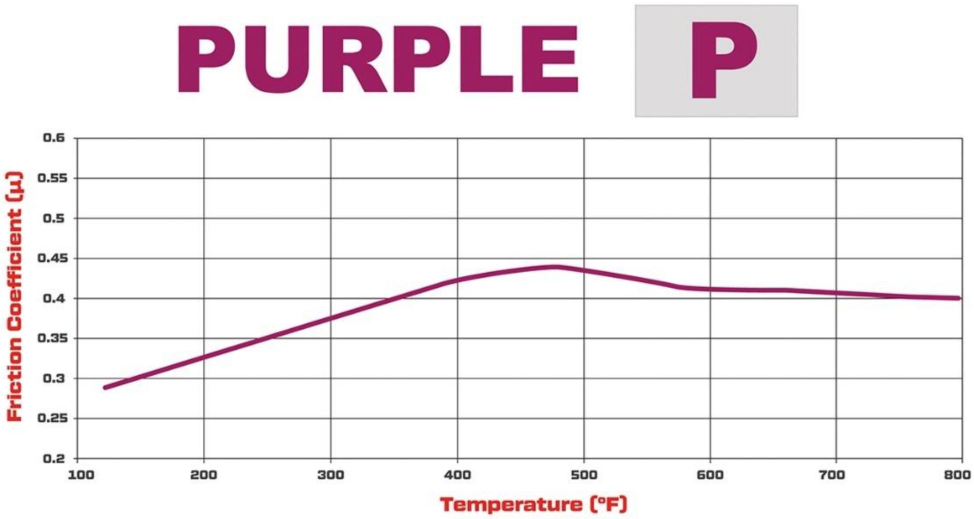


Figure 124. Purple Pad Friction Coefficient

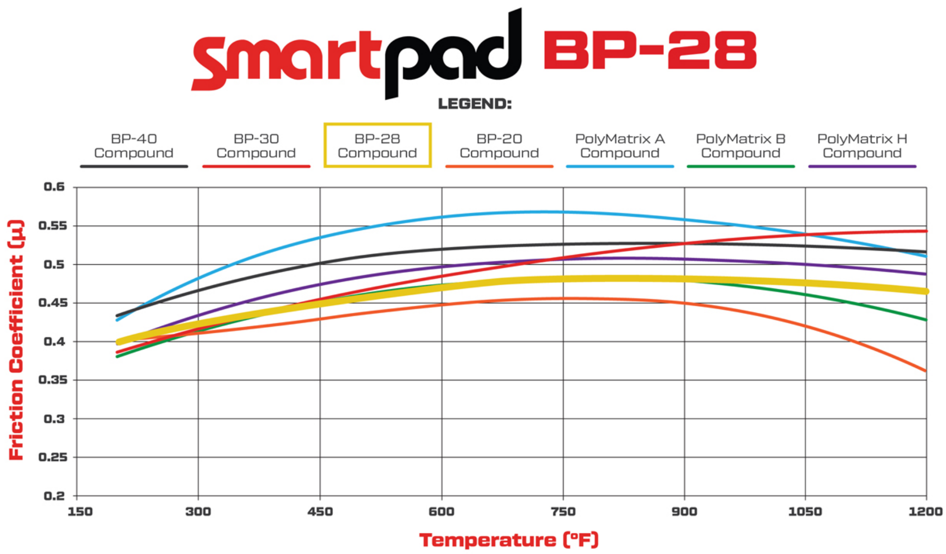


Figure 125. BP-28 Pad Friction Coefficient

The Brake Rotors should also be replaced with the NU 23 Brake Rotors to verify if the Brake Force is reduced by the new Rotor Design.

This must be tested on NU 24. Both tests should take place on campus and at SMSP. At SMSP the tracks that are used by NU Racing are concrete whereas the ICT Carpark is asphalt. The tests should be conducted on both surface types, with new tyres, to verify results.

If these recommendations do not remedy the issue, the following can be investigated:

- Changing the Pedal Ratio to influence the brake pressure for the same force
- Alter the Brake Rotors to ensure that the entire Brake Pad is being used.
- Changing the Uprights to achieve one of the following:
    - Increase Rotor Size – (near impossible due to clearance)
    - Change Brake Caliper

It should be noted that the Pedal Ratio should be the most preferred of these solutions, as it is the easiest to prototype whilst being quick and easy to test. However, this will change the braking feel of the car as the required travel of the Brake Pedal to fully actuate the Master Cylinders will change. Experienced drivers must be used to provide relevant feedback about the travel and feel of the Brakes. This will increase the Brake Pressure which should not be an issue as the Aeroflow AN-3 Steel Braided Lines can handle up to 4000 psi of pressure.

If it is deemed that the Uprights need to change the Rotor size, or the Brake Caliper clearances will need to carefully be checked. There is approximately 8 mm of clearance to the rim from the Brake Caliper as shown in Figure 126. This should not be reduced, and new Rotors are most likely not the solution.

Figure 126. Brake Caliper Clearance to Rim

Changing the bore size of the Master Cylinder is also not feasible. The two Tilton 78's have a 5/8" bore, which is the smallest they offer. To increase the Brake Pressure the bore size needs to reduce, so new Master Cylinders smaller than 5/8" would be required to make a change. This is also not viewed as an ideal solution.

10.8. Cooling

All NU 24 Cooling work was completed by the 2024 Cooling Engineer, Jayden Hardinge. This section briefly details why NU 24 naturally cooled better than NU 23. For more detail on the Tractive System Cooling refer to Joshua Hayward's report

Much time was spent in 2024 collaborating with PWR about the design of the new Radiator. As it was initially mean to be used for 2024 there was much concern as with how the new Emrax 228 would affect the Cooling System as a whole. Initially, the Chief Engineer Joshua Wenham, wanted a 200 mm × 200 mm radiator maximum to be specified for NU 24. However, with little data on the temperature characteristics of the 228 Motor, PWR strongly urged the Cooling Engineer, Jayden Hardinge, to increase the size of the Radiator to 255 mm × 260 mm.

Looking at the cooling data from NU 23 during Endurance of the 2023 competition, shown in Figure 127, the Emrax 188 reached a maximum temperature of 83° C. The temperature on this day was 26° C.

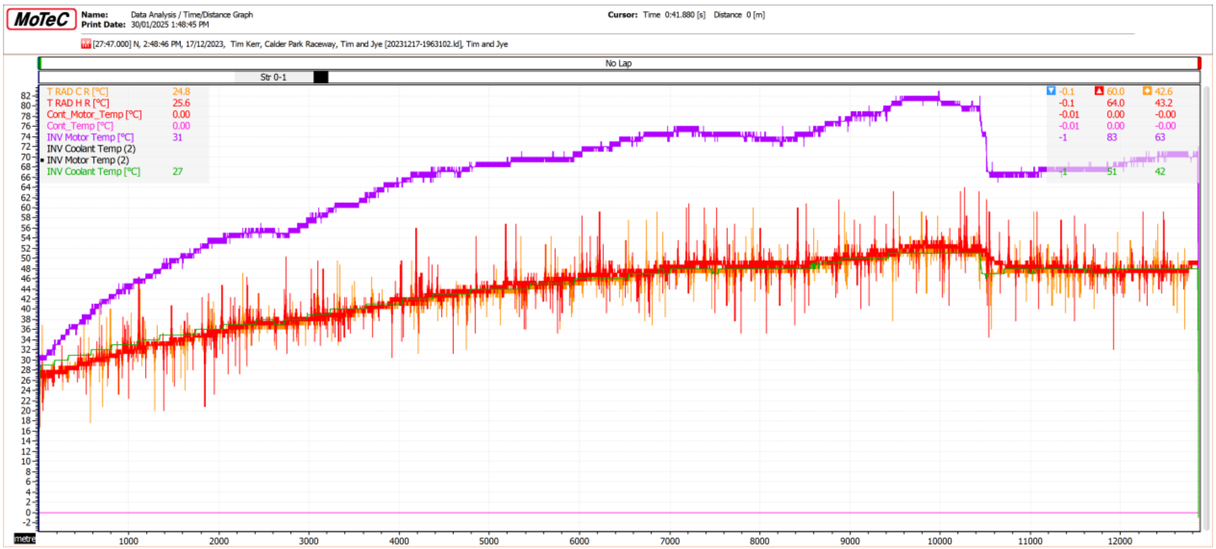


Figure 127. NU 23 Drivetrain Temperatures in Endurance

Comparing this to the Endurance of NU 24 at competition, shown in Figure 128, show that the Emrax 228 only reached 57° C using the same Radiator, Pumps, and Thermo Fan.

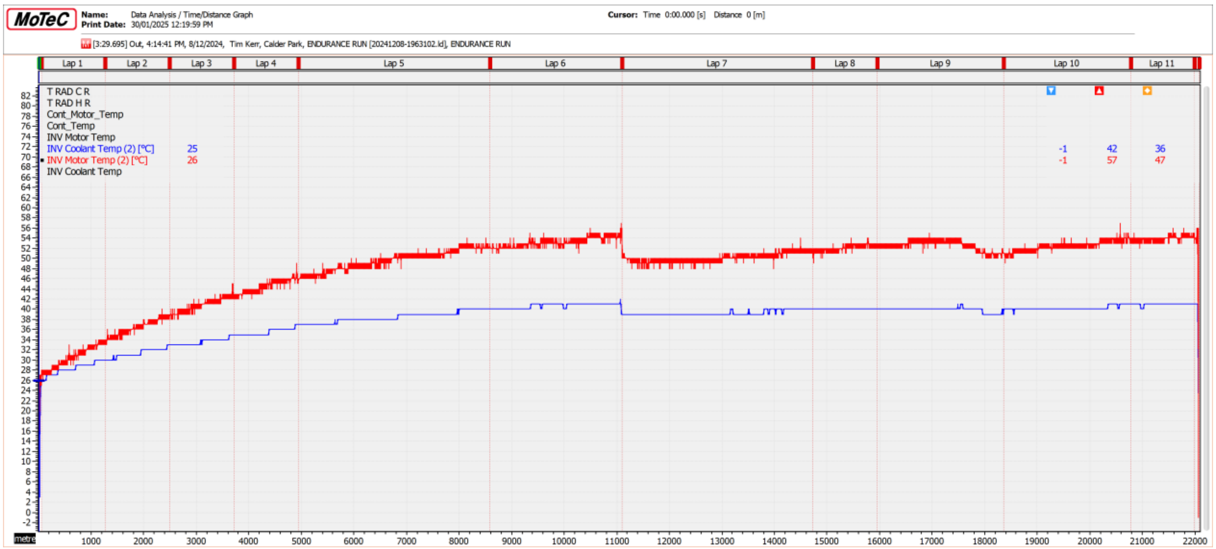


Figure 128. NU 24 Drivetrain Temperatures in Endurance

Due to the gear ratio of NU 23 being 60:11 to achieve higher levels of torque, it meant that the 188 had to spin at naturally higher rpm than NU 24. Figure 129 shows that the maximum speed of the 188 during Endurance in competition what 5790 rpm, which corresponded to a speed of 78.7 km/h. When compared to the maximum speed of the 228 for NU 24 in Endurance was 3376 rpm at 78.1 km/h. It should be noted that for the Motor, both for NU 23 and NU 24, the motor spins in the negative direction according to the Motor Controller. The 228 and 188 can spin clockwise and anticlockwise. For our application they must run clockwise due to the orientation of the Motor in the Drivetrain, which means when reading the MoTeC data the Motor Speed reads negative.

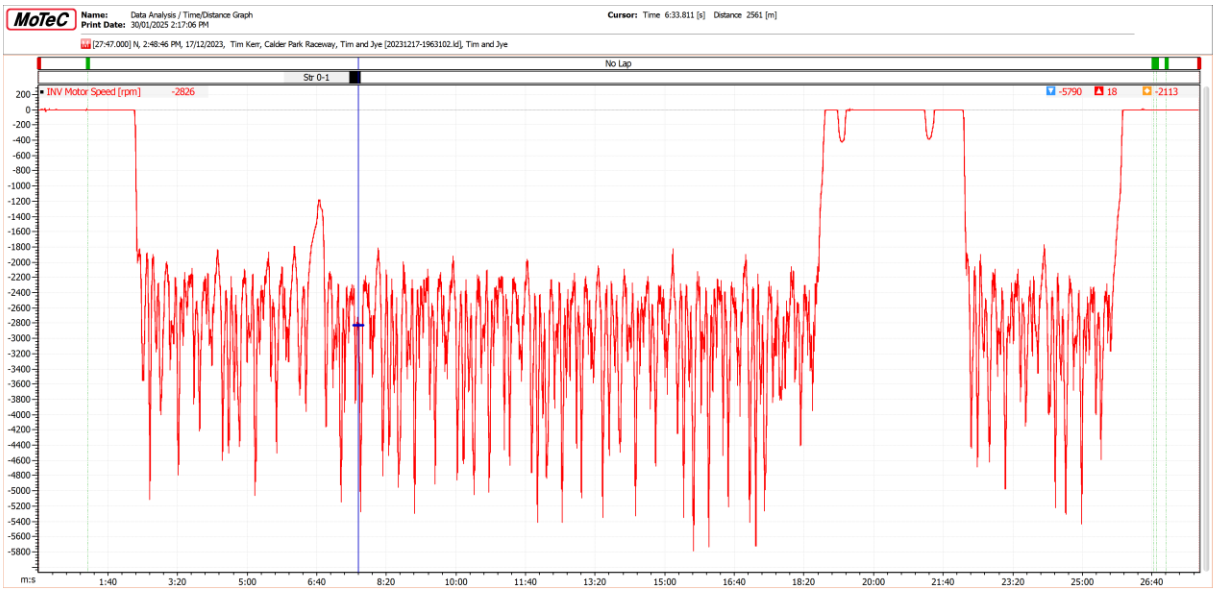


Figure 129. NU 23 Motor Speed [rpm] During Endurance

Figure 130. NU 24 Motor Speed [rpm] During Endurance

Due to the higher speeds the 188 Motor had to hold during competition it sustained higher temperatures throughout, which is expected.

Due to changes to the Low Voltage Topology of NU 24, there was no readings for the temperature sensors for the Radiator. Due to this the coolant temperature was only estimated by the Motor Controller coolant temperature sensor. The Emrax 228 has a maximum coolant temperature of 50° C [6]. If the coolant temperature during Endurance is a similar temperature to the coolant reading given by the Motor Controller, a maximum of 42° C, then the cooling package can be reduced in size. In 2025 the radiator temperature sensors should be read by the Expansion Port on the CEN.

It can be seen in that the cooling package for NU 24 was possibly excessive. This is a positive considering the cost of the Motor Controller and Motor. If either component was damaged due to excessive temperature, NU Racing would not have had the budget, nor the lead time, to get a replacement. However, in a racing perspective, this means that NU 24 carried excess weight, and at a minimum the radiator size could likely be reduced. With the Radiator for NU 25 purchased, it is expected that the Inverter will be cooled better, as the coolant from its loop will not be derated by the higher temperature Motor coolant. The Motor is expected to cool similarly to NU 24.

11. Testing

Practical testing can be the simplest way and sometimes only way to test things. An example of this is testing the capability of the Cooling System and the temperatures of the Motor Controller and Motor (without a dyno setup). Practical testing should also be used to verify hand calculations and FEA. A method of doing this is using strain gauges. Physical testing is essential to ensure the vehicles reliability and performance.

Validating a part or systems performance is also critical to building a competitive vehicle. If a part or system does not have data proving that it is a clear upgrade or improvement it should not be utilised. Spending time testing new parts and systems is critical to determining performance characteristics.

In 2024 the Motor Controller failed on August 3rd and NU 24 was not driven again until October 28th., this is discussed in more detail in Joshua Hayward's and Alec Chapman's reports respectively [32], [39]. This massively reduced the available testing time from five months to two months. The time available after the new Motor Controller was implemented was only six weeks.

Due to this some testing the author and Leadership Team made decisions to not complete or limit certain testing or training items that were scoped at the start of 2024. These include, but are not limited to:

- Strain gauge testing for Suspension and Chassis Loads. This included testing for the:
  - Uprights
  - Control Arms
  - Front Hoop
  - Tie Rods

- Full competition emulations including the Brake Test
- Thorough Vehicle Dynamic evaluation

This limited the potential and data gathering capability of NU 24.

In the period between October 28th and December 3rd there were eight SMSP track days and two on campus track days, with minimum two track days a week. This took an excessive load on the team, and through their commitment NU 24 was able to complete 350 km of testing.

Most of these track days had at least one issue, especially electrical issues which are detailed thoroughly by Alec Chapman [32]. Due to this there was often large periods of downtime at track days.

Also hampering NU Racing was the failure to book the Skid Circuit track at SMSP. The Skid Circuit track is the only track where it is possible to run Skid Pad, Acceleration, and high-speed Autocross runs. This heavily hampered testing, especially for Vehicle Dynamics as Skid Pad was only driven three times prior to competition.

Without the large importance placed on the value of track days, NU 24 would not have competed well during competition. Testing time is invaluable and is the only way to fully test a fully integrated system.

12. 2024 Competition

This section will detail the timeline and results from the 2024 Competition. NU Racing left Newcastle on December 3rd, ready to begin competition on December 5th (Thursday).

12.1. Static Events and Technical Inspection (Thursday – Friday)

The team had settled into the accommodation and were making last minute adjustments to NU 24 as well as washing the Body Kit. The author and Alec Chapman were completing the Cost Amendment Report and the Cost Scenario in the morning.

The team bumped into Calder Park and set up the pits. This included shelving, all tools and spare parts, and preparing NU 24 for Technical Inspection.

The author and people relevant to the Cost Event attended the Cost Event Briefing.

Thursday and Friday included the Static Events and all Technical Inspections.

A timeline of the events on Thursday is shown in Table 2.

Table 2. Thursday Competition Schedule

Time	Event	Notes
9:00 AM	Cost Event	Detailed in the Cost Event section of this report
11:00 AM	Accumulator Inspection	Detailed in Alec Chapman's Report
2:00 PM	EV Static Inspection	Detailed in Alec Chapman's Report
3:00 PM	Mechanical Inspection	Detailed in the Technical Inspection section of this report

The Cost Event was completed within its allocated timeslot.

Accumulator Inspection failed on only one item, which was fixed and reinspected the next day, which then passed [32].

EV Static and Mechanical Inspection were both passed. Several Issues appeared in Mechanical Inspection, detailed in the Technical Inspection section of this report.

A timeline of the Friday is detailed in Table 3.

Table 3. Friday Competition Schedule

Time	Event	Notes
1:00 PM	EV Functional	Detailed in Alec Chapman's Report
2:40 PM	Business Presentation	Detailed in Rishi Mathuria's Report
5:00 PM	Design Event	The initial time was 11:00 am but was changed due to FSAE scheduling issues
N/A	Weigh Station	Not scheduled - After Mechanical Inspection
N/A	Tilt Test	Not scheduled - After Mechanical Inspection
N/A	Brake Test	Not scheduled - After Mechanical Inspection and EV Functional
N/A	Rain Test	Not scheduled - After EV Functional

The Weigh Station, Tilt Test, Rain Test, and Brake Test all require that prerequisite inspections are completed prior to them.

The Tilt Test and Weigh Station were completed after Mechanical Inspection on Thursday. NU 24 had an official weight of 242.5 kg.

The Tilt Test caused some worry. The height of the centre of gravity (CoG) of NU 24 was never calculated. When going into the test the team was confident that it would pass. However, due to changes to the Coilovers being mounted to the Upper Control Arm and placing the Motor above the Spool Assembly meant that the CoG height had increased. This was paired with the reduced track width of NU 24. One of the inspection officials noted that the after being tilted to 60°, they noticed that the sidewall of the highest tyre was not as compressed as the lower one, noting it was the closest car to failing they had seen. Despite this the Tilt Test was passed.

The main change to limit this causing an issue in the future would be lowering components, as this would lower the CoG, including the Coilovers back to the Lower Control Arms and the Motor. The author recommends for 2026 (NU 26) that if a new Accumulator does not allow enough space for the Emrax 228 to be placed in the same configuration as NU 23 (same height and in front of the Spool Assembly) the placement of the 228 behind the Spool Assembly should be investigated. This will lead to an increase in the total weight of the Chassis as it will have to increase is length to accommodate the change and may also affect the weight distribution of the car, however placing it behind the Spool Assembly means that the wheelbase will not need to be increased. This is only a recommendation for investigation, not change.

Also, the knowledge of height of the CoG is unknown, but assumed to be less than 310 mm. At 60° it was known that the higher wheel began to lift. This can only occur if the CoG passes the reaction force from the lowest tyre and beings to create a moment that wants to roll the car. A sketch of this, made by Joshua Wenham is shown in Figure 131. It should be noted this was generated in Onshape, where the ride height of NU 24 is 50 mm, which is larger than the real ride height at competition of 38 mm. This would lower the CoG height as well.

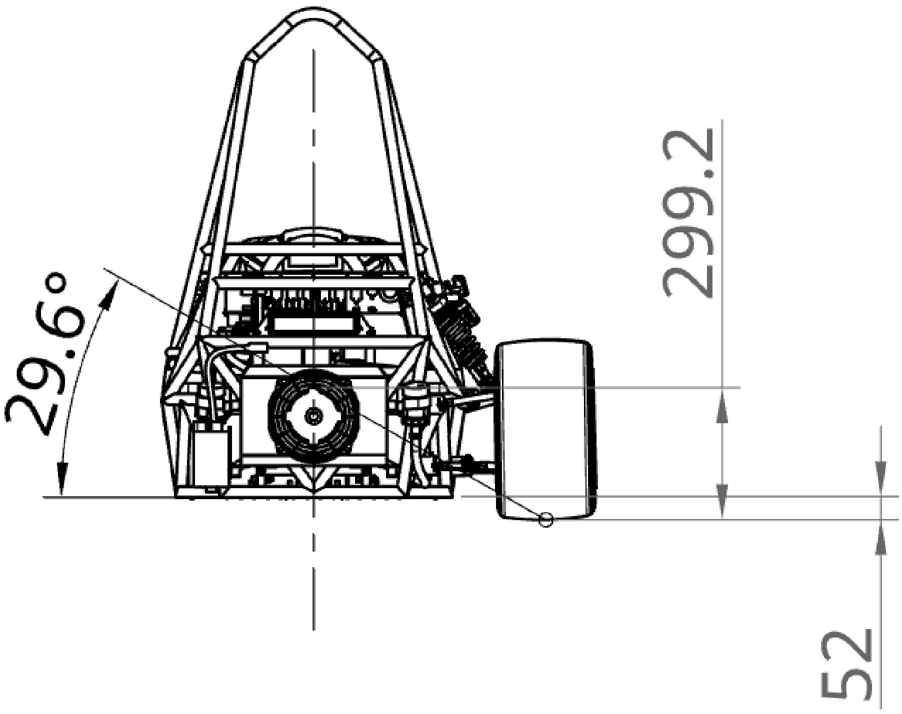


Figure 131. Approximate CoG Height

EV Functional was completed and NU 24 then completed the Rain Test immediately afterwards. This is shown in Figure 132.

Figure 132. NU 24 in the Rain Test

Immediately following the Rain Test NU 24 went to complete the Brake Test. This process is detailed in section 10.7.

The Design Event was completed by the entire team, with the author defending the Vehicle Performance category.

This marked the end of the Static Events and Technical Inspection and NU Racing began preparation for the Dynamic Events.

12.2. Dynamic Events

The Dynamic Event schedule is shown in Table 4.

Table 4. Dynamic Event Schedule

Time	Event
Saturday	
9:00 AM	Skid Pad Event Open
12:30 PM	Acceleration Event Open
Sunday	
9:00 AM	Auto Cross Event Open
1:00 PM	Endurance Event Open

12.2.1. Skid Pad

Skid Pad was completed on a wet surface due to the Melbourne Weather. Due to budget restraints, mostly due to purchase of a new Motor Controller, new wet tyres could not be purchased. Older wet tyres were used instead.

The first driver, Alec Chapman, completed using the old Wet Tyres, however due to their age was not able to set a representative time. This meant the second driver, the author, had to set a reasonable time to ensure points were gained for the event.

The author, on slick tyres, placed the car second fastest. As NU 24 was 10th out of 23 cars, and conditions seemingly worsening the team thought they had achieved a podium in the first event. However, as the event still had over an hour left conditions improved significantly and six cars were able to beat this time. It should be noted that every car that beat NU 24, had their last driver on track after the author.

Figure 133. The Second Skid Pad Driver

12.2.2. Acceleration

Following Skid Pad the track surface at Calder Park had greatly improved and set the scene for Acceleration. During the event both drivers, Marisa McLean and Holly Nicholas, the first and second drivers respectively, achieved sub 4 second runs. These were by far the fastest times in NU Racing history, 0.511 seconds faster than 2023's time. This time was painfully only 0.017 seconds off a podium at 3.9397 seconds. The team was blown away by the achievement. This was allowed by the Emrax 228 and Drivetrain which allowed for increased torque and speed. A top speed of 104 km/h was reached before the line, and 108 km/h after the line.

Figure 134. The Second Acceleration Driver

12.2.3. Autocross

After such a great Saturday, Autocross left a bad taste in the team's mouth. The same Accumulator Management System (AMS) fault stopped NU 24 that had stopped NU 23 in its Endurance. This is spoken in more detail in Alec Chapman's report [32].

Timothy Kerr, the first Autocross driver had set a good banker lap and halfway through a lap, that was already approximately 3 seconds faster than his first, the AMS fault occurred. Due to the FSAE Rules the car had to be abandoned and the second driver, Zak Lobko, did not get the opportunity to drive.

12.2.4. Endurance

After a difficult morning, that shattered the team, the Mechatronic Team fixed NU 24 and it was ready for Endurance.

The first driver, Timothy Kerr, drove great, managing State of Charge (SOC) usage and temperatures well, but noted during the driver swap that they were very easy to manage. The author was the second driver and on his first lap missed a gate. Following this the author was yellow flagged for a car that kept driving then stopping. After the first yellow flags were dropped the author picked up speed again. Immediately after this the car in front came to a halt and no yellow flags were presented, and one of the officials' vehicles was driving next to the author. An excerpt from the GoPro footage is shown in Figure 135.

Figure 135. Second Endurance Driver's Confusion with the Marshals

FSAE Rule D.4.1.9 states that a vehicle cannot pass under a yellow flag unless directed by the corner workers. The author, after the corner workers finally displayed a yellow flag, nearly comes to a full stop asking to go around the car. The marshals gave no instructions and just stared at the driver. The driver spent 10 seconds asking to go around the stopped car. Upon nothing being said the stopped car had begun driving again before stopping not even a corner later. The author, not close enough to the next marshal station decided to slowly drive around the stopped vehicle and continued the run. 30 seconds was lost this lap. This is shown in Table 17.

Despite this NU 24 completed Endurance and placed 5th. The team was ecstatic as this was done in a lightning time. The time, including the 30 seconds lost, would have equated to 4th if not for the penalty incurred by the author or the yellow flag issue did not ensue. This was beyond a great result.

Included in this the team also placed 4th in Efficiency, narrowly missing a podium.

Figure 136. The Second Endurance Driver Finishing the Event

12.3. Competition Conclusion

NU Racing where able to finish 4th overall in the FSAE-A competition in 2024. This was the teams tied best results, but smashing the previous points record claiming 733.86 points out of 1000. Having more luck in the Skid Pad event, having a later time in the dryer weather, or not having the AMS fault in Autocross would have resulted in a podium. It is estimated that the team lost anywhere between 40-70 points due to the two events.

This was an amazing achievement by all involved and a true testament to the grit and determination of the little blue team.

This event now meant that NU Racing was ranked the 12th best car in FSAE globally [40].

The overall results of FSAE-A 2024 are shown in Figure 137.

Formula SAE-A 2024

Overall Results

EV Class

O/All PLACE	Car Number	Team Name	Design	Costs	Presentation	Skidpan	Acceleration	Autocross	Endurance	Efficiency	OVERALL RESULTS
1	A65	Monash University	150.00	70.63	75.00	75.00	86.18	125.00	265.03	15.72	862.56
2	E47	The University of Auckland	143.00	41.98	73.19	61.85	100.00	114.55	251.60	8.37	794.54
3	E14	Curtin University	126.00	86.53	72.41	61.18	48.25	105.55	237.71	21.69	759.33
4	E3	University of Newcastle	120.00	75.55	54.05	42.64	71.79	78.13	250.87	40.82	733.86
5	E42	The University of Queensland	133.00	90.50	44.29	33.39	20.42	88.94	275.00	40.67	726.21
6	E13	University of Canterbury	121.00	85.33	69.31	61.32	52.16	0.00	195.42	100.00	684.55
7	E85	University of Wollongong	129.00	75.82	57.80	27.42	18.67	54.03	269.34	44.90	676.98
8	E20	University of Western Australia	137.00	72.57	54.31	64.99	64.52	81.48	129.15	21.26	625.28
9	E8	The University of Adelaide	127.00	65.01	46.29	30.13	22.81	82.03	229.50	0.43	603.20
10	E44	University of Tasmania	108.00	88.83	62.59	43.42	70.22	0.00	154.70	50.57	578.33
11	A63	University of New South Wales	139.00	76.01	68.79	65.03	59.61	57.13	16.00	0.00	481.56
12	E88	RMIT University	133.00	12.75	62.07	22.96	48.09	78.61	5.00	0.00	362.47
13	E107	National Taipei University of Technology	101.00	0.00	40.09	43.24	22.33	54.71	67.87	27.04	356.28
14	E17	Swinburne University of Technology	132.00	48.28	40.34	0.00	72.97	0.00	0.00	0.00	293.59
15	E46	Queensland University of Technology	105.00	79.42	71.38	0.00	4.50	0.00	0.00	0.00	260.30
16	E111	Griffith University	105.00	66.41	54.70	0.00	0.00	6.50	0.00	0.00	232.61
17	E301	University of Melbourne	111.00	62.98	47.72	0.00	0.00	0.00	1.00	0.00	222.70
18	E25	University of Waikato	104.00	59.02	51.79	0.00	0.00	0.00	0.00	0.00	214.81
19	E22	The University of Sydney	103.00	16.40	62.46	0.00	0.00	0.00	0.00	0.00	181.86
20	E16	University of South Australia	104.00	0.00	37.24	0.00	0.00	0.00	0.00	0.00	141.24
21	E59	University of Technology Sydney	69.00	3.00	62.59	0.00	0.00	0.00	0.00	0.00	134.59
22	A79	Western Sydney University	45.00	4.55	42.55	0.00	0.00	0.00	0.00	0.00	92.10

Figure 137. Overall FSAE-A Results 2024

13. NU 25

The initial approach to 2024 for the Mechanical Department was to first manufacture the car designed by 2023's team, before moving into the design of 2025 following the manufacturing period. This responsibility to manage this design process, initially was left to the author, was handed to Chief Engineer Joshua Wenham due to the authors growing workload this responsibility.

The author informed Wenham of every time one of the Mechanical Engineers had fully completed their required work on NU 24 and supplied a template Task List. This was the only impact the author had on the initial design of NU 25 as focus was kept on the 2024 competition.

The goals for NU 25 aim to build on the positives of NU 24 with a reduced manufacturing load than 2024. This is such that design of 2026 can occur earlier in the year and track testing can begin earlier as well. The scope of NU 25 should follow Table 5.

Table 5. NU 25 Scope and Goals

Scope	How this will be achieved
Reduce manufacturing load	More parts reused from NU 24, including the Accumulator, Steering, Control Arms
Simple self-documenting systems	Through design reviews and alignment to system and team goals
Increase serviceability	Maintain designs similar to NU 24 where possible. Thorough design reviews and scoping. Modelling of tools to verify clearances when for assembly/disassembly

Increase manufacturability	Heavy consultation with the Prototyping Workshop and thorough design reviews and scoping
Prioritise long term team performance	Maintain commitment to ENGG2200 and bringing the design phase earlier into the year
Tend to evolve previous designs over mass redesign	Iterating designs and smaller scale changes from previous systems. Mass redesign parts are done in parallel with the intention to not be used on NU 25
Traction limited EV	Manufacture a Drivetrain that can withstand 230 Nm of torque from the Emrax 228
First implementation of the Drexler Differential	Manufacture of a suitable Powerbox, new Rear Uprights and Spindles
Increase Brake Capacity	Change Brake Pad compound to BP-28, redesign Brake Rotors if required

For reasons unknown the design of NU 25 halted after competition. This means that the 2025 team has not been provided with fully designed systems, instead only a fully designed Chassis has been provided. A Drivetrain iteration is nearly complete but remains non-compliant due to the Chain Guard, and no Scatter Shield has been designed.

The author, following the submission of this report will be attempting to complete some of these designs, namely the Drivetrain and the Steering mounting, to assist the 2025 team.

This has left 2025 with a larger design workload than desired and has partially destroyed the ‘build first, design second’ philosophy set in 2024. The author hopes that the 2025 team will give the 2026 team what we did not give them.

14. Conclusion and Recommendations

2024 was a huge success for a small team that had undergone such a volatile year. The loss of NU Racing's Academic Supervisor and Champion Dr Alexander Gregg was immense and felt across all of NU Teams. The loss of three months of testing and a massive hole in the budget due to the Motor Controller failure tried to kill the team's spirit. However, the small team size of only 15 full time members, with such a high workload, proved to be stubborn and beyond passionate about NU Racing.

NU Racing finished the FSAE-A Event 4th overall and ranked 12th Globally. This was such a reward after such a high intensity year.

2025 aim needs to be to take the positives from NU 23 and NU 24 and once again iterate these designs. 2024 was the first year of truly iterative design, with nearly every major change to NU 24 being a direct iteration of a system from NU 23. The author recommends that NU 25 follows in these footsteps to avoid bottlenecks and continue to build performance through reliability and track testing. The scope and goals of NU 25 should remain deathly similar NU 24's.

Simple designs and promoting ease of manufacture is vital to the growth and performance of NU Racing. At the end of the day all of the drivers are amateur at best, and maximising seat time is far more valuable than minor changes in weight or performance, which can chew up time.

Prototyping and validating designs remains crucial and should be at the forefront of the Mechanical Design Process. In particular, validating clearances by 3D printing an entire system (where applicable) and assembling it together should be completed before manufacture commences. The killer of most FSAE teams is trying to achieve too much in a single year. NU Racing must avoid this by setting realistic goals and expectations.

The Leadership Team for 2025 needs to have a fully transparent relationship with the rest of the team. At times in 2024 this was not the case, and the rest of the team were left wondering what was going on, especially during Track Days. Being fully transparent will allow them to have an honest and open relationship with their team, which for small teams such as NU Racing, is vital to success.

Track Days need to be deliberate and thoroughly planned. Track testing is the most important method of validation and integration testing, it tests the system's ability to complete its function. They cannot be treated lightly, as in 2024, once they are limited it creates great difficulty for the rest of the year, especially at competition.

Both Department Leads, not just the Chief Mechanical Engineer, must work hard to utilise proper project management skills. The most important part of being in any leadership role is being organised and having an organised team that understand their roles and responsibilities. This can only occur if you lead by example. Be on time, be professional, be prepared. This will set the foundation for a strong year. Historically team management has been poor, and the Department Leads have instead just completed the brunt of the work, which did occur again in 2024. However, 2024 was a year where proper strategies and project management were implemented, and they must be continued to be used to get the most out of the team.

The Department Leads cannot be relied on by the entire team to complete every critical task. In 2024 both leaders were spread incredibly thin. This came to head at competition where they were responsible for the entire Cost Event, Technical Inspection, Design Event Sections, and both being competition drivers. The author hopes that no future member must endure a workload this large.

Utilise NU 24 as a development as testing car. In 2024, NU 23 was barely used to test changes or complete driver training. This was a waste of an extremely valuable resource as it would've allowed for data gathering to inform design choices throughout 2024. This is especially important for the Mechatronic Department; however, this should be utilised by the Mechanical Department. It should be used to understand Suspension and Chassis loads, complete large amounts of Suspension setup changes and gain a strong understanding of NU 24’s dynamic characteristics, and how parts can be simplified and iterated for the design of NU 26 in the latter stages of the year. Use strain gauges on the Control Arms, Tie Rods, Uprights, and Chassis to understand loads generated through driving.

To echo 2023’s Chief Engineer Jye Hollier, “Systems should never be used at competition if they do not have data to justify being on the car.”. Every system and part need to have been thoroughly tested and have a benefit to the car. If not, remove them.

Move the NU 26 design date much earlier. Due to the events of 2024 and poor management, the team completed limited design of NU 25. By doing this, the initial workload for NU 25 will be higher. This means that the risk of issues for NU 25 due to il-conceived designs are quite high and will need to be carefully monitored with extremely thorough design reviews and scopes.

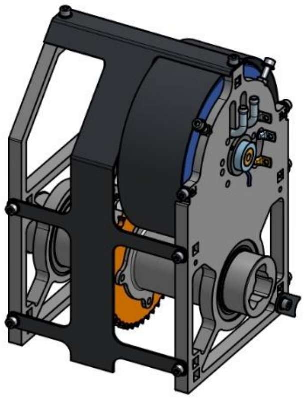
This report was written with the intent of giving context to management, critical design choices, and a reasonable overview of every system in NU 24. The author hopes this resource can be used effectively and provide knowledge that previously was never recorded.

The author sincerely hopes that NU Racing in 2025 achieves great results and competes strongly and competition.

15. Appendices

15.1. Appendix A – Drivetrain V1 Manufacturing Drawings

Item	Name	Quantity	Vendor	Material
1	MOTOR PLATE	1	MANUFACTURED	Aluminum - 6061
2	BRAKE PLATE	1	MANUFACTURED	Aluminum - 6061
3	CHAIN GUARD	1	MANUFACTURED	Carbon Steel
4	SCATTER SHIELD	1	MANUFACTURED	Carbon Steel
5	SPOOL ASSEMBLY	1	SUPPLIED	N/A
6	228 MOTOR ASSEMBLY	1	SUPPLIED	N/A
7	DRIVE SPROCKET 14T	1	SUPPLIED	Aluminum - 6061
8	TRANSMISSION SHAFT	1	MANUFACTURED	Steel 4140
9	SPROCKET SPACER	1	MANUFACTURED	Carbon Steel
10	DRIVETRAIN CHASSIS TABS	4	SUPPLIED	Carbon Steel



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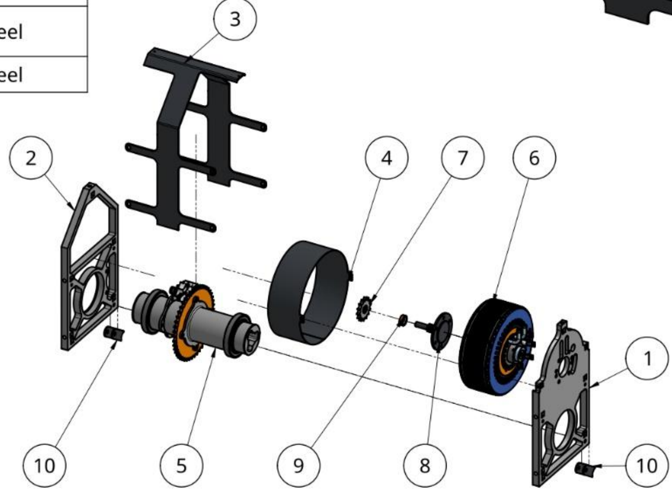

DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D
REVISIONS				

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0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: NU 24 DRIVETRAIN

		NAME	SIGNATURE	DATE
PROJECT NO.:	APPV'D			
FINISH: 3.2 UOS	CHK'D	L. FISHER		
QUANTITY: 1	DRAWN	R. MATHURIA		2024-05-12
MATERIAL: SEE TABLE				

DRAWING NO.:
REVISION:
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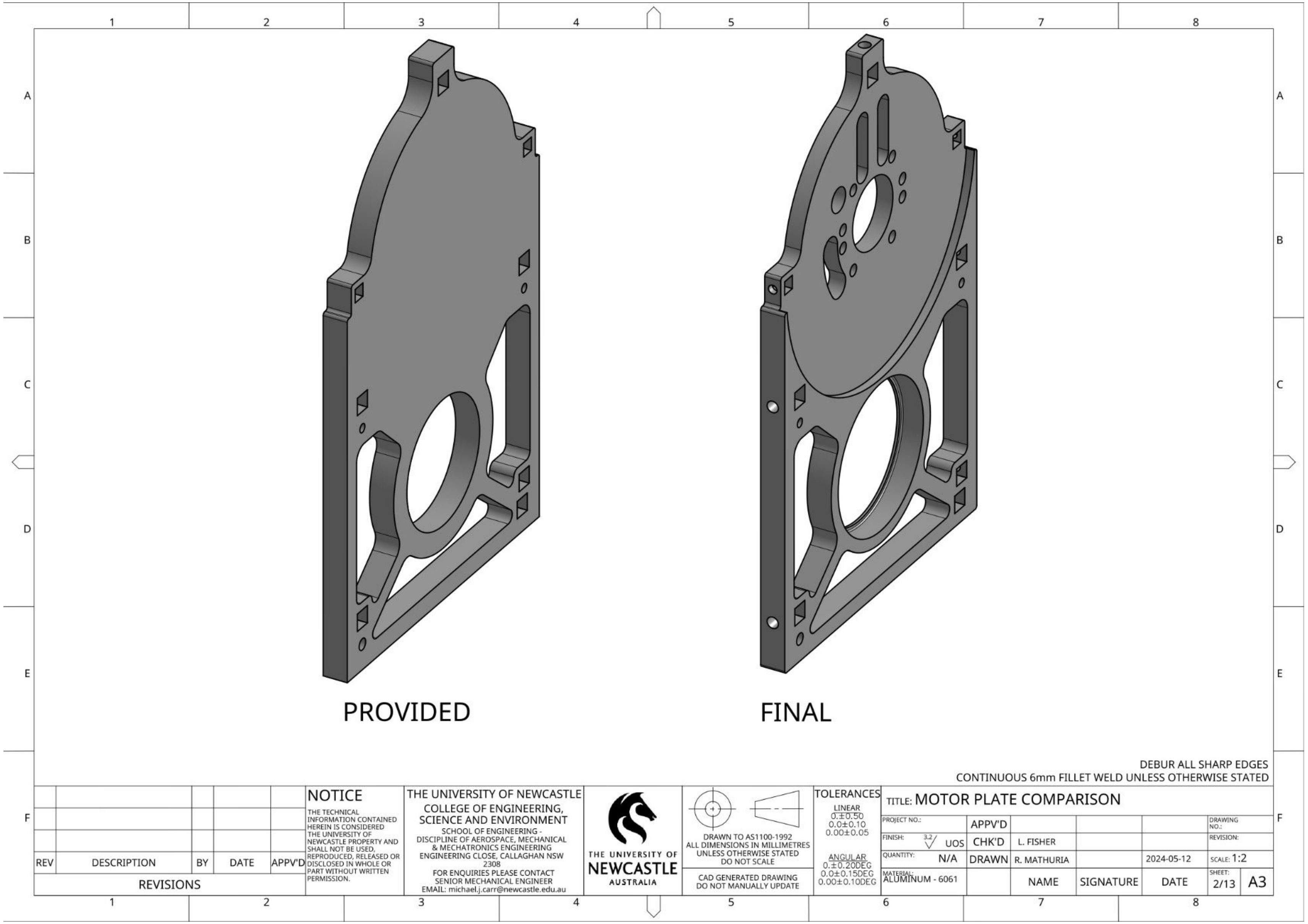
SHEET: 1/13 A3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0.0±0.15DEG
0.00±0.10DEG
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PROJECT NO.:
APPV'D
DRAWING NO.:
FINISH: 3.2 UOS
CHK'D
L. FISHER
REVISION:
QUANTITY: N/A
DRAWN
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2024-05-12
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NAME
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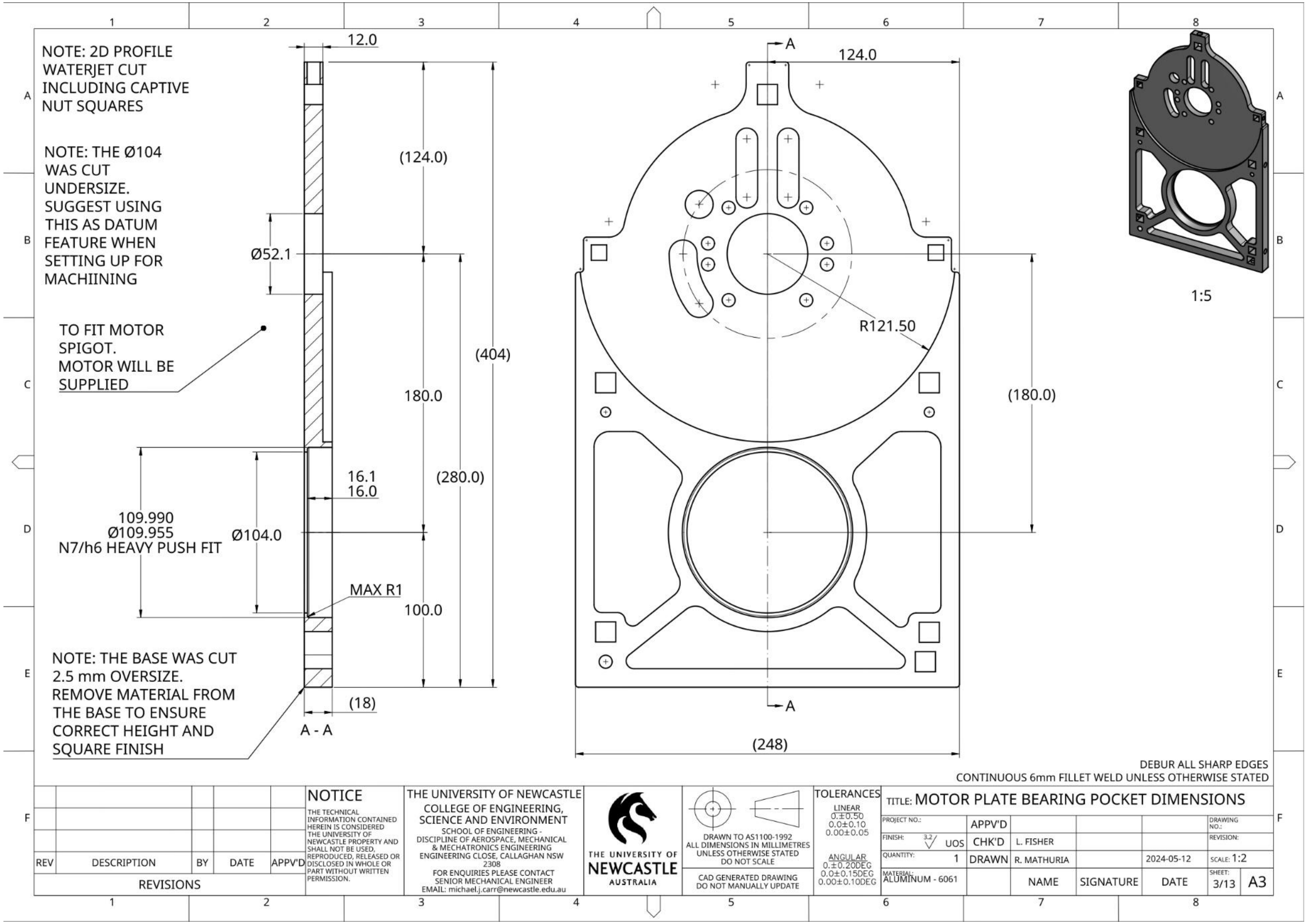
NOTE: 2D PROFILE WATERJET CUT INCLUDING CAPTIVE NUT SQUARES
NOTE: THE Ø104 WAS CUT UNDERSIZE. SUGGEST USING THIS AS DATUM FEATURE WHEN SETTING UP FOR MACHIINING
TO FIT MOTOR SPIGOT. MOTOR WILL BE SUPPLIED
109.990
Ø109.955
N7/h6 HEAVY PUSH FIT
NOTE: THE BASE WAS CUT 2.5 mm OVERSIZE. REMOVE MATERIAL FROM THE BASE TO ENSURE CORRECT HEIGHT AND SQUARE FINISH
12.0
(124.0)
Ø52.1
180.0
(404)
16.1
16.0
(280.0)
Ø104.0
MAX R1
100.0
(18)
A - A
124.0
R121.50
(180.0)
(248)
1:5
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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FOR ENQUIRIES PLEASE CONTACT SENIOR MECHANICAL ENGINEER
EMAIL: michael.j.carr@newcastle.edu.au
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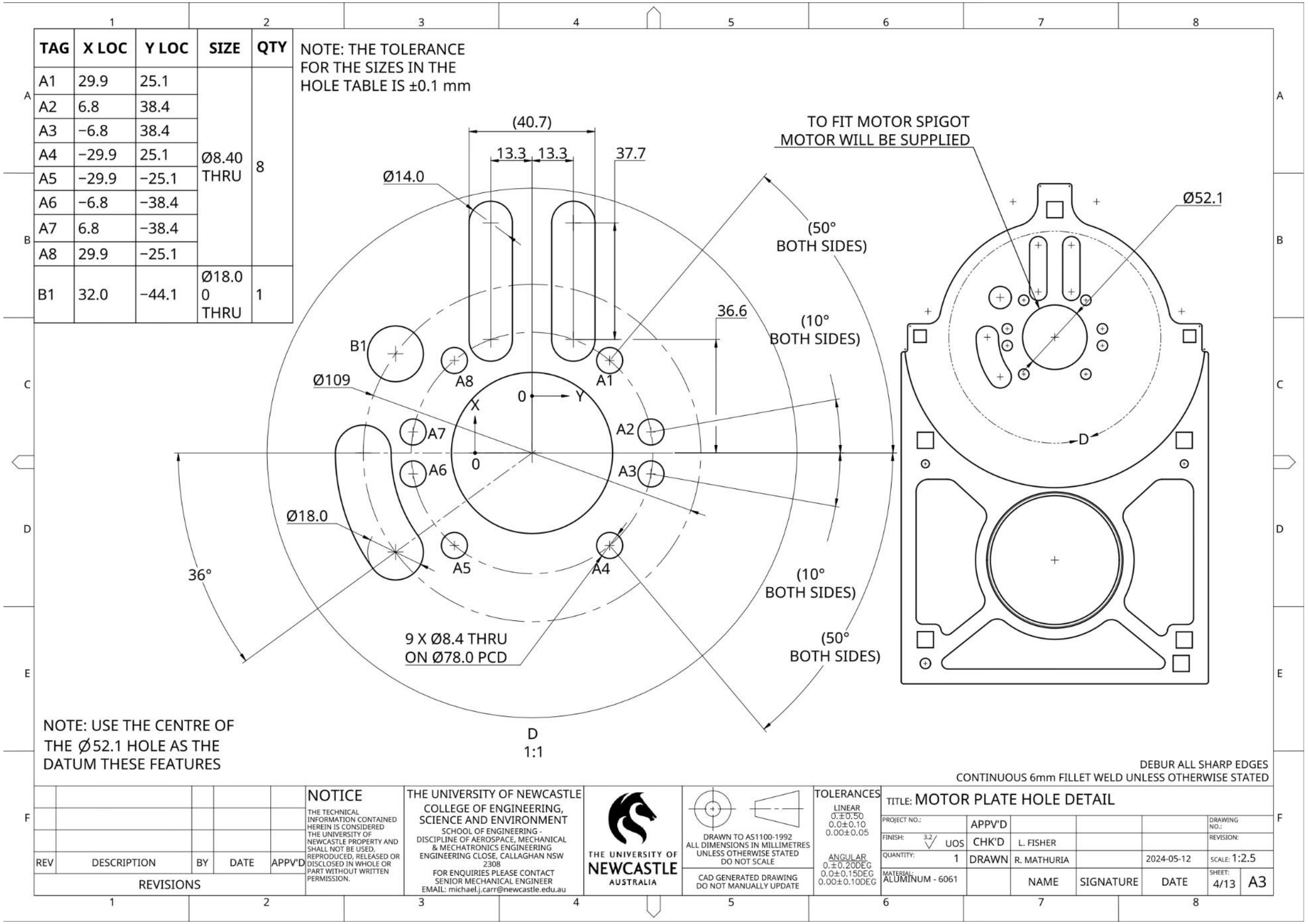
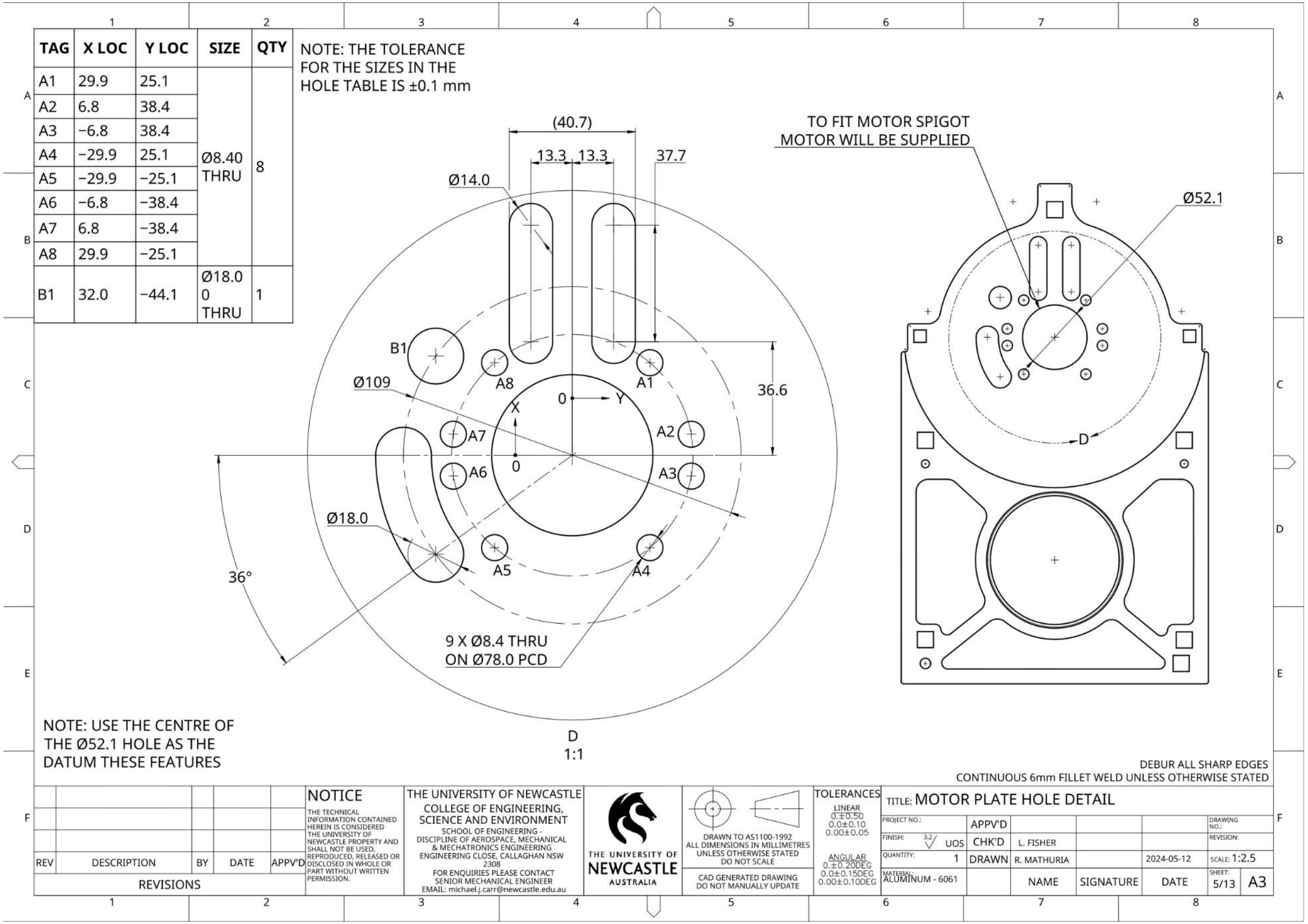
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: MOTOR PLATE BEARING POCKET DIMENSIONS
PROJECT NO.:
APPV'D
FINISH: 3.2 UOS
CHK'D L. FISHER
QUANTITY: 1
DRAWN R. MATHURIA 2024-05-12
MATERIAL: ALUMINUM - 6061
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 3/13
A3

TAG	X LOC	Y LOC	SIZE	QTY
A1	29.9	25.1	Ø8.40 THRU	8
A2	6.8	38.4		
A3	−6.8	38.4		
A4	−29.9	25.1		
A5	−29.9	−25.1		
A6	−6.8	−38.4		
A7	6.8	−38.4		
A8	29.9	−25.1		
B1	32.0	−44.1	Ø18.00 THRU	1





TAG	X LOC	Y LOC	SIZE	QTY
A1	29.9	25.1	Ø8.40 THRU	8
A2	6.8	38.4		
A3	-6.8	38.4		
A4	-29.9	25.1		
A5	-29.9	-25.1		
A6	-6.8	-38.4		
A7	6.8	-38.4		
A8	29.9	-25.1		
B1	32.0	-44.1	Ø18.00 THRU	1

NOTE: THE TOLERANCE FOR THE SIZES IN THE HOLE TABLE IS ±0.1 mm
(40.7)
13.3
13.3
37.7
Ø14.0
TO FIT MOTOR SPIGOT
MOTOR WILL BE SUPPLIED
Ø52.1
B1
A8
A1
Ø109
36.6
A7
A2
A6
A3
Ø18.0
A5
A4
36°
9 X Ø8.4 THRU
ON Ø78.0 PCD
D
1:1
NOTE: USE THE CENTRE OF THE Ø52.1 HOLE AS THE DATUM THESE FEATURES
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
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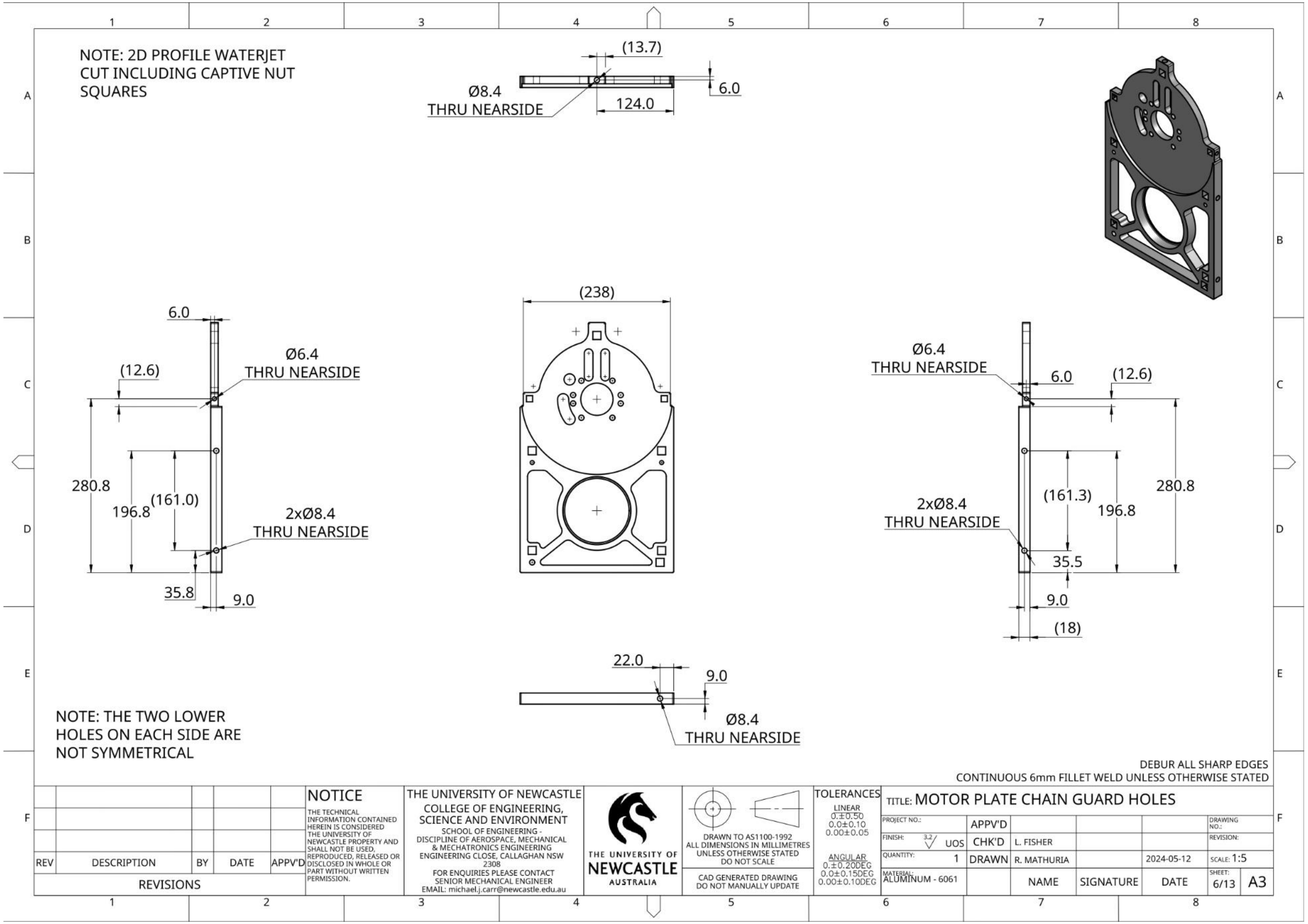
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: MOTOR PLATE HOLE DETAIL
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINUM - 6061
APPV'D
CHK'D L. FISHER
DRAWN R. MATHURIA 2024-05-12
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2.5
SHEET: 5/13
A3


NOTE: 2D PROFILE WATERJET CUT INCLUDING CAPTIVE NUT SQUARES
(13.7)
Ø8.4
THRU NEARSIDE
6.0
124.0
(238)
6.0
Ø6.4
THRU NEARSIDE
(12.6)
280.8
196.8
(161.0)
2xØ8.4
THRU NEARSIDE
35.8
9.0
Ø6.4
THRU NEARSIDE
6.0
(12.6)
280.8
(161.3)
196.8
2xØ8.4
THRU NEARSIDE
35.5
9.0
(18)
22.0
9.0
Ø8.4
THRU NEARSIDE
NOTE: THE TWO LOWER HOLES ON EACH SIDE ARE NOT SYMMETRICAL
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
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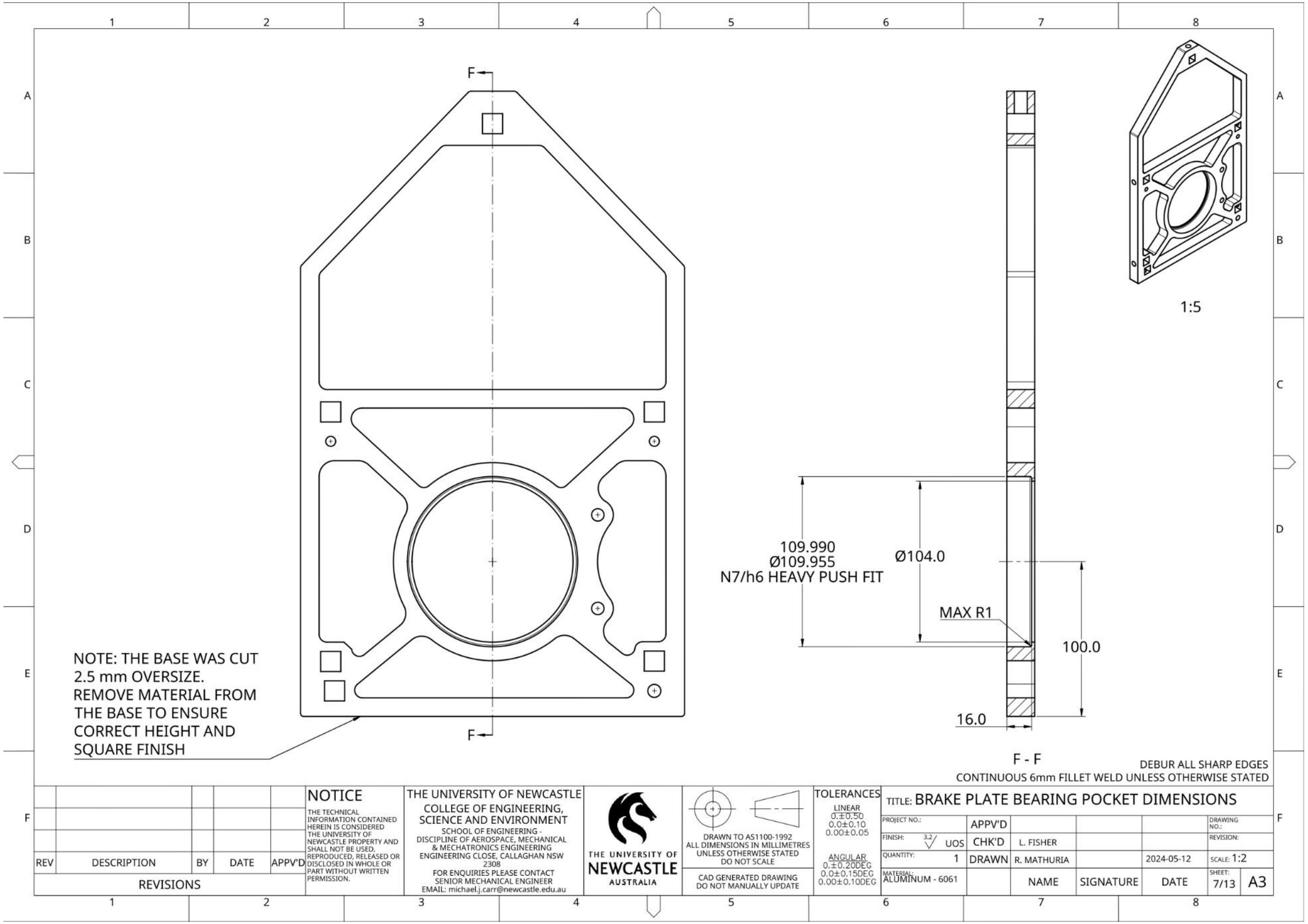
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: MOTOR PLATE CHAIN GUARD HOLES
PROJECT NO.:
APPV'D
FINISH: 3.2 UOS
CHK'D L. FISHER
QUANTITY: 1
DRAWN R. MATHURIA 2024-05-12
MATERIAL: ALUMINUM - 6061
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:5
SHEET: 6/13
A3



F
F
NOTE: THE BASE WAS CUT 2.5 mm OVERSIZE. REMOVE MATERIAL FROM THE BASE TO ENSURE CORRECT HEIGHT AND SQUARE FINISH
109.990
Ø109.955
N7/h6 HEAVY PUSH FIT
Ø104.0
MAX R1
100.0
16.0
F - F
1:5
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV DESCRIPTION BY DATE APPV'D
REVISIONS
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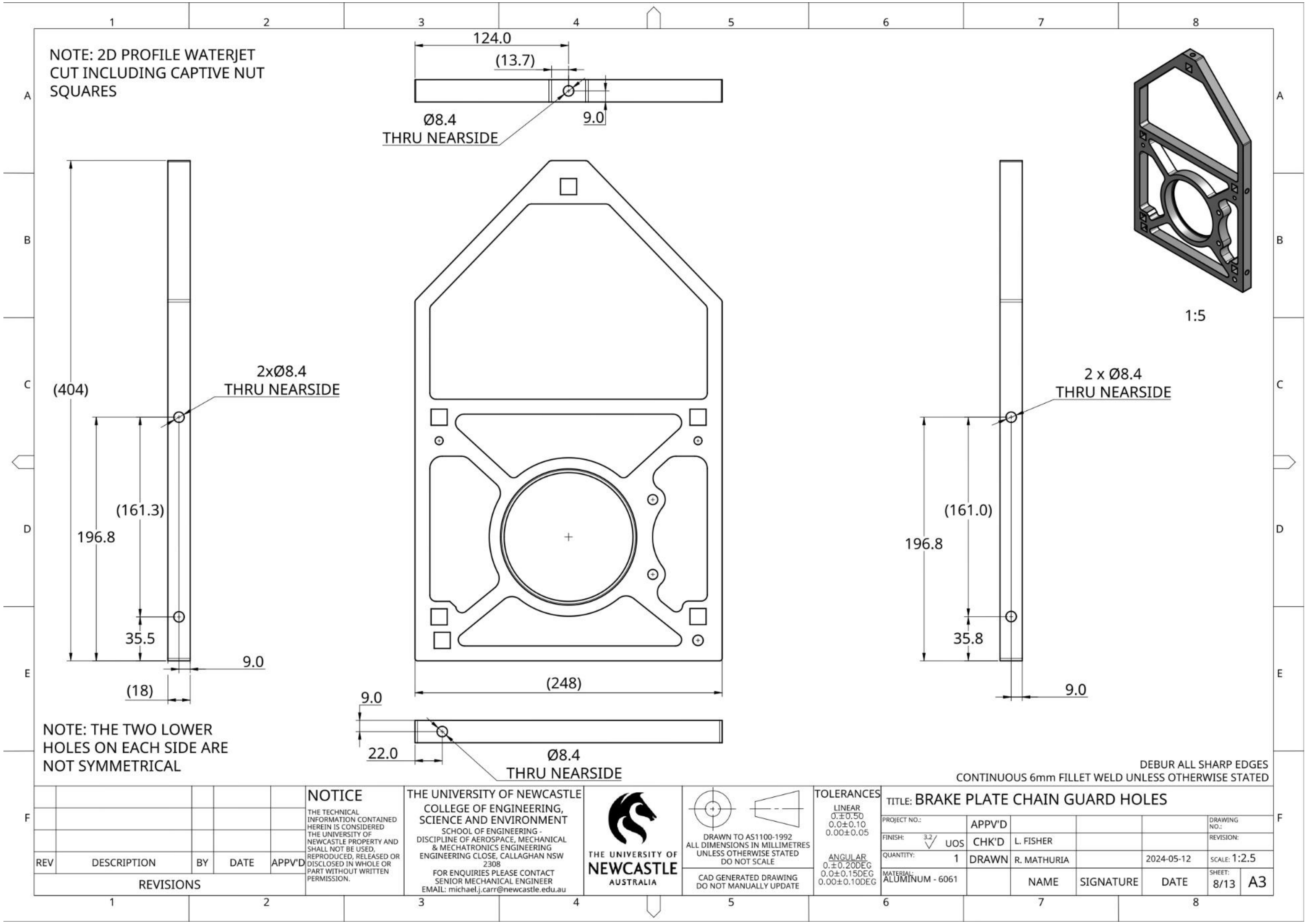
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: BRAKE PLATE BEARING POCKET DIMENSIONS
PROJECT NO.:
APPV'D
FINISH: 3.2 UOS
CHK'D L. FISHER
QUANTITY: 1
DRAWN R. MATHURIA 2024-05-12
MATERIAL: ALUMINUM - 6061
NAME SIGNATURE DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 7/13
A3


NOTE: 2D PROFILE WATERJET CUT INCLUDING CAPTIVE NUT SQUARES
124.0
(13.7)
Ø8.4
THRU NEARSIDE
9.0
(404)
2xØ8.4
THRU NEARSIDE
(161.3)
196.8
35.5
9.0
(18)
(248)
9.0
22.0
Ø8.4
THRU NEARSIDE
2 x Ø8.4
THRU NEARSIDE
(161.0)
196.8
35.8
9.0
1:5
NOTE: THE TWO LOWER HOLES ON EACH SIDE ARE NOT SYMMETRICAL
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
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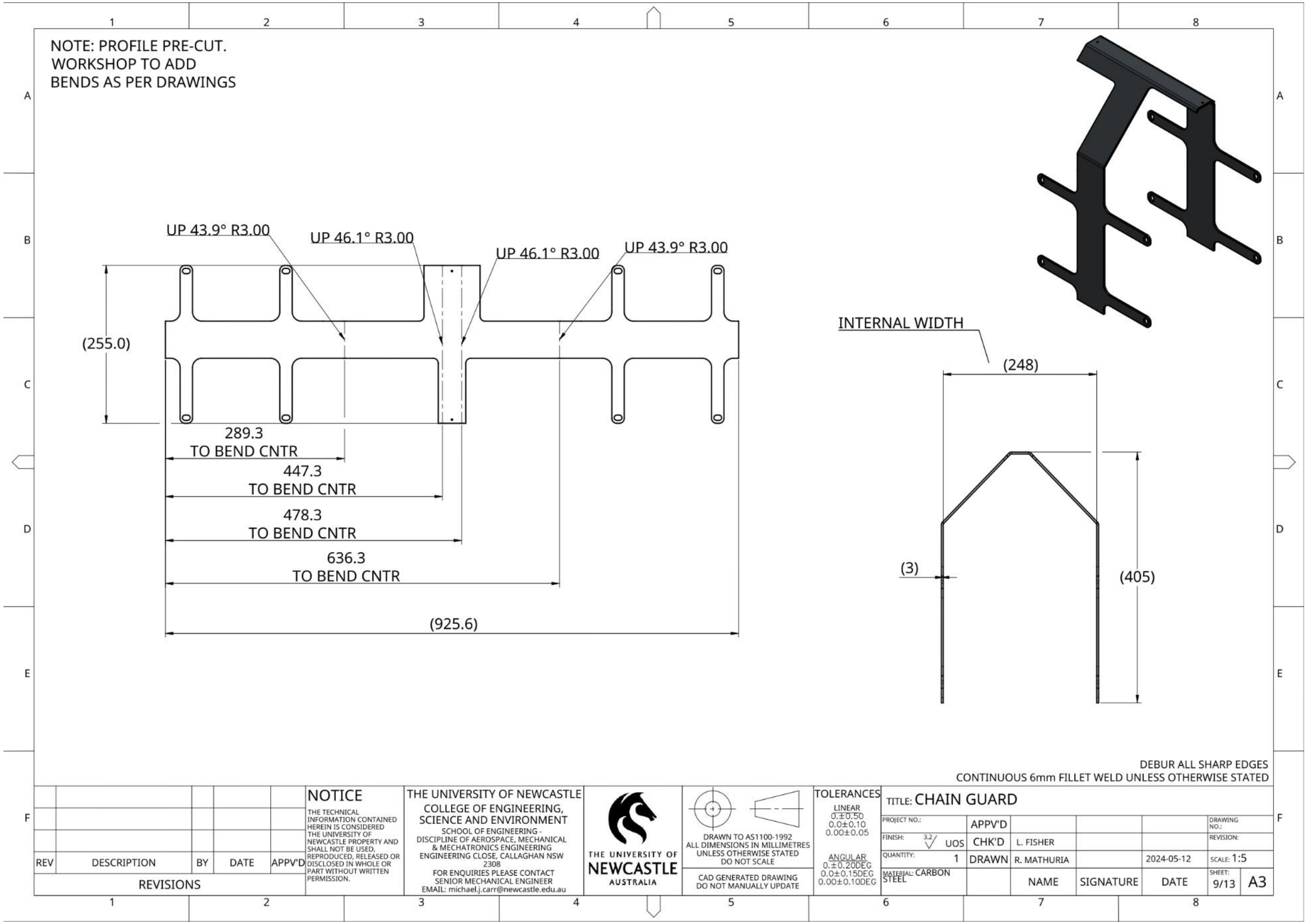
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: BRAKE PLATE CHAIN GUARD HOLES
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINUM - 6061
APPV'D
CHK'D L. FISHER
DRAWN R. MATHURIA 2024-05-12
NAME SIGNATURE DATE
DRAWING NO.:
REVISION:
SCALE: 1:2.5
SHEET: 8/13
A3


NOTE: PROFILE PRE-CUT.
WORKSHOP TO ADD
BENDS AS PER DRAWINGS
UP 43.9° R3.00
UP 46.1° R3.00
UP 46.1° R3.00
UP 43.9° R3.00
(255.0)
289.3
TO BEND CNTR
447.3
TO BEND CNTR
478.3
TO BEND CNTR
636.3
TO BEND CNTR
(925.6)
INTERNAL WIDTH
(248)
(3)
(405)
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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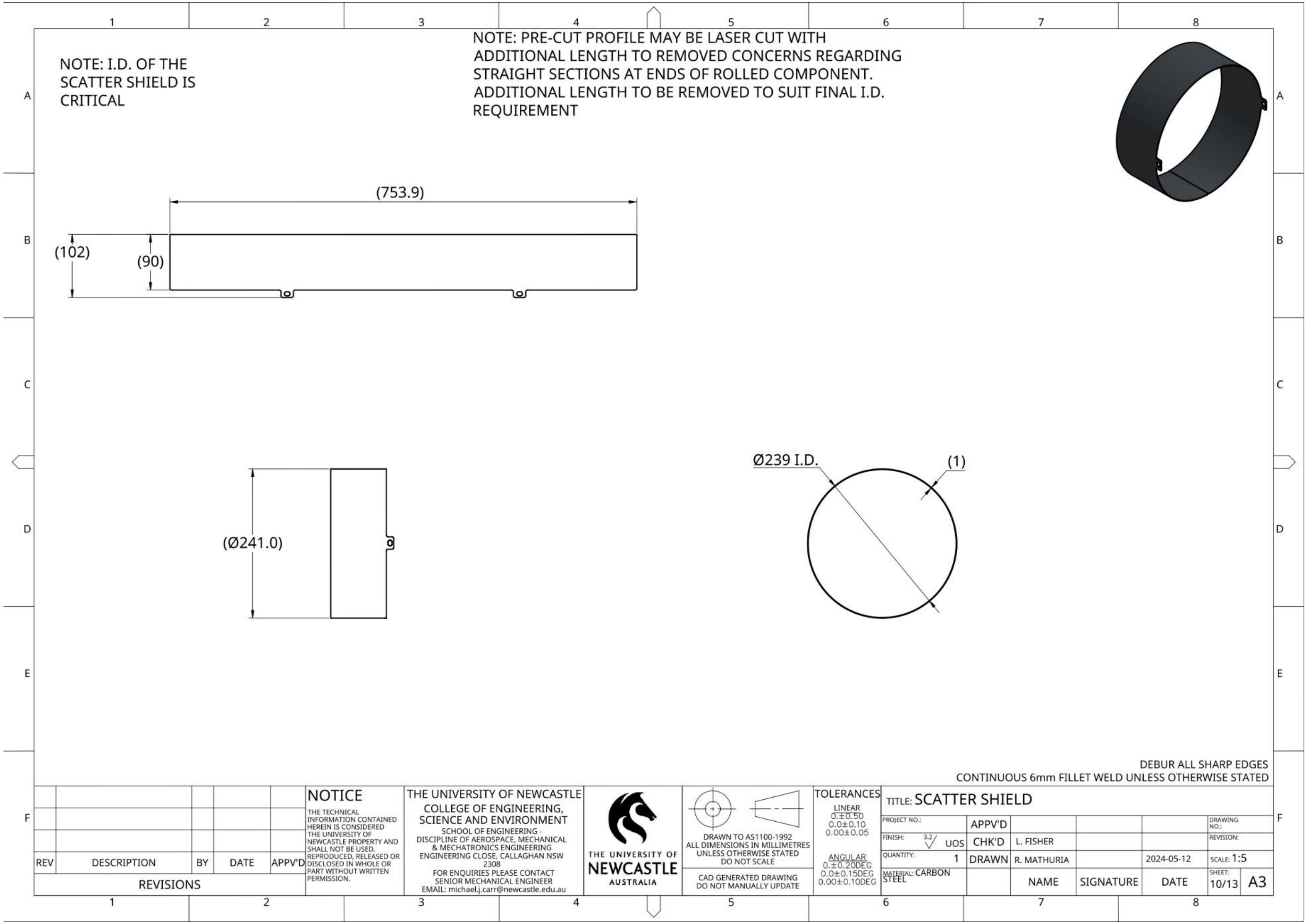
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: CHAIN GUARD
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: CARBON STEEL
APPV'D
CHK'D L. FISHER
DRAWN R. MATHURIA 2024-05-12
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:5
SHEET: 9/13
A3


NOTE: I.D. OF THE SCATTER SHIELD IS CRITICAL
NOTE: PRE-CUT PROFILE MAY BE LASER CUT WITH ADDITIONAL LENGTH TO REMOVED CONCERNS REGARDING STRAIGHT SECTIONS AT ENDS OF ROLLED COMPONENT. ADDITIONAL LENGTH TO BE REMOVED TO SUIT FINAL I.D. REQUIREMENT
(753.9)
(102)
(90)
(Ø241.0)
Ø239 I.D.
(1)
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
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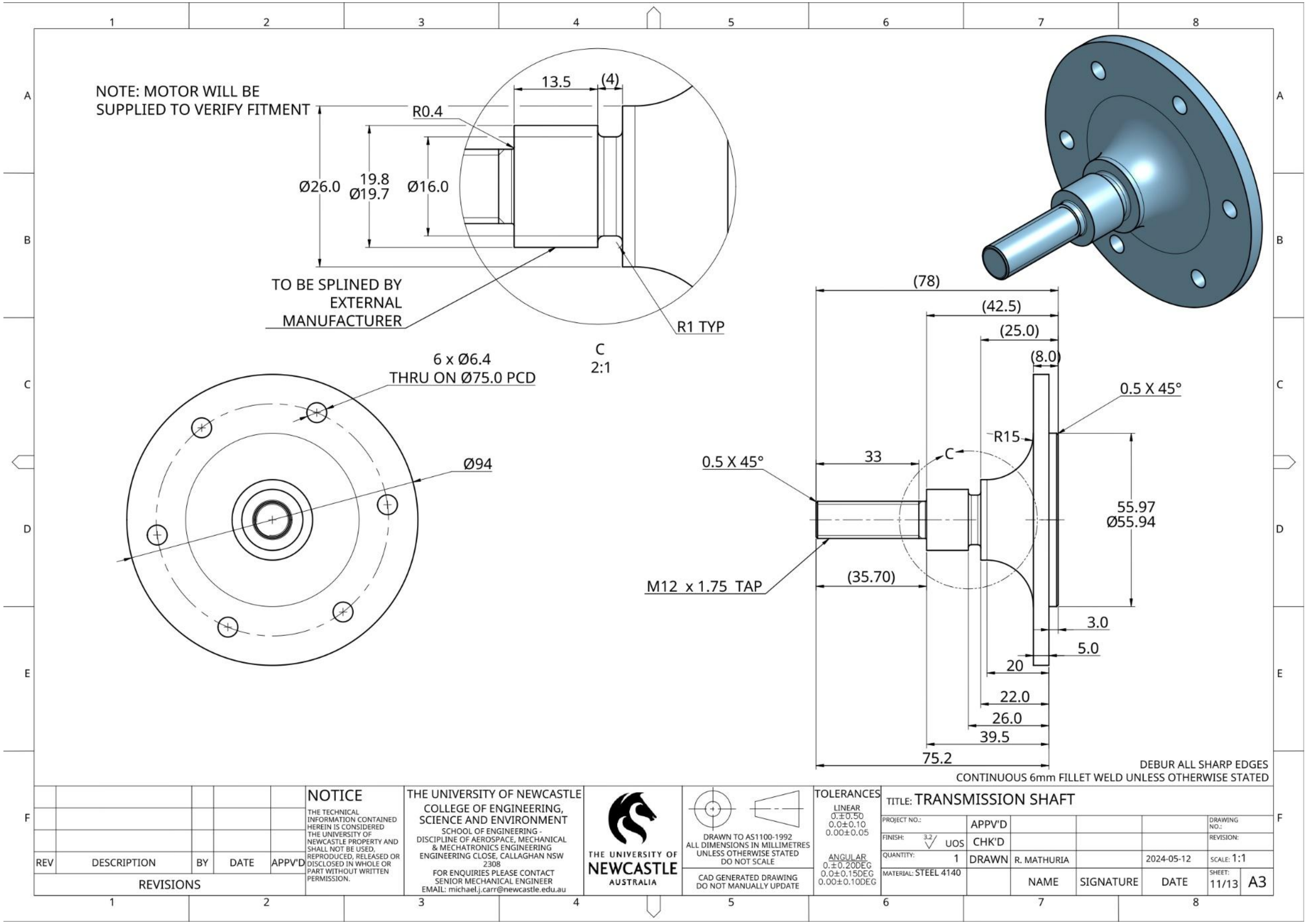
UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: SCATTER SHIELD
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: CARBON STEEL
APPV'D
CHK'D L. FISHER
DRAWN R. MATHURIA 2024-05-12
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:5
SHEET: 10/13
A3


NOTE: MOTOR WILL BE SUPPLIED TO VERIFY FITMENT
TO BE SPLINED BY EXTERNAL MANUFACTURER
6 x Ø6.4 THRU ON Ø75.0 PCD
M12 x 1.75 TAP
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
TITLE: TRANSMISSION SHAFT
MATERIAL: STEEL 4140
DRAWN R. MATHURIA 2024-05-12
SCALE: 1:1
SHEET: 11/13 A3
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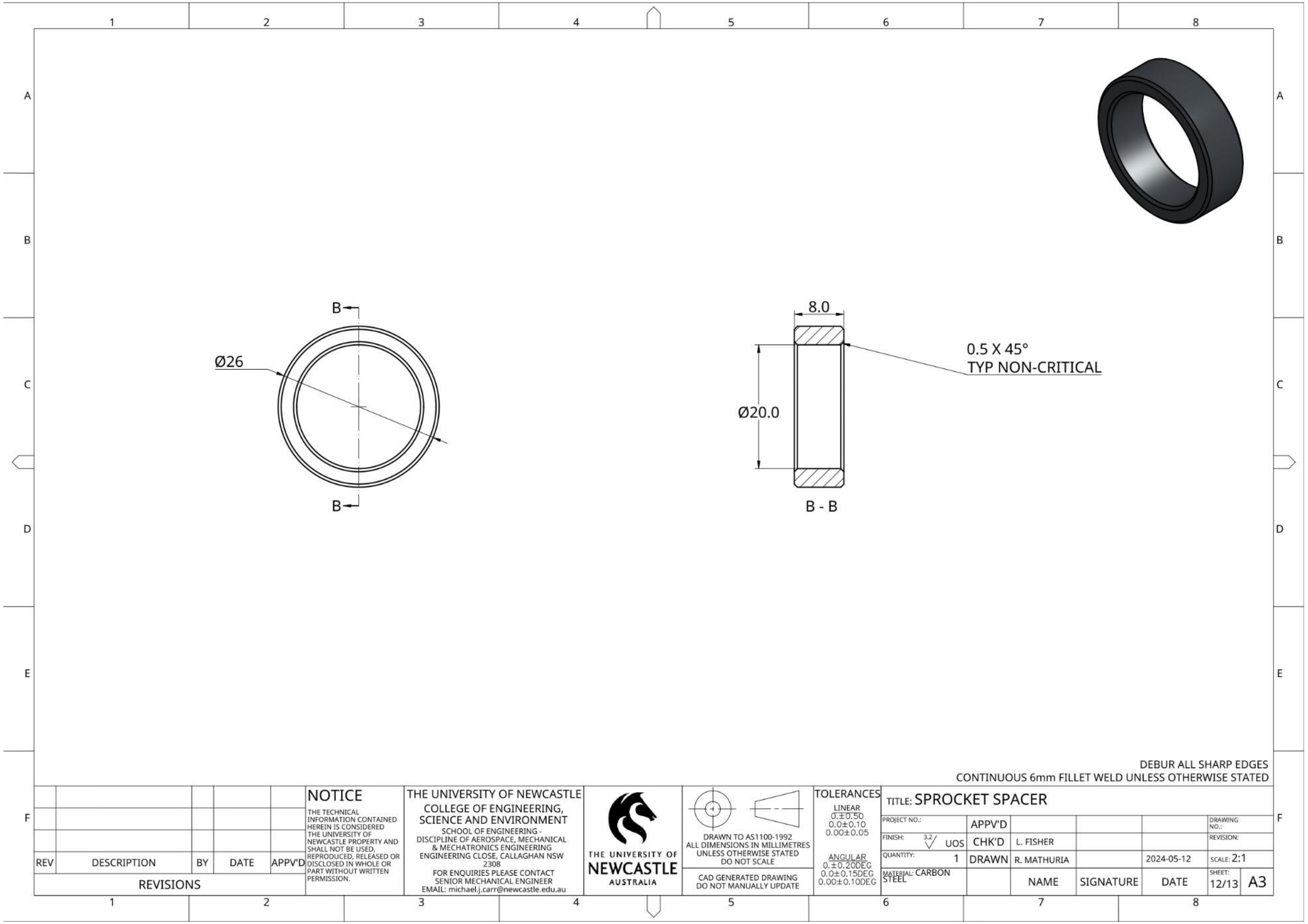
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE


B
Ø26
B
8.0
0.5 X 45°
TYP NON-CRITICAL
Ø20.0
B - B
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
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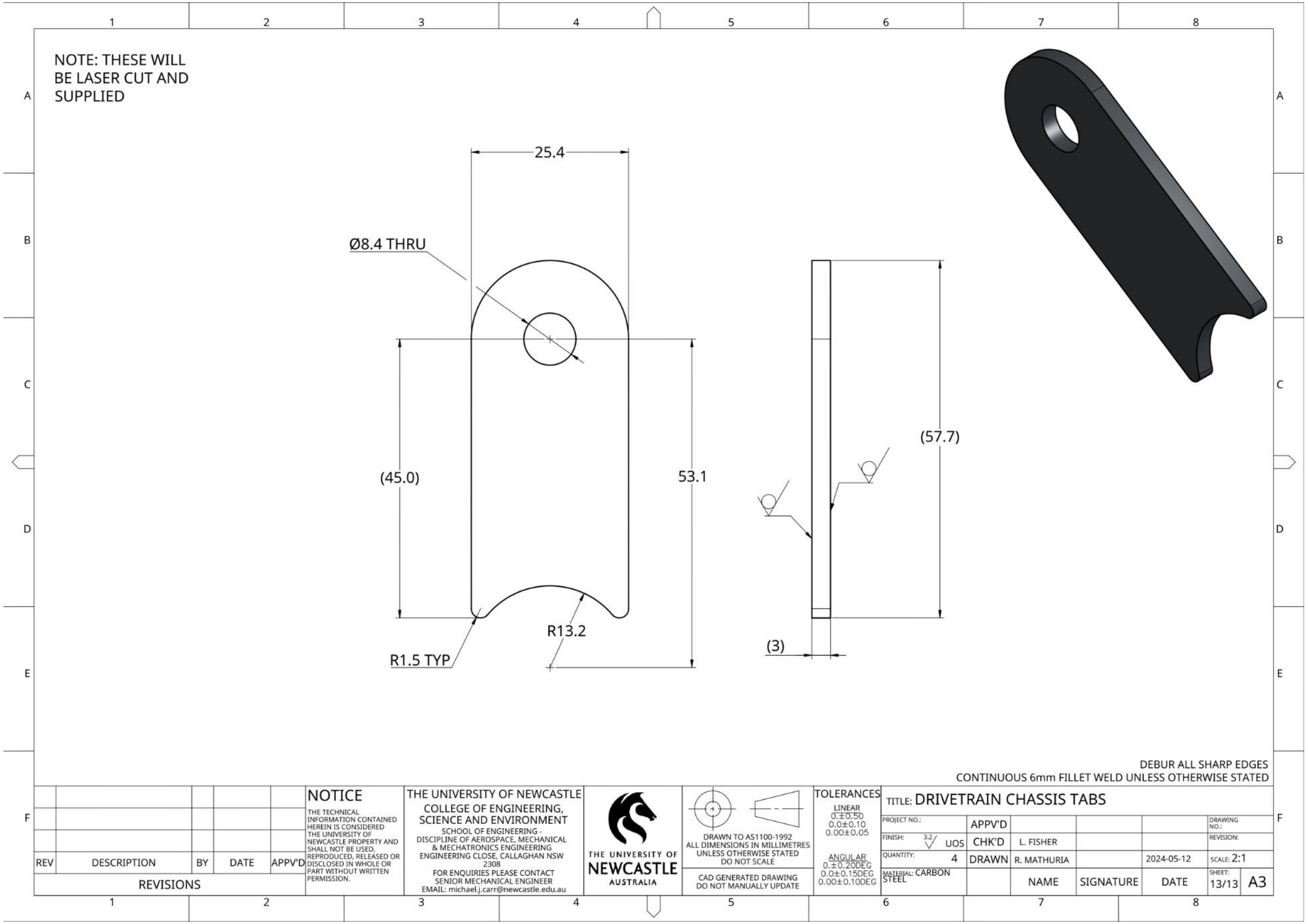
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: SPROCKET SPACER
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: CARBON STEEL
APPV'D
CHK'D L. FISHER
DRAWN R. MATHURIA 2024-05-12
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 12/13
A3


NOTE: THESE WILL BE LASER CUT AND SUPPLIED
25.4
Ø8.4 THRU
(45.0)
53.1
R13.2
R1.5 TYP
(57.7)
(3)
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
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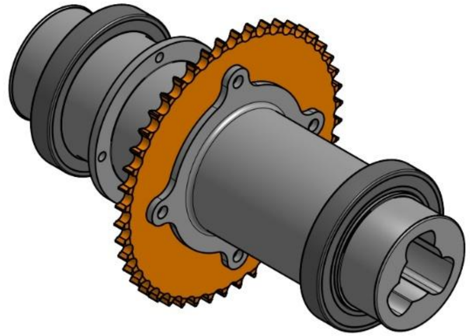
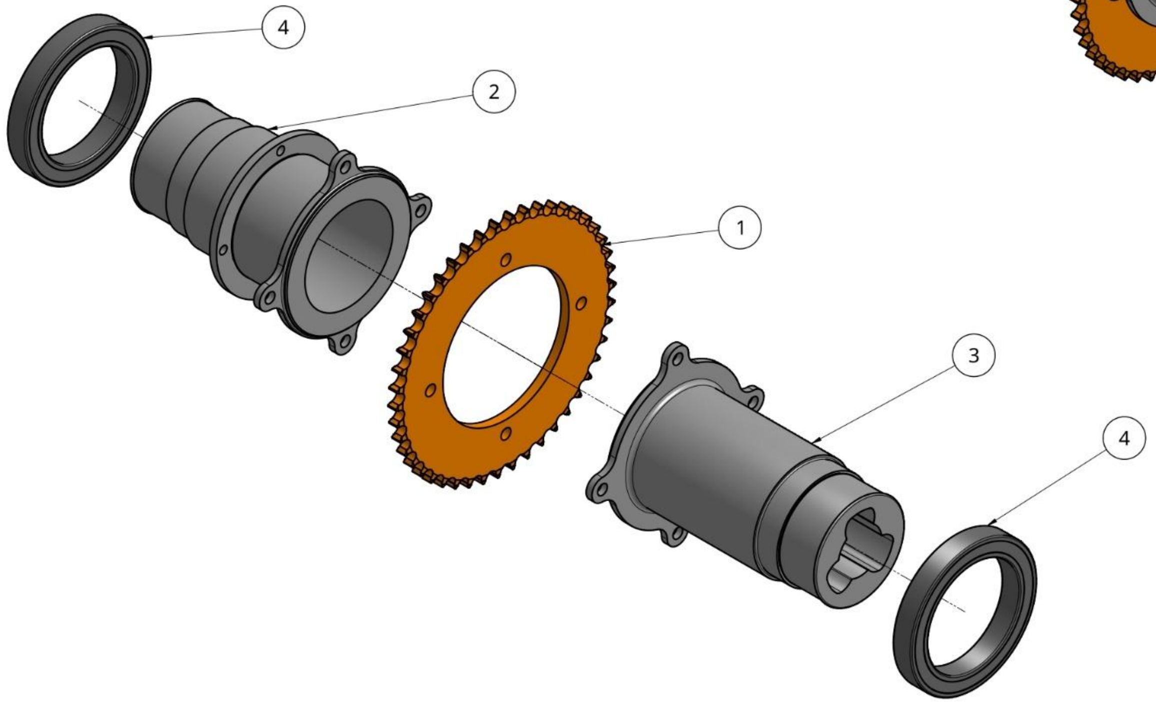
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: DRIVETRAIN CHASSIS TABS
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 4
MATERIAL: CARBON STEEL
APPV'D
CHK'D L. FISHER
DRAWN R. MATHURIA 2024-05-12
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 13/13
A3

Item	Name	Quantity	Vendor	Material
1	DRIVEN SPROCKET 46T	1	SUPPLIED	Aluminum
2	TRIPOD HOUSING BRAKE SIDE	1	MANUFACTURED	Aluminium 6061
3	TRIPOD HOUSING DRIVE SIDE	1	MANUFACTURED	Aluminum 6061
4	6916-ZZ BEARING	2	SUPPLIED	N/A





DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D

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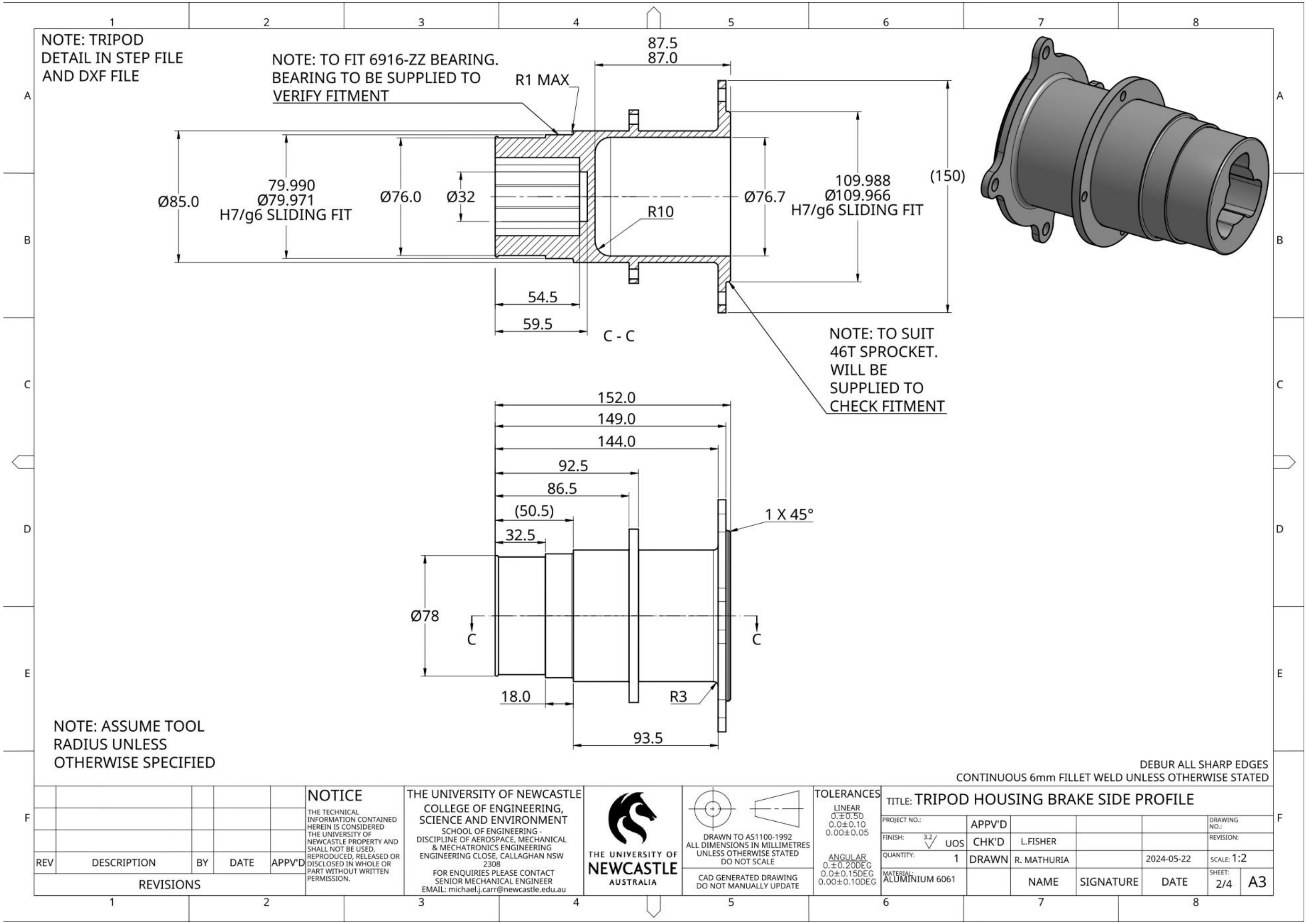
UNLESS OTHERWISE STATED
DO NOT SCALE

CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE

TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: SPOOL ASSEMBLY

		NAME	SIGNATURE	DATE	
PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D	L.FISHER			REVISION:
QUANTITY: 1	DRAWN	R. MATHURIA		2024-05-22	SCALE: 1:2.5
MATERIAL: SEE TABLE					SHEET: 1/4 A3


NOTE: TRIPOD DETAIL IN STEP FILE AND DXF FILE
NOTE: TO FIT 6916-ZZ BEARING. BEARING TO BE SUPPLIED TO VERIFY FITMENT
R1 MAX
87.5
87.0
Ø85.0
79.990
Ø79.971
H7/g6 SLIDING FIT
Ø76.0
Ø32
R10
Ø76.7
109.988
Ø109.966
H7/g6 SLIDING FIT
(150)
54.5
59.5
C - C
NOTE: TO SUIT 46T SPROCKET. WILL BE SUPPLIED TO CHECK FITMENT
152.0
149.0
144.0
92.5
86.5
(50.5)
32.5
1 X 45°
Ø78
C
C
18.0
R3
93.5
NOTE: ASSUME TOOL RADIUS UNLESS OTHERWISE SPECIFIED
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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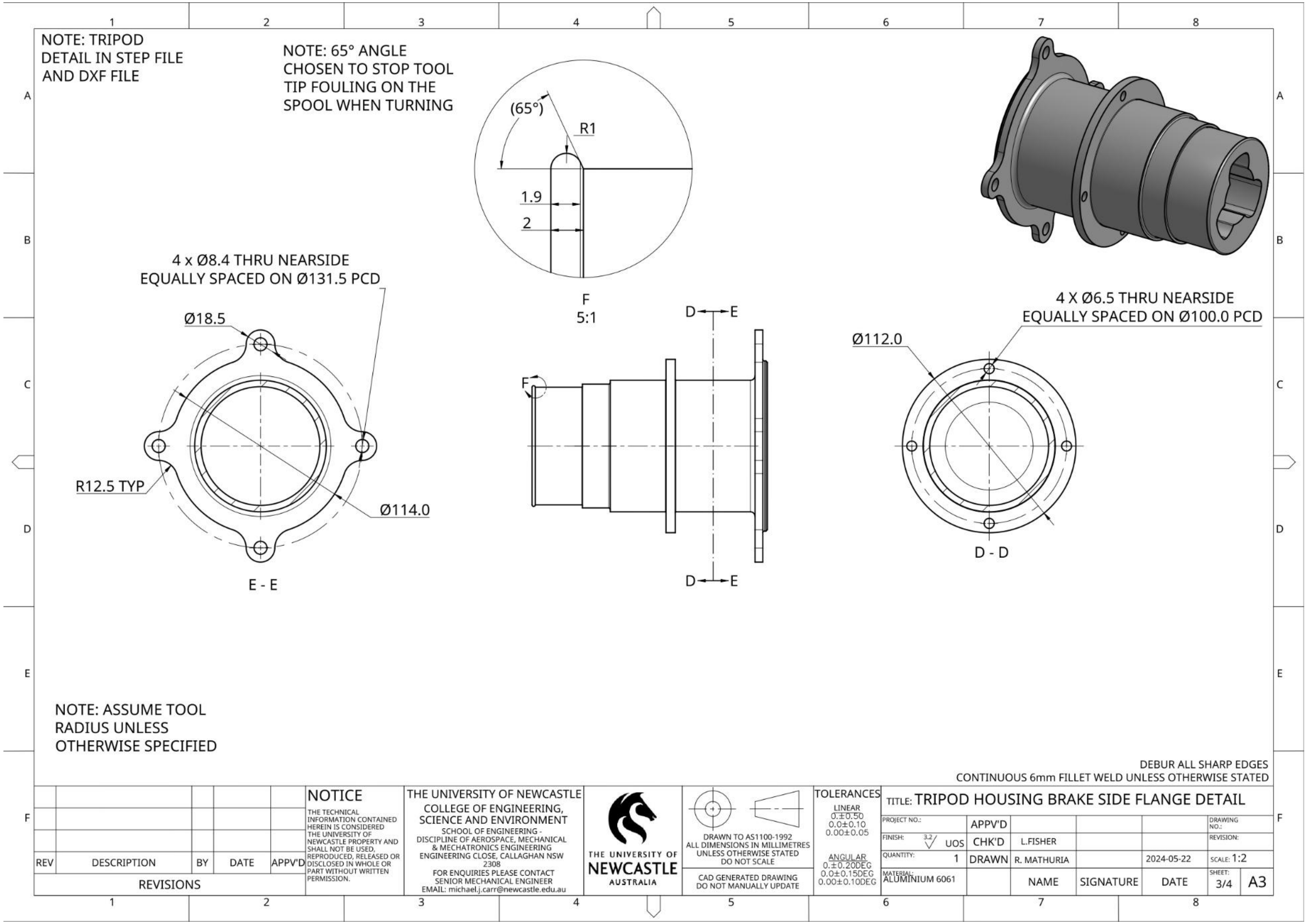
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: TRIPOD HOUSING BRAKE SIDE PROFILE
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINIUM 6061
APPV'D
CHK'D L.FISHER
DRAWN R. MATHURIA 2024-05-22
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 2/4
A3


NOTE: TRIPOD DETAIL IN STEP FILE AND DXF FILE
NOTE: 65° ANGLE CHOSEN TO STOP TOOL TIP FOULING ON THE SPOOL WHEN TURNING
(65°)
R1
1.9
2
F
5:1
4 x Ø8.4 THRU NEARSIDE EQUALLY SPACED ON Ø131.5 PCD
Ø18.5
R12.5 TYP
Ø114.0
E - E
D
E
4 X Ø6.5 THRU NEARSIDE EQUALLY SPACED ON Ø100.0 PCD
Ø112.0
D - D
NOTE: ASSUME TOOL RADIUS UNLESS OTHERWISE SPECIFIED
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
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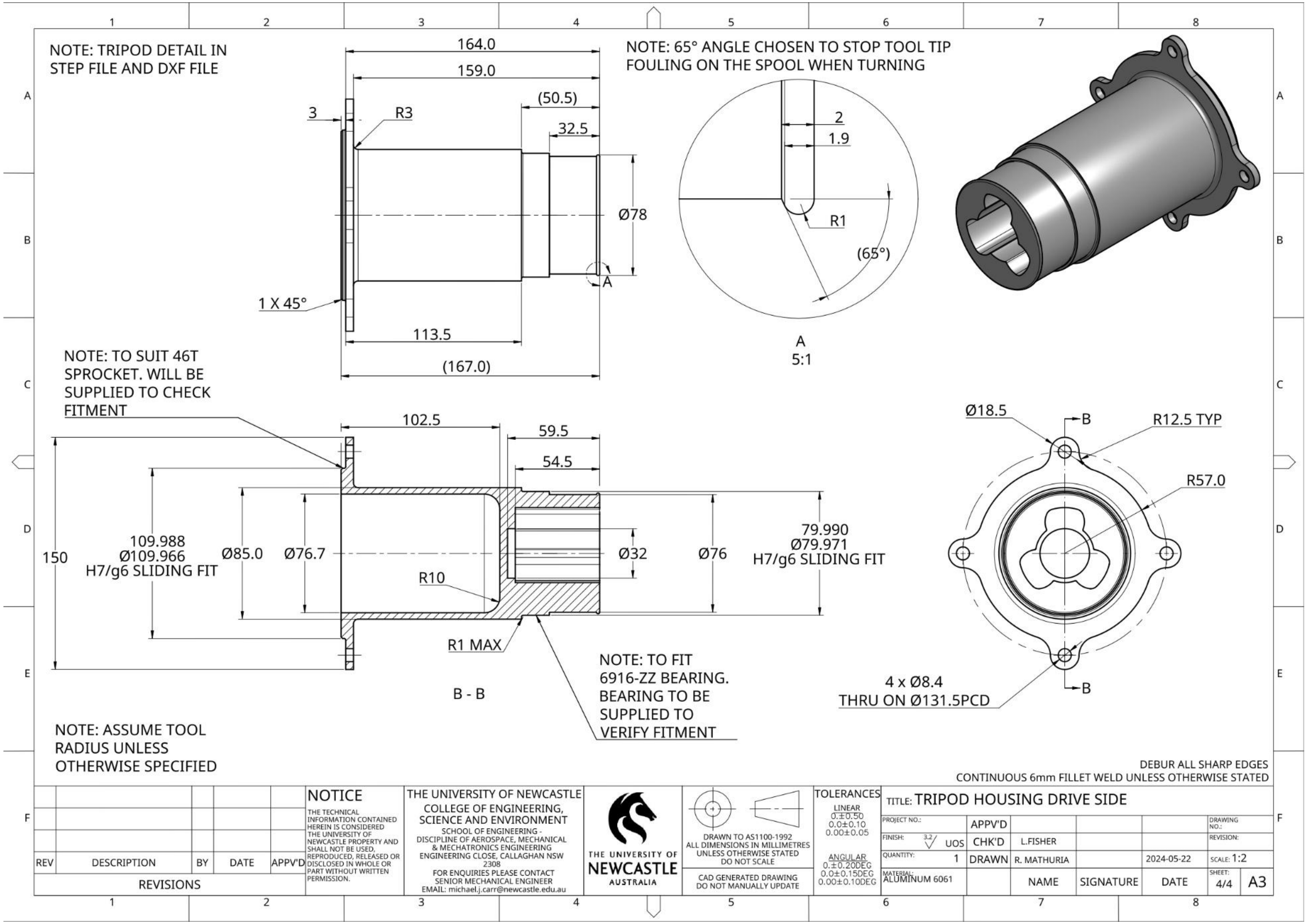
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: TRIPOD HOUSING BRAKE SIDE FLANGE DETAIL
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINIUM 6061
APPV'D
CHK'D L.FISHER
DRAWN R. MATHURIA 2024-05-22
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 3/4
A3


NOTE: TRIPOD DETAIL IN STEP FILE AND DXF FILE
NOTE: 65° ANGLE CHOSEN TO STOP TOOL TIP FOULING ON THE SPOOL WHEN TURNING
164.0
159.0
(50.5)
32.5
3
R3
Ø78
A
1 X 45°
113.5
(167.0)
2
1.9
R1
(65°)
A
5:1
NOTE: TO SUIT 46T SPROCKET. WILL BE SUPPLIED TO CHECK FITMENT
102.5
59.5
54.5
150
109.988
Ø109.966
H7/g6 SLIDING FIT
Ø85.0
Ø76.7
R10
Ø32
Ø76
79.990
Ø79.971
H7/g6 SLIDING FIT
R1 MAX
B - B
NOTE: TO FIT 6916-ZZ BEARING. BEARING TO BE SUPPLIED TO VERIFY FITMENT
Ø18.5
B
R12.5 TYP
R57.0
4 x Ø8.4
THRU ON Ø131.5PCD
B
NOTE: ASSUME TOOL RADIUS UNLESS OTHERWISE SPECIFIED
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
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DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: TRIPOD HOUSING DRIVE SIDE
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINUM 6061
APPV'D
CHK'D L.FISHER
DRAWN R. MATHURIA 2024-05-22
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 4/4
A3

15.2. Appendix B – Brake Force Calculations

Brake Pressure

Pressure on one circuit	1248	psi
	8604660.48	Pa
Bore Area (5/8")	0.000197933	m
Force	1703.142899	N
Pedal Ratio	3.865684733	-
Force on Pedal (for one circuit)	440.5798756	N
Force in kg (for one circuit)	44.9113023	kg
Total Force on the Pedal	89.82260461	kg

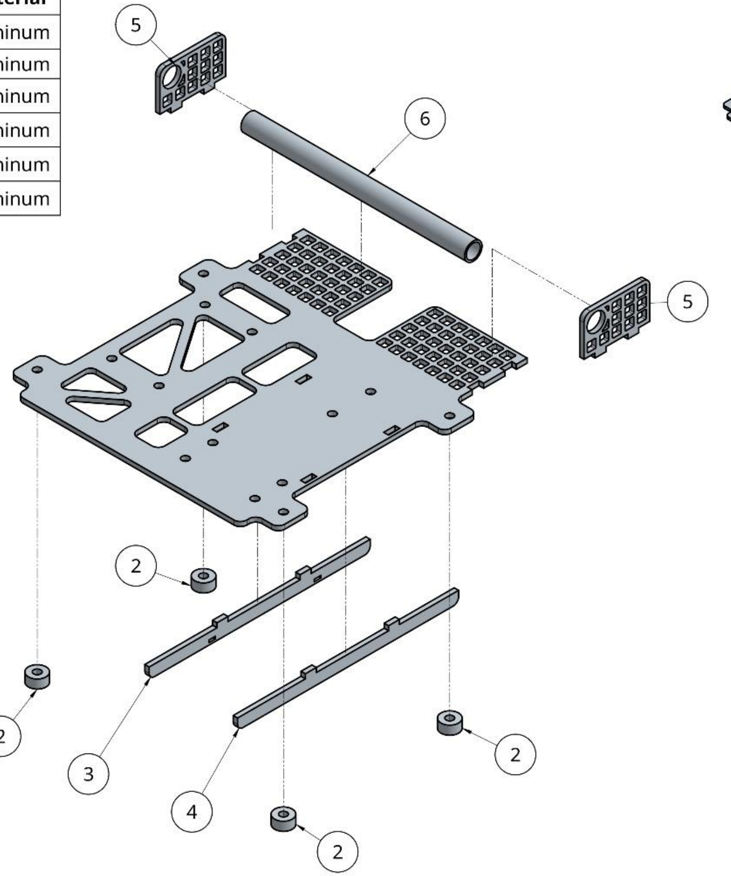
Sanity Check

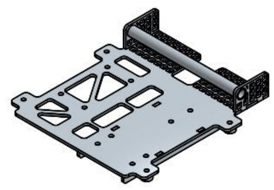
Force on the pedal (halved for 1 circuit)	440.5798756
Pedal Ratio	3.865684733
Force into the Master	1703.142899
Area of the master	0.000197933
Pressure Pa	8604660.48
Psi	1248

Brake Torque			
Pressure	1248	psi	
Pressure	8604660.48	Pa	
Piston Area	0.00079173	m2	
Force	6812.571594	N	
friction coeff	0.28	-	Purple Pads at 100 F
D	0.16495128	m	
d	0.10346554		
Friction Force	1907.520046	N	
Radius	0.067104205	m	
Torque	256.0052325	Nm	
Braking Force at the wheel			
Tire Diameter	0.4064	m	
Tire Radius	0.2032		
F-Front	1259.86827	N	Per Wheel on the front tyres
F-Rear	629.934135	N	Per Wheel on the rear tyres

15.3. Appendix C –Base Plate Manufacturing Drawings

Item	Name	Quantity	Vendor	Material
1	BASE PLATE	1	SUPPLIED	Aluminum
2	BASE SPACER	4	MANUFACTURED	Aluminum
3	CENTRE SUPPORT	1	SUPPLIED	Aluminum
4	LHS SUPPORT	1	SUPPLIED	Aluminum
5	SIDE PLATE	2	SUPPLIED	Aluminum
6	FOOT SUPPORT	1	MANUFACTURED	Aluminum





1:5

DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D

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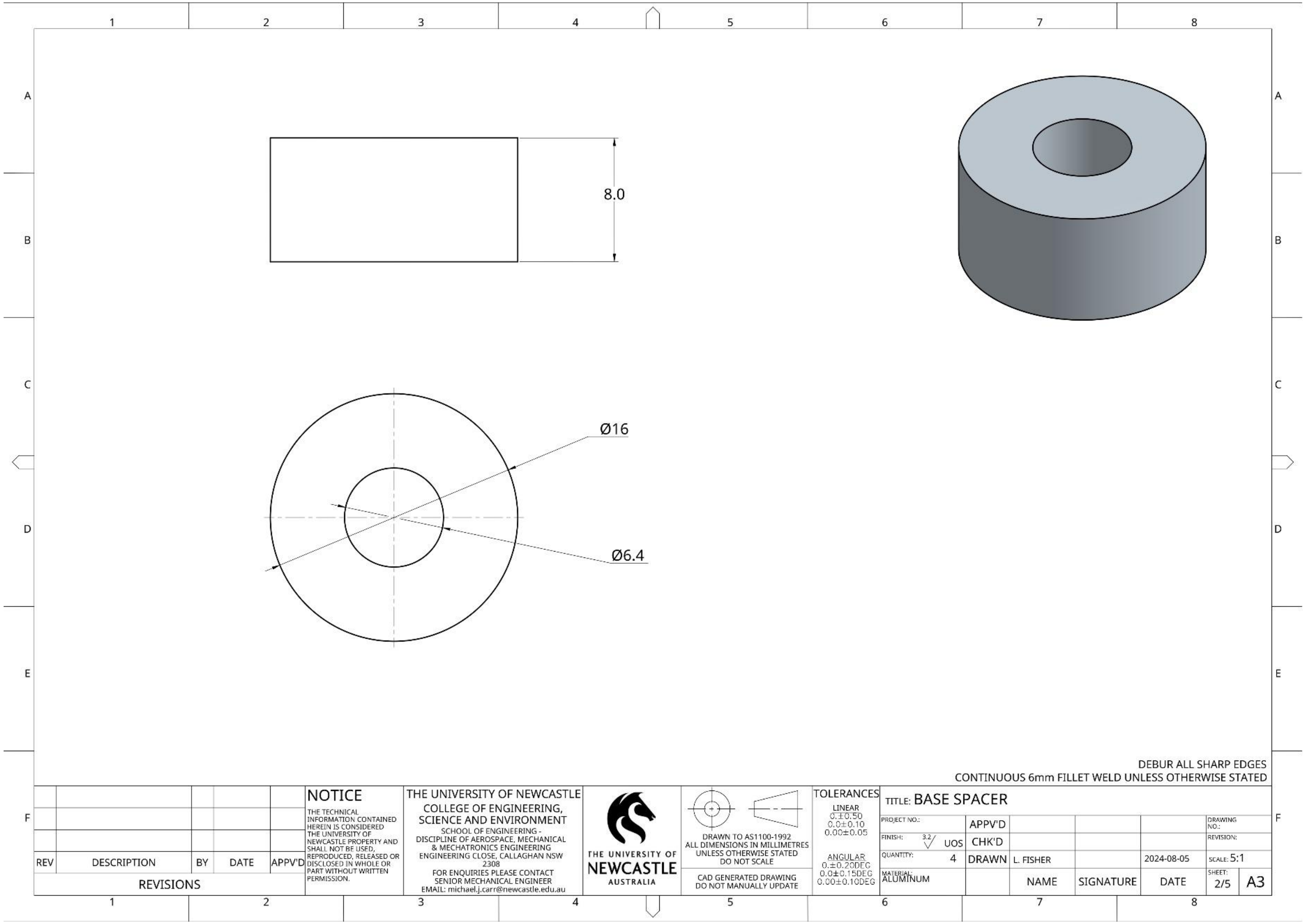
DO NOT SCALE

CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE

TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: BASE PLATE ASSEMBLY

PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D				REVISION:
QUANTITY: 1	DRAWN	L. FISHER		2024-08-05	SCALE: 1:2.5
MATERIAL: SEE TABLE		NAME	SIGNATURE	DATE	SHEET: 1/5 A3


8.0
Ø16
Ø6.4
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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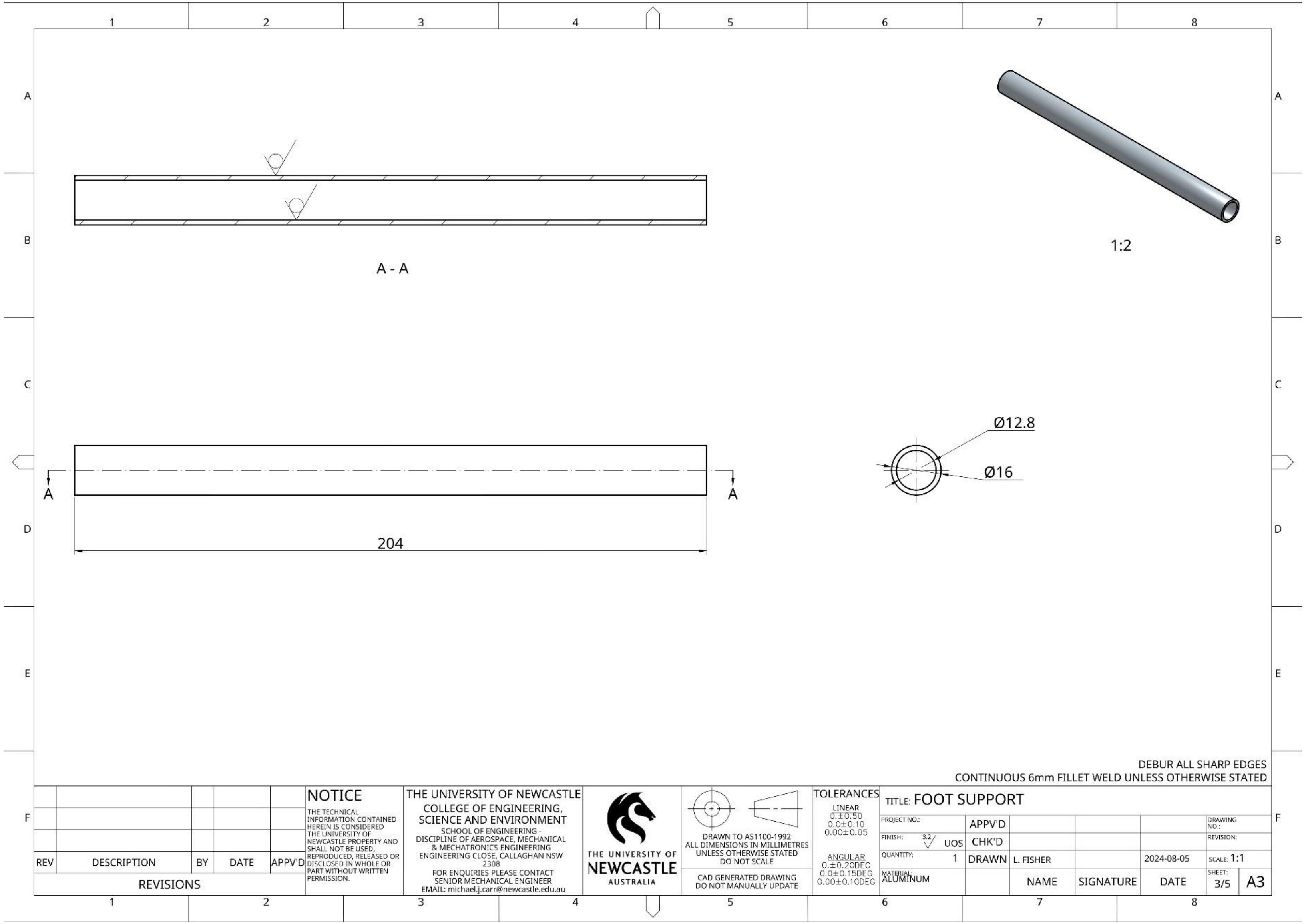
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: BASE SPACER
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 4
MATERIAL: ALUMINUM
APPV'D
CHK'D
DRAWN L. FISHER 2024-08-05
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 5:1
SHEET: 2/5
A3


A - A
1:2
Ø12.8
Ø16
A
A
204
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
NOTICE
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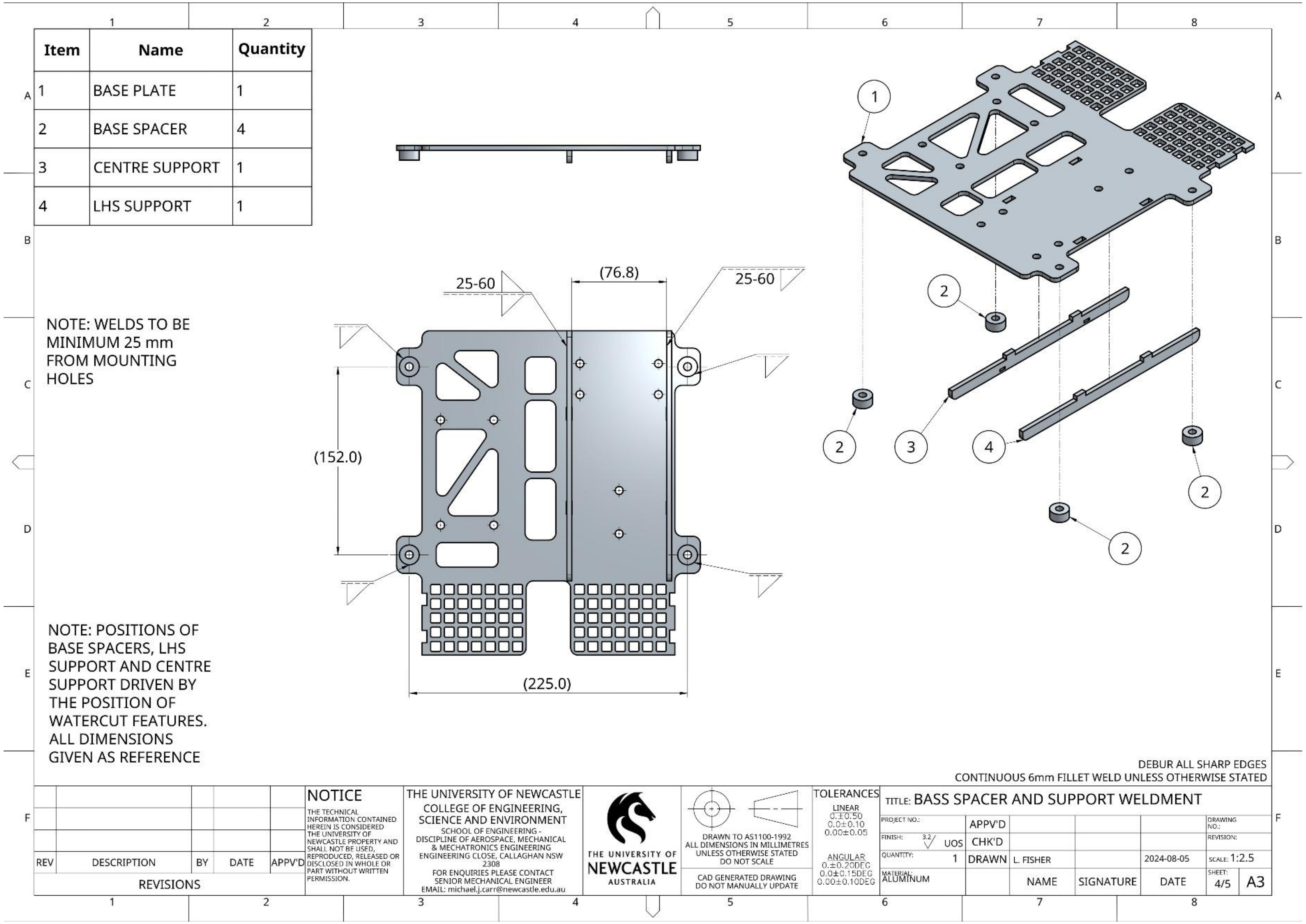
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: FOOT SUPPORT
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINUM
APPV'D
CHK'D
DRAWN L. FISHER 2024-08-05
NAME SIGNATURE DATE
DRAWING NO.:
REVISION:
SCALE: 1:1
SHEET: 3/5
A3
REV DESCRIPTION BY DATE APPV'D
REVISIONS


Item
Name
Quantity
1 BASE PLATE 1
2 BASE SPACER 4
3 CENTRE SUPPORT 1
4 LHS SUPPORT 1
NOTE: WELDS TO BE MINIMUM 25 mm FROM MOUNTING HOLES
NOTE: POSITIONS OF BASE SPACERS, LHS SUPPORT AND CENTRE SUPPORT DRIVEN BY THE POSITION OF WATERCUT FEATURES. ALL DIMENSIONS GIVEN AS REFERENCE
25-60
(76.8)
25-60
(152.0)
(225.0)
1
2
2
3
4
2
2
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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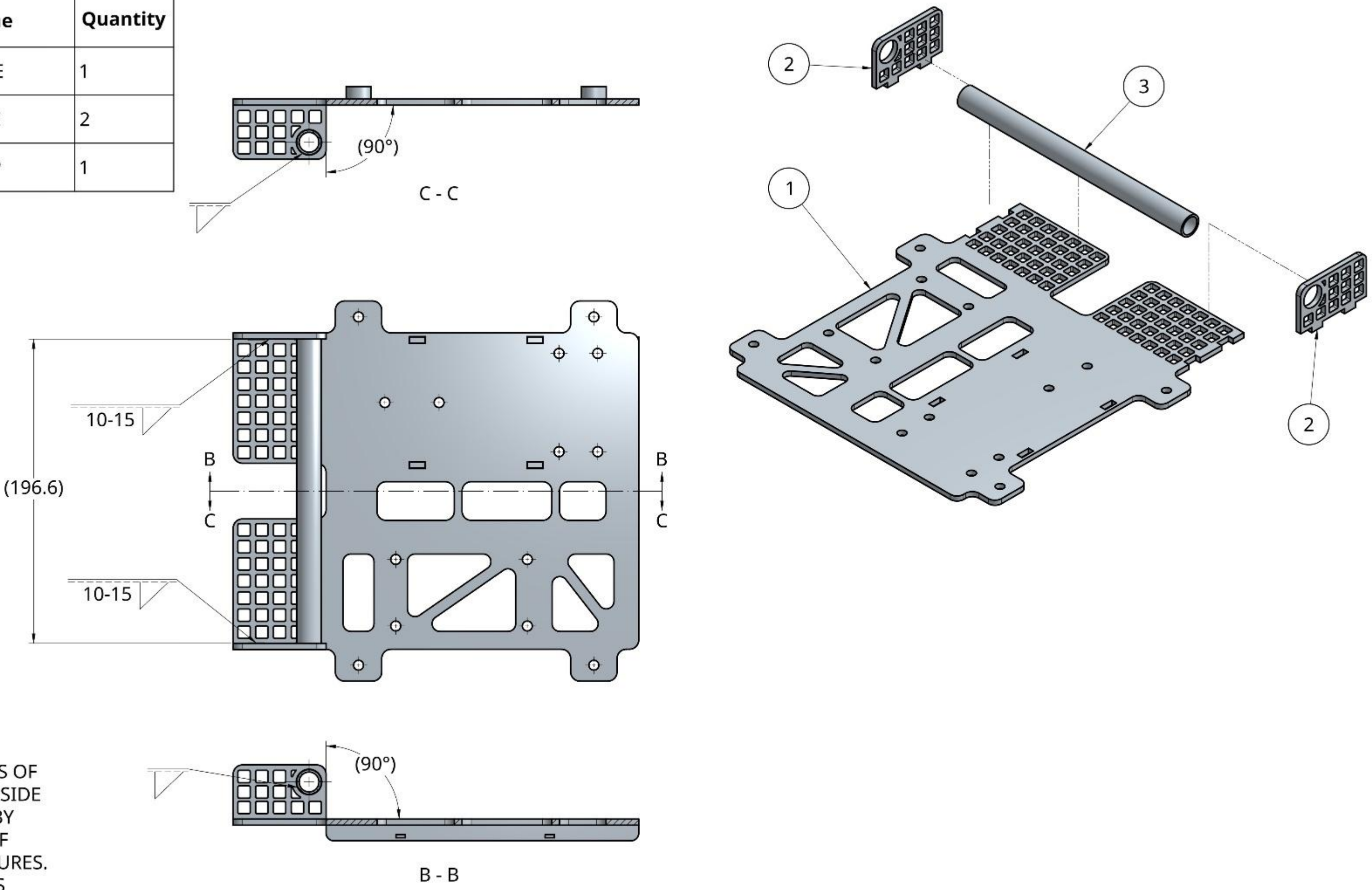
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: BASS SPACER AND SUPPORT WELDMENT
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINUM
APPV'D
CHK'D
DRAWN L. FISHER 2024-08-05
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2.5
SHEET: 4/5
A3

Item	Name	Quantity
1	BASE PLATE	1
2	SIDE PLATE	2
3	FOOT STOP	1



NOTE: POSITIONS OF FOOT STOP AND SIDE PLATES DRIVEN BY THE POSITION OF WATERCUT FEATURES. ALL DIMENSIONS GIVEN AS REFERENCE

DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D
REVISIONS				

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DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE

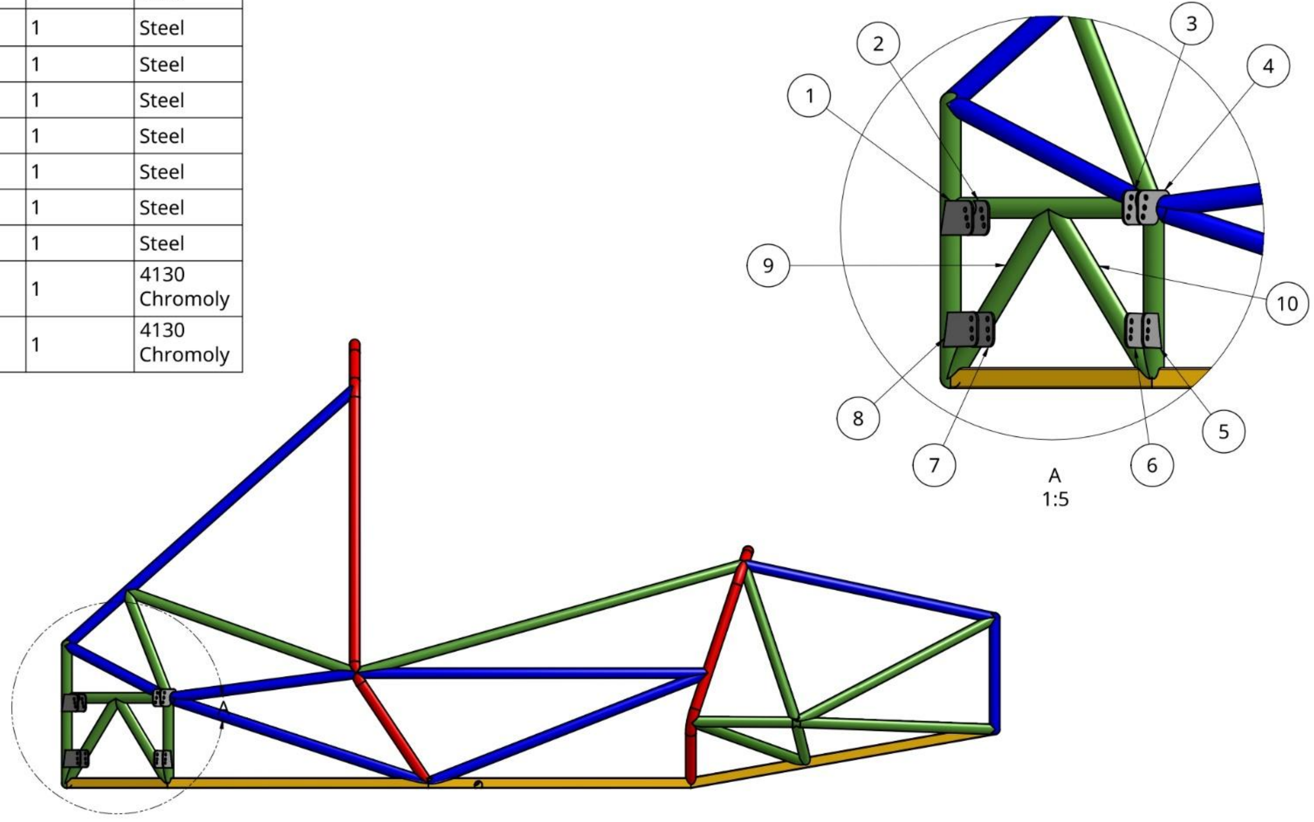
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: FOOT STOP WELDMENT

PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D				REVISION:
QUANTITY: 1	DRAWN	L. FISHER		2024-08-05	SCALE: 1:2.5
MATERIAL: ALUMINUM		NAME	SIGNATURE	DATE	SHEET: 5/5 A3

15.4. Appendix D – RIS Chassis Member Manufacturing Drawings

Item	Name	Quantity	Material
1	RLUF-R	1	Steel
2	RLUF-F	1	Steel
3	RLUR-R	1	Steel
4	RLUR-F	1	Steel
5	RLLF-F	1	Steel
6	RLLF-R	1	Steel
7	RLLR-F	1	Steel
8	RLLR-R	1	Steel
9	RIS-T-R-2	1	4130 Chromoly
10	RIS-T-R-1	1	4130 Chromoly



DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D

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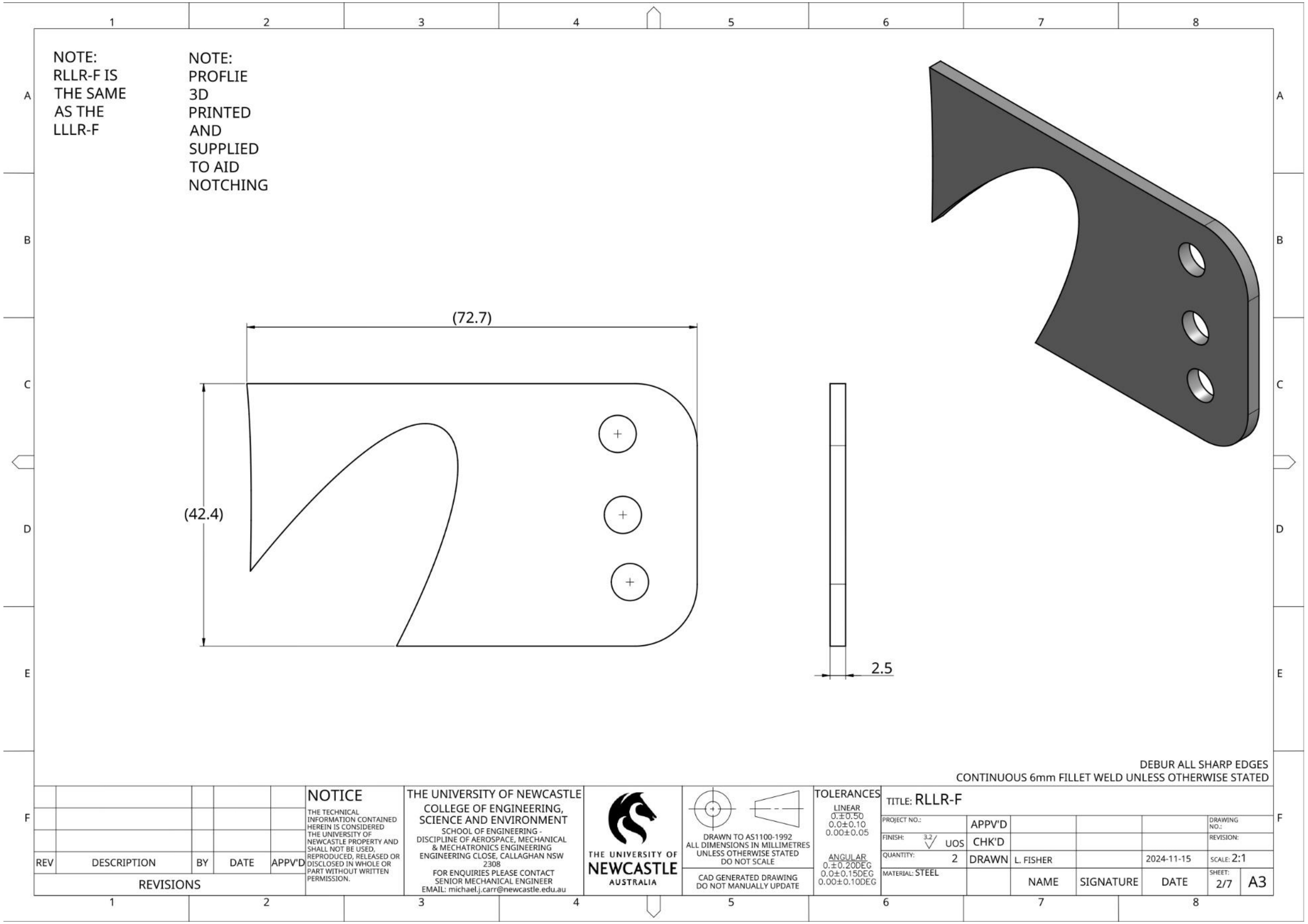
DO NOT SCALE

CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE

TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: RIS ADDITIONAL MEMBER ASSEMBLY

PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D				REVISION:
QUANTITY: 1	DRAWN	L. FISHER		2024-11-15	SCALE: 1:10
MATERIAL: SEE TABLE		NAME	SIGNATURE	DATE	SHEET: 1/7 A3


NOTE:
RLLR-F IS
THE SAME
AS THE
LLLR-F
NOTE:
PROFLIE
3D
PRINTED
AND
SUPPLIED
TO AID
NOTCHING
(72.7)
(42.4)
2.5
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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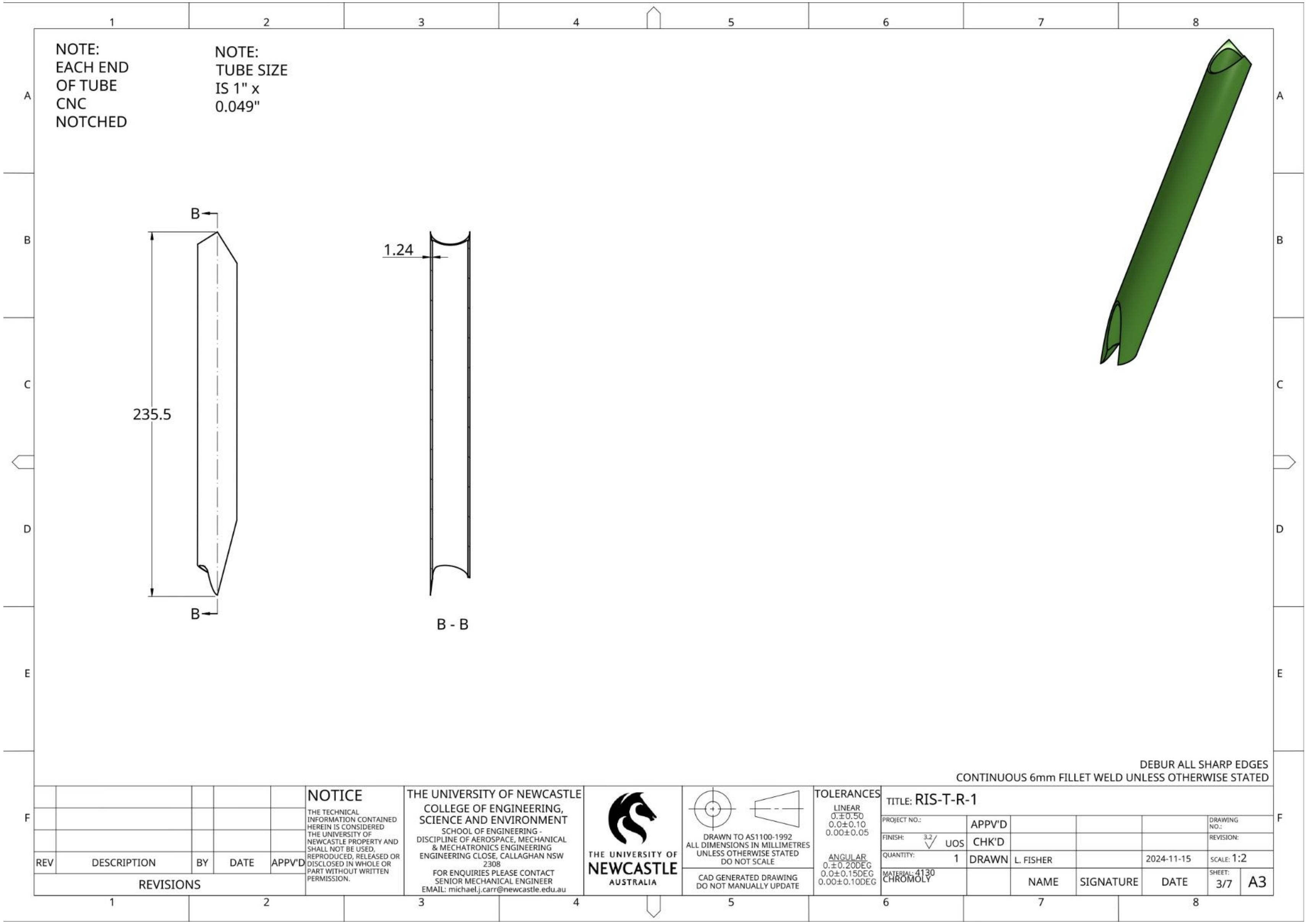
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: RLLR-F
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 2
MATERIAL: STEEL
APPV'D
CHK'D
DRAWN L. FISHER 2024-11-15
NAME SIGNATURE DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 2/7
A3


NOTE:
EACH END
OF TUBE
CNC
NOTCHED
NOTE:
TUBE SIZE
IS 1" x
0.049"
B
235.5
B
1.24
B - B
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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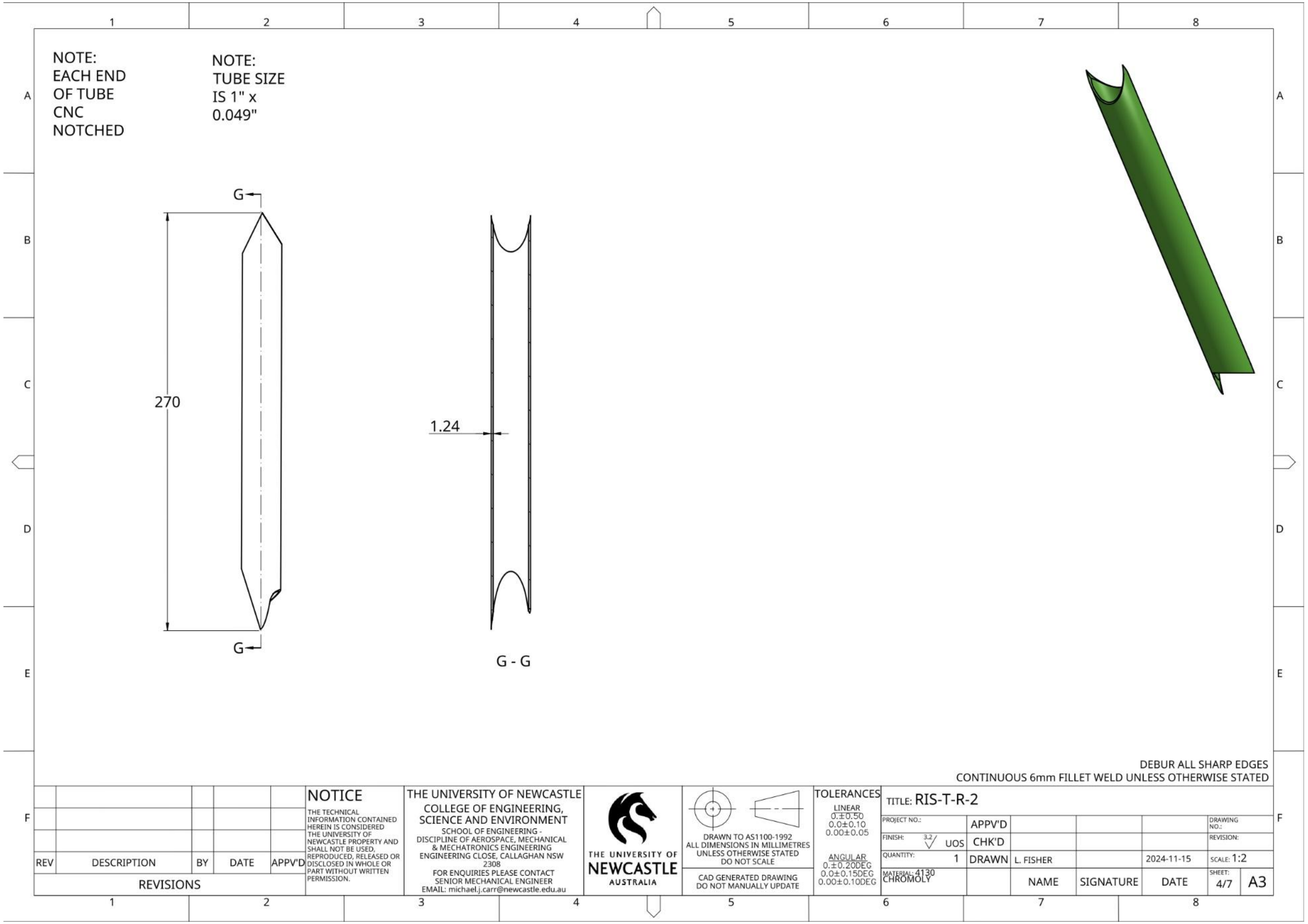
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: RIS-T-R-1
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: 4130 CHROMOLY
APPV'D
CHK'D
DRAWN L. FISHER 2024-11-15
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 3/7
A3


NOTE:
EACH END
OF TUBE
CNC
NOTCHED
NOTE:
TUBE SIZE
IS 1" x
0.049"
G
270
G
1.24
G - G
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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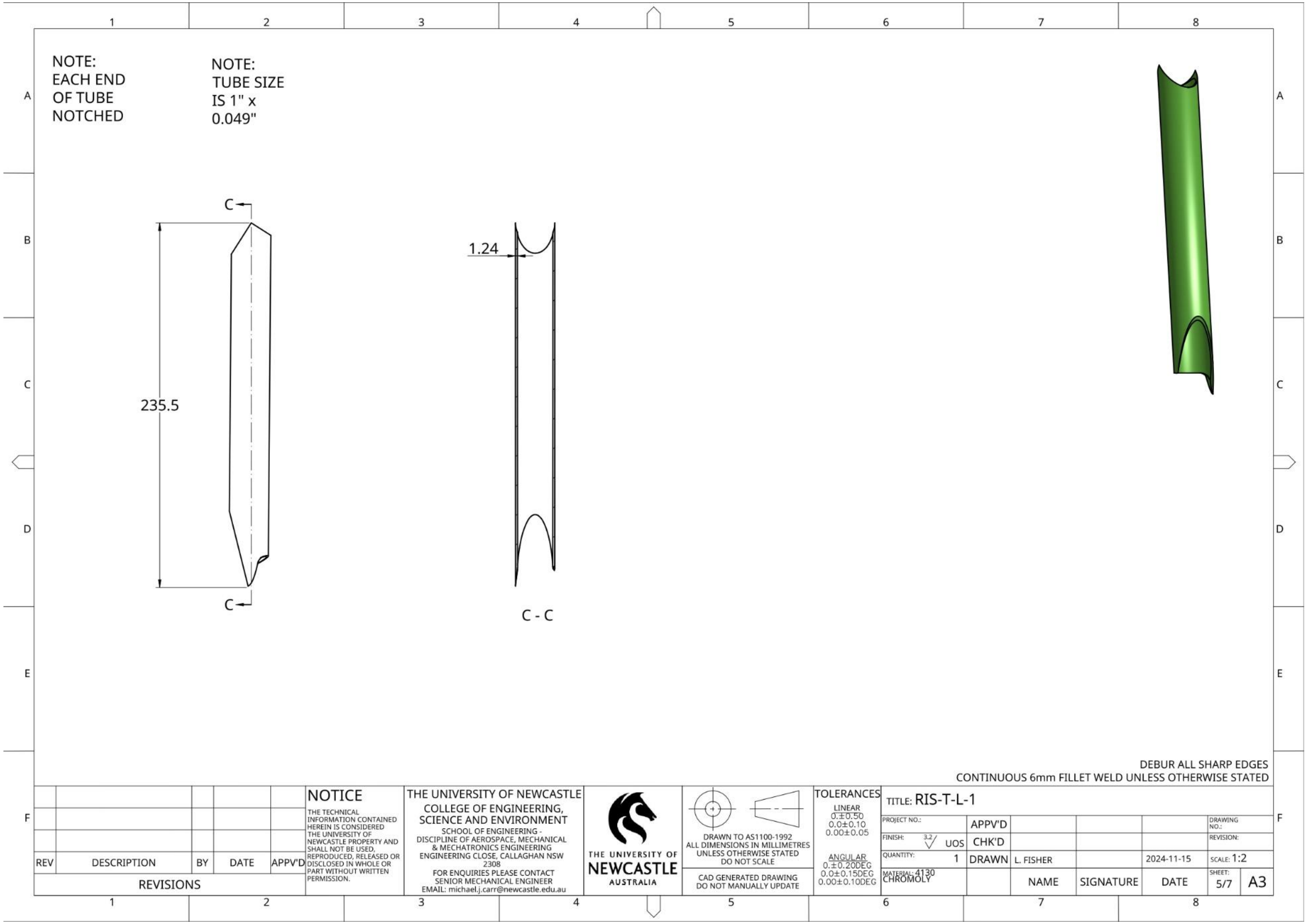
ALL DIMENSIONS IN MILLIMETRES
UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: RIS-T-R-2
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: 4130 CHROMOLY
APPV'D
CHK'D
DRAWN L. FISHER 2024-11-15
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 4/7
A3


NOTE:
EACH END
OF TUBE
NOTCHED
NOTE:
TUBE SIZE
IS 1" x
0.049"
235.5
1.24
C - C
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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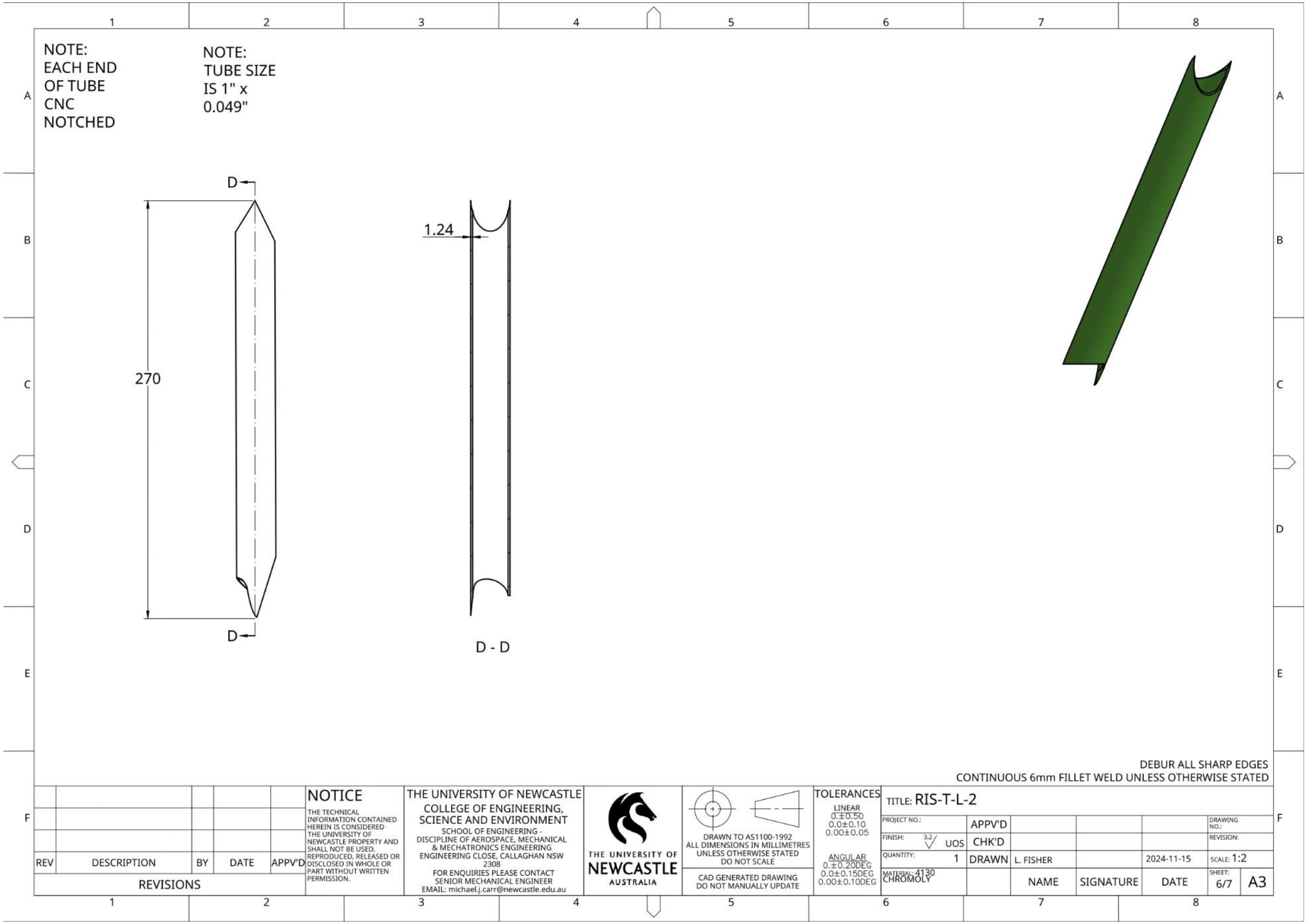
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: RIS-T-L-1
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: 4130 CHROMOLY
APPV'D
CHK'D
DRAWN L. FISHER 2024-11-15
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 5/7
A3


NOTE:
EACH END
OF TUBE
CNC
NOTCHED
NOTE:
TUBE SIZE
IS 1" x
0.049"
D
270
1.24
D - D
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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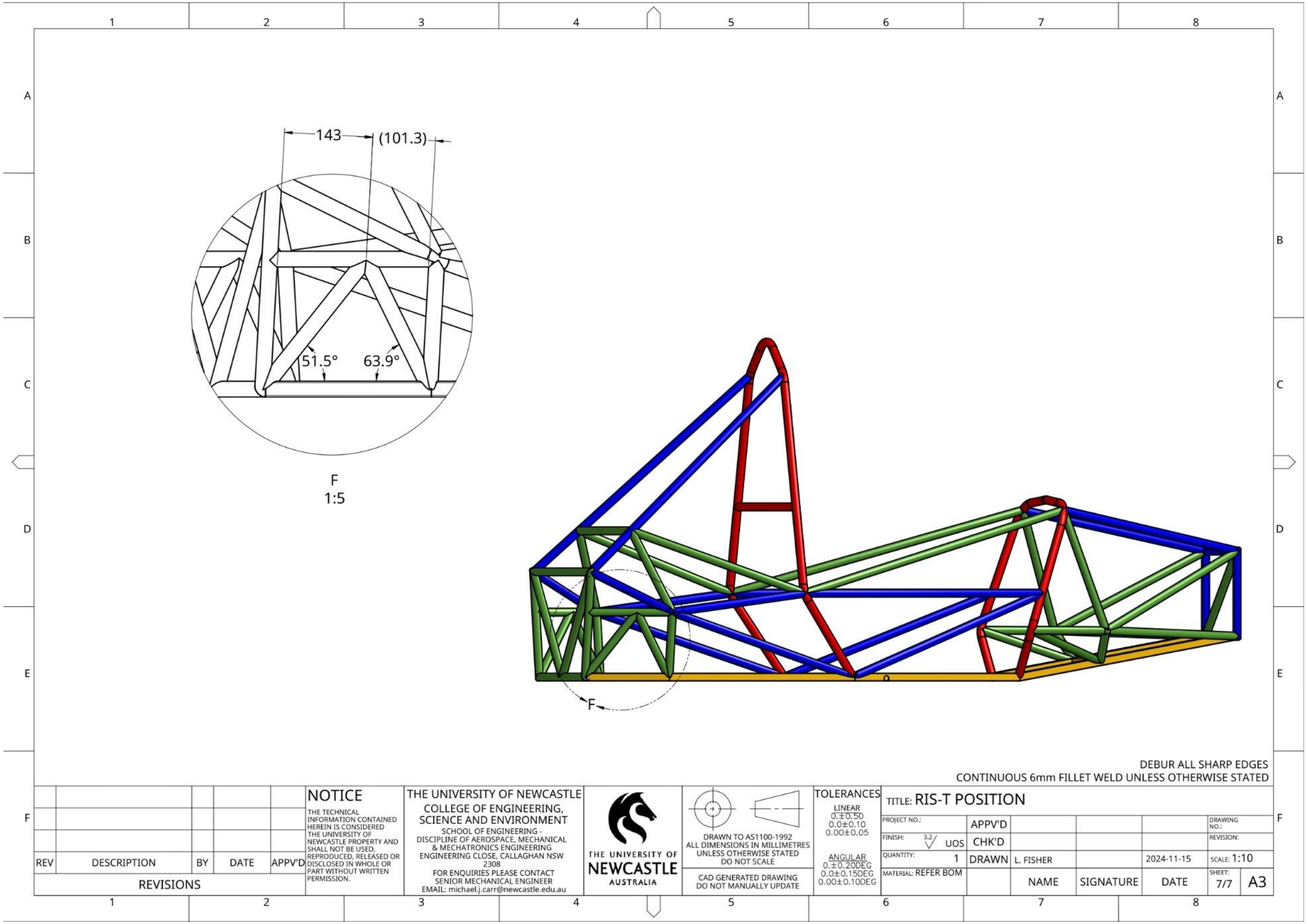
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: RIS-T-L-2
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: 4130 CHROMOLY
APPV'D
CHK'D
DRAWN
L. FISHER
2024-11-15
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 6/7
A3


143
(101.3)
51.5°
63.9°
F
1:5
F
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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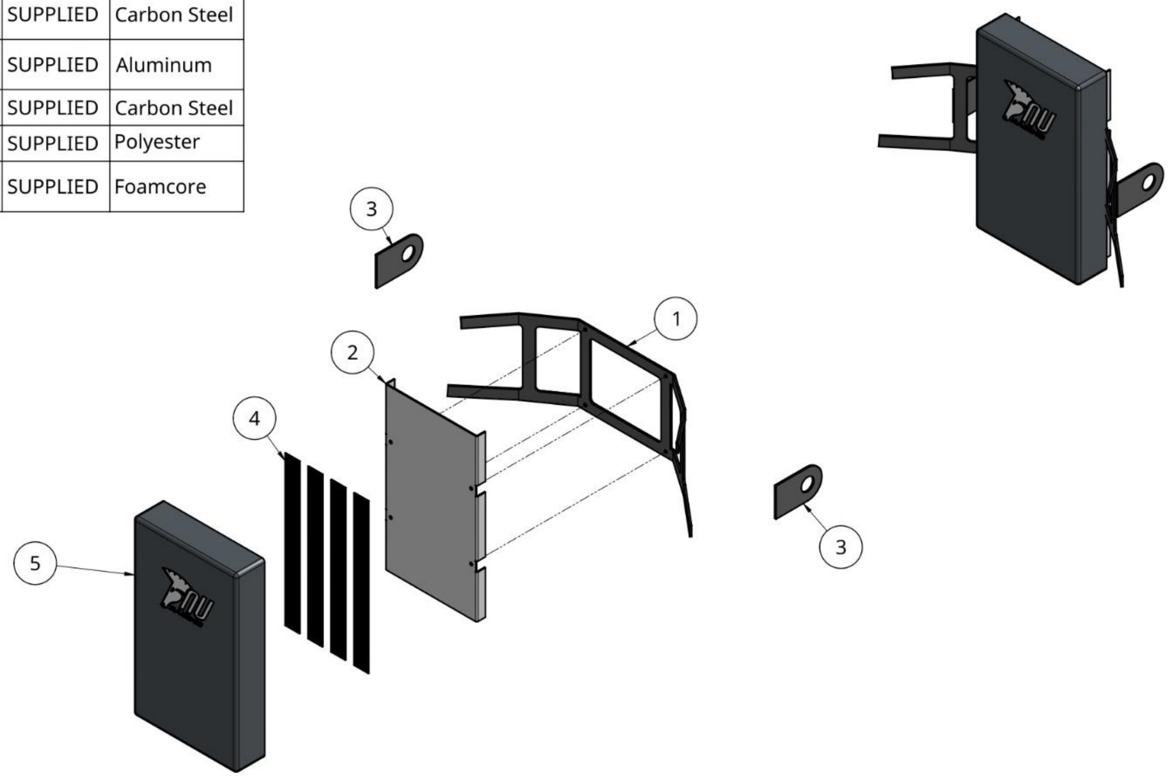
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: RIS-T POSITION
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: REFER BOM
APPV'D
CHK'D
DRAWN L. FISHER 2024-11-15
NAME SIGNATURE DATE
DRAWING NO.:
REVISION:
SCALE: 1:10
SHEET: 7/7
A3

15.5. Appendix E – Head Restraint Manufacturing Drawings

Item	Name	Quantity	Vendor	Material
1	HEAD RESTRAINT BACKING PLATE	1	SUPPLIED	Carbon Steel
2	HEAD RESTRAINT ALLOY PLATE	1	SUPPLIED	Aluminum
3	E STOP PLATE	2	SUPPLIED	Carbon Steel
4	VELCRO STRIP	4	SUPPLIED	Polyester
5	HEAD RESTRAINT PADDING	1	SUPPLIED	Foamcore



DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D
REVISIONS				

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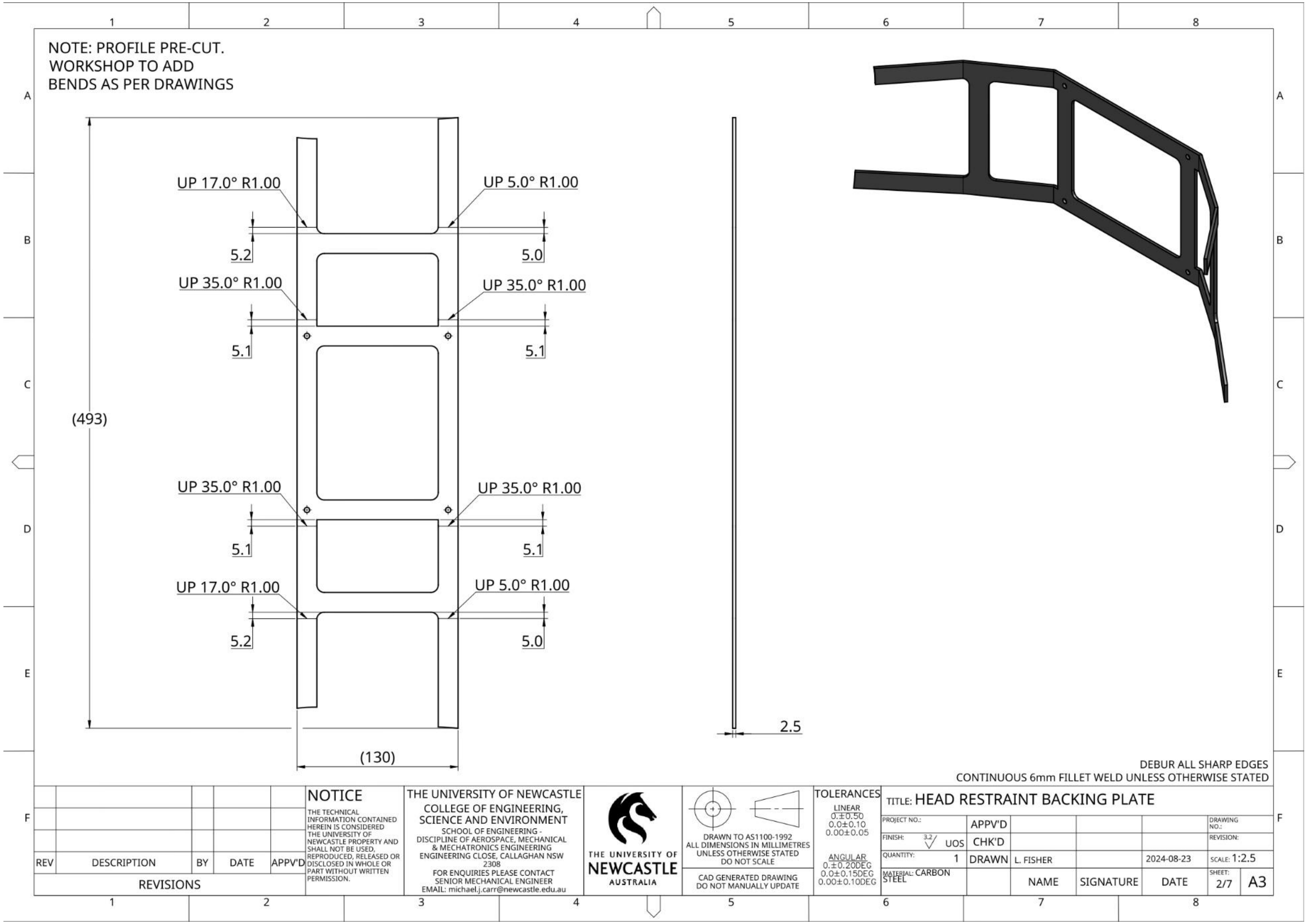
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE

TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: HEAD RESTRAINT ASSEMBLY

		NAME	SIGNATURE	DATE	
PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D				REVISION:
QUANTITY: 1	DRAWN	L. FISHER		2024-08-23	SCALE: 1:5
MATERIAL: SEE TABLE					SHEET: 1/7 A3


NOTE: PROFILE PRE-CUT.
WORKSHOP TO ADD
BENDS AS PER DRAWINGS
UP 17.0° R1.00
UP 5.0° R1.00
5.2
5.0
UP 35.0° R1.00
UP 35.0° R1.00
5.1
5.1
(493)
UP 35.0° R1.00
UP 35.0° R1.00
5.1
5.1
UP 17.0° R1.00
UP 5.0° R1.00
5.2
5.0
(130)
2.5
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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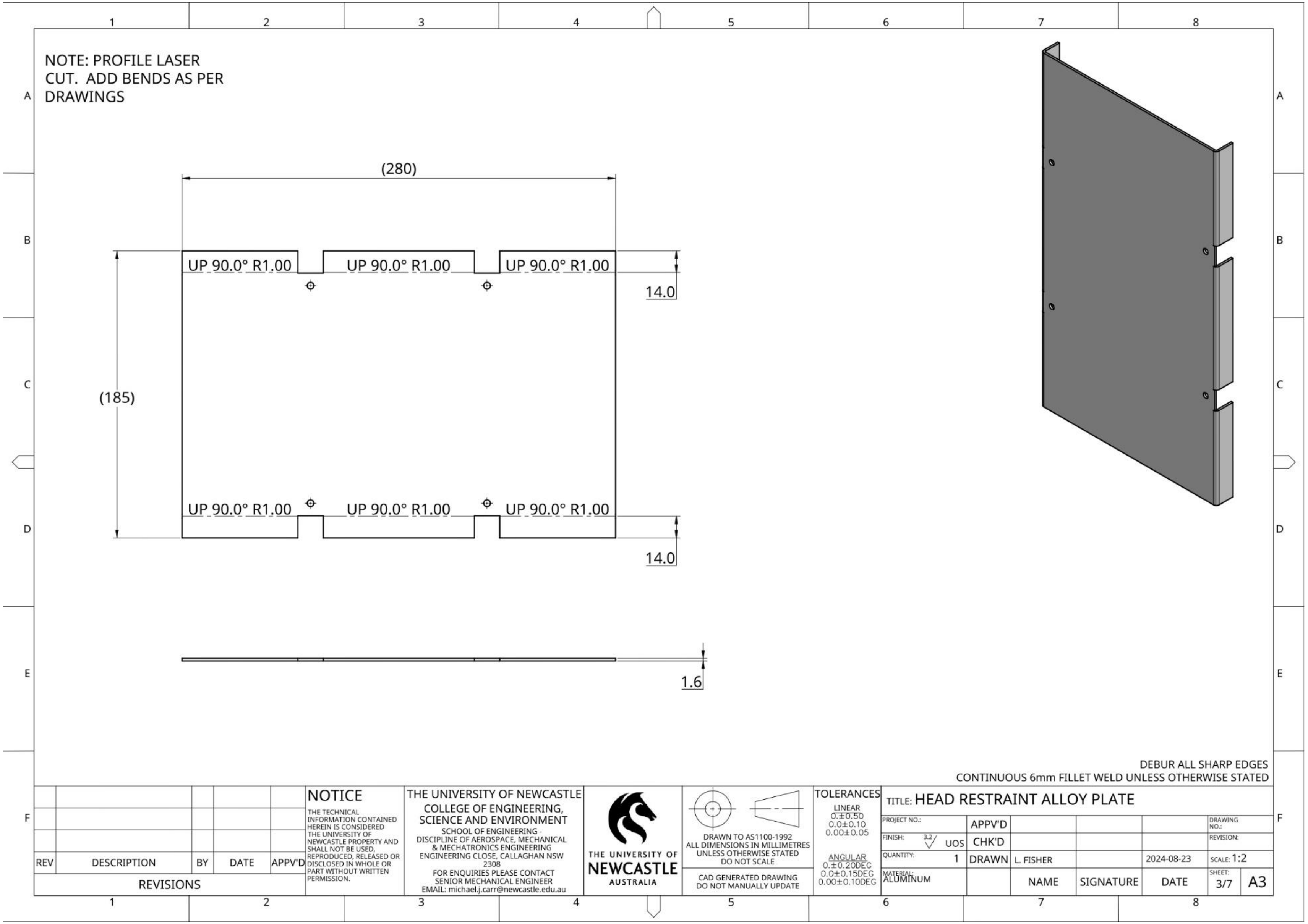
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES
UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: HEAD RESTRAINT BACKING PLATE
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: CARBON STEEL
APPV'D
CHK'D
DRAWN
L. FISHER
2024-08-23
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2.5
SHEET: 2/7
A3



NOTE: PROFILE LASER CUT. ADD BENDS AS PER DRAWINGS
(280)
(185)
UP 90.0° R1.00
UP 90.0° R1.00
UP 90.0° R1.00
14.0
UP 90.0° R1.00
UP 90.0° R1.00
UP 90.0° R1.00
14.0
1.6
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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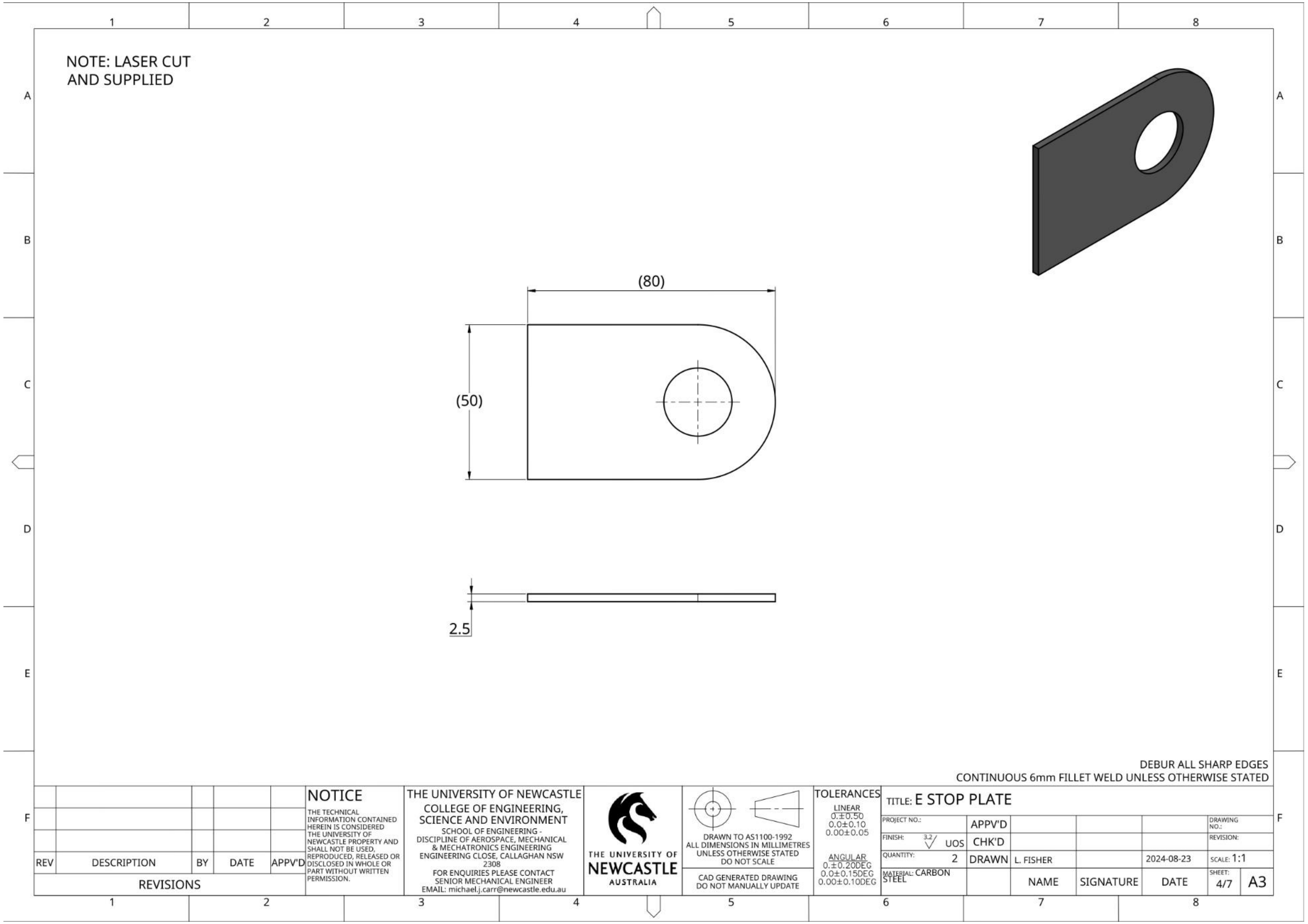
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: HEAD RESTRAINT ALLOY PLATE
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINUM
APPV'D
CHK'D
DRAWN L. FISHER 2024-08-23
NAME SIGNATURE DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 3/7
A3


NOTE: LASER CUT
AND SUPPLIED
(80)
(50)
2.5
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
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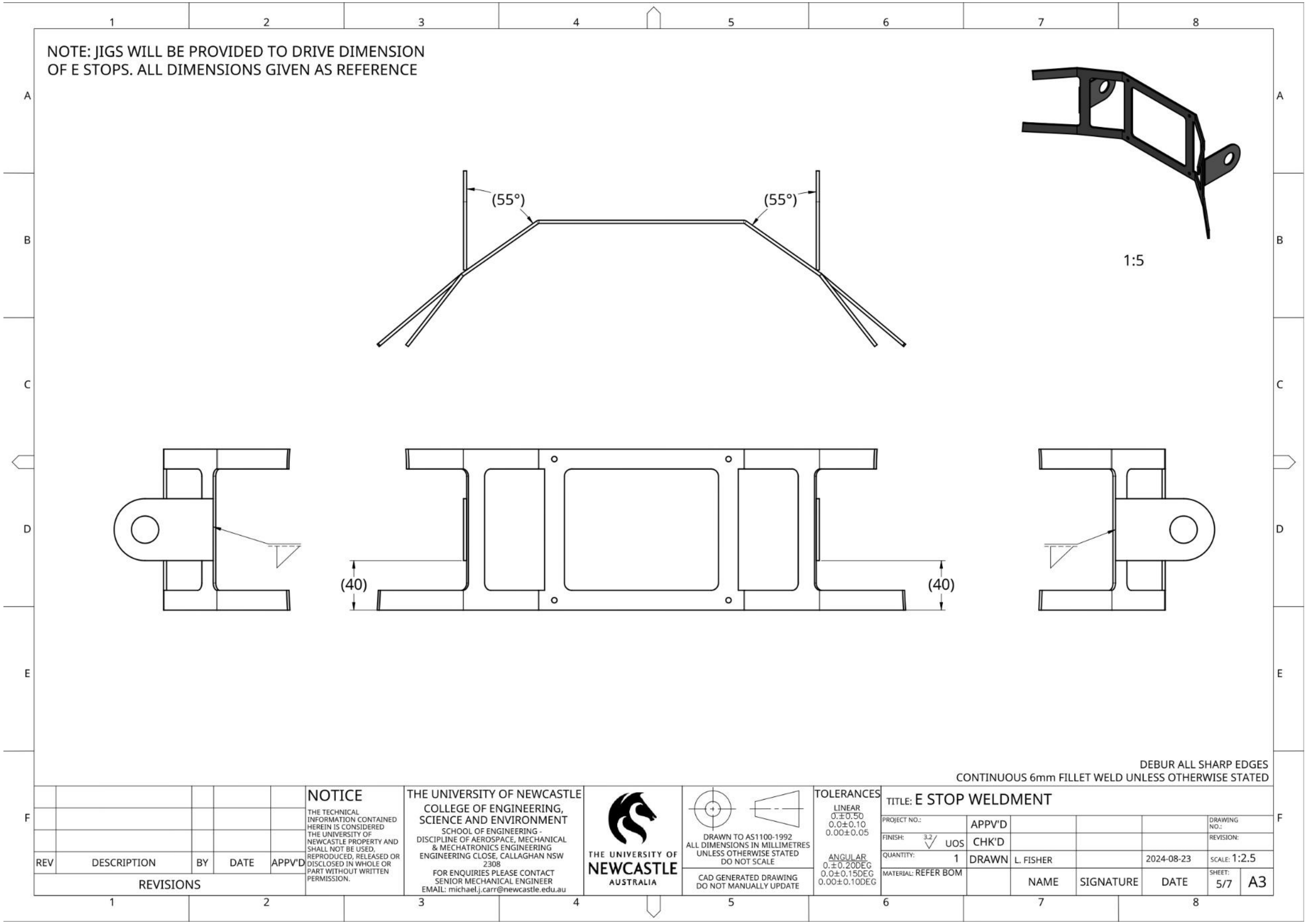
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: E STOP PLATE
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 2
MATERIAL: CARBON STEEL
APPV'D
CHK'D
DRAWN L. FISHER 2024-08-23
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:1
SHEET: 4/7
A3


NOTE: JIGS WILL BE PROVIDED TO DRIVE DIMENSION
OF E STOPS. ALL DIMENSIONS GIVEN AS REFERENCE
(55°)
(55°)
1:5
(40)
(40)
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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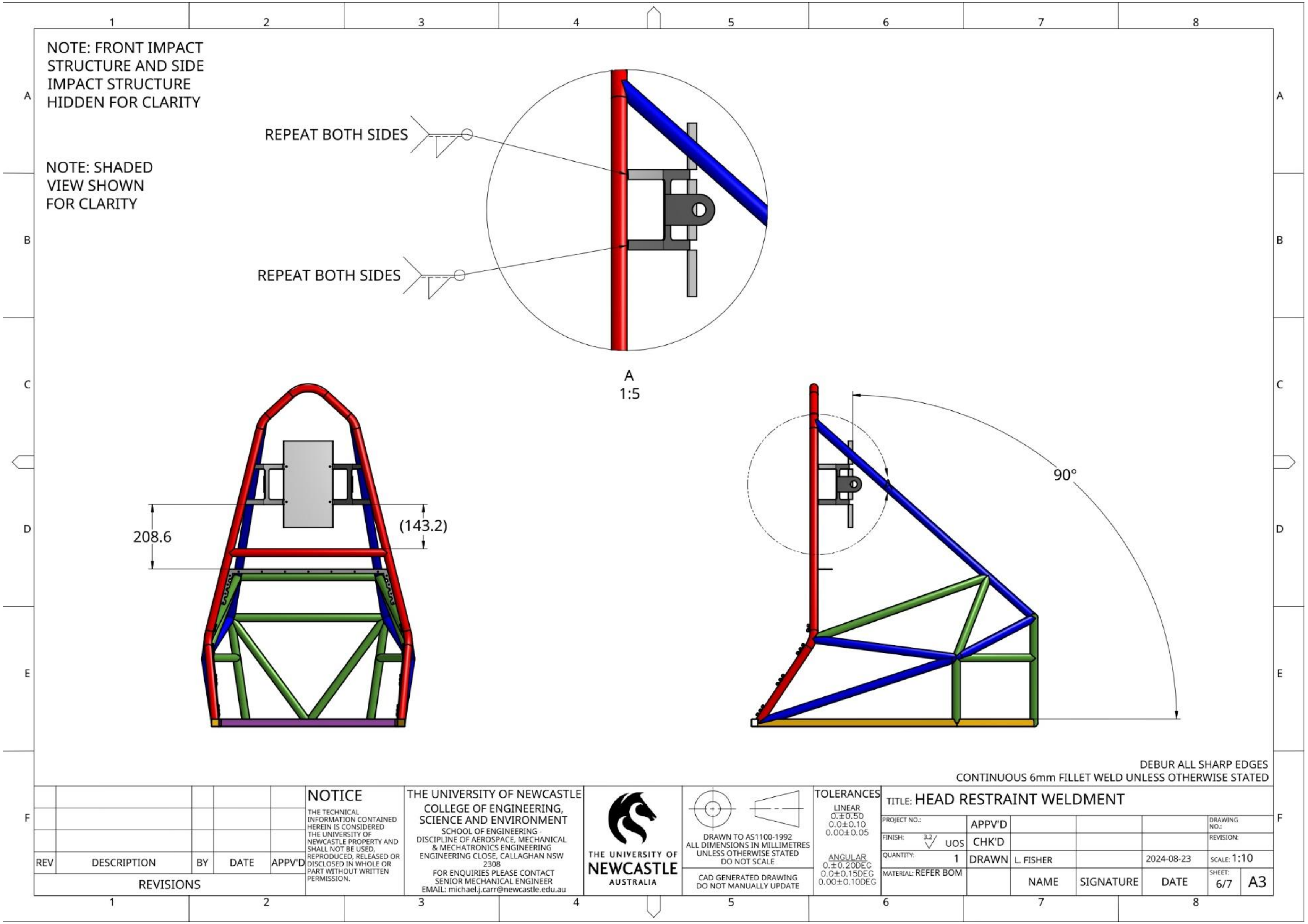
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES
UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: E STOP WELDMENT
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: REFER BOM
APPV'D
CHK'D
DRAWN L. FISHER 2024-08-23
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2.5
SHEET: 5/7
A3


NOTE: FRONT IMPACT STRUCTURE AND SIDE IMPACT STRUCTURE HIDDEN FOR CLARITY
NOTE: SHADED VIEW SHOWN FOR CLARITY
REPEAT BOTH SIDES
REPEAT BOTH SIDES
A
1:5
208.6
(143.2)
90°
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV DESCRIPTION BY DATE APPV'D
REVISIONS
NOTICE
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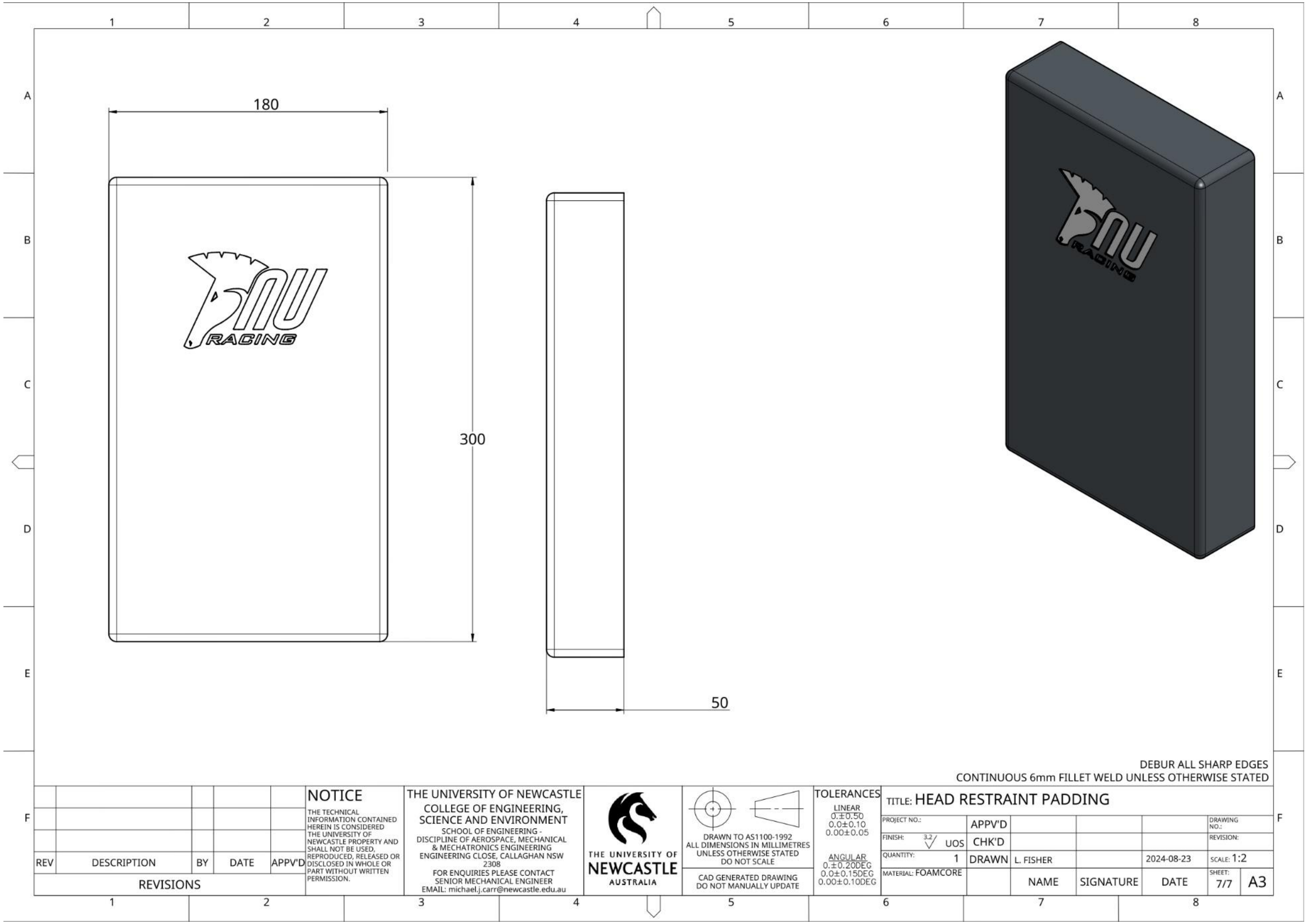
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: HEAD RESTRAINT WELDMENT
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: REFER BOM
APPV'D
CHK'D
DRAWN L. FISHER 2024-08-23
NAME SIGNATURE DATE
DRAWING NO.:
REVISION:
SCALE: 1:10
SHEET: 6/7
A3


180
300
50
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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DRAWN TO AS1100-1992
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DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: HEAD RESTRAINT PADDING
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: FOAMCORE
APPV'D
CHK'D
DRAWN
L. FISHER
2024-08-23
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 7/7
A3

15.6. Appendix F – Transmission Shaft Hand Calculations

Stress Calc - Trans Shaft

D	0.016	m	Diameter
R	0.008	m	Radius
F	8127.855009	N	Force
T	230	Nm	Torque
I	3.21699E-09	m^4	Second Moment of Area
d	0.011933	m	Moment Arm Distance
y	0.008	m	Distance fromm Neutral Axis
M	96.98969383	Nm	Moment
J	6.43398E-09	m^4	Polar Second Moment of Area

Torsion	285.9815384	MPa
Bending Stress	241.1935813	MPa
Von Mises Stress	550.936171	MPa
FEA Max Stess	645	Mpa
Error	17.07%	

t = fd

f = t-d

DESIGN REPORT

NU 24

Vehicle Dynamics

Lachlan Fisher

2024

Table of Contents

1. Introduction

The author began the year as the Vehicle Dynamics Engineer. The initial scope was as follows:

- Manufacture NU 24's Steering
- Design NU 25's Steering
- Implement a balanced Suspension set-up to optimise points in each event
- Utilise Tyre Data to drive initial setup changes
- Use MoTeC i2, physical data, and driver feedback to make setup decisions and changes
- Create track layouts to test dynamic characteristics of NU 24
- Potential to create Tyre Models and simulations

Due to the authors change in scope to become the Chief Mechanical Engineer the initial scope was limited as it was known as the extra workload would impact the Vehicle Dynamics scope. Of the initial scope it was expected that the following would be done to a limited extent or not completed:

- Utilise Tyre Data to a full extent
- Create Tyre Models and simulations

To being 2024 the author was responsible for the manufacture of the NU 24 Steering System, designed by Drew Bender [1].

2. Literature Review

Vehicle Dynamics describe the motion and forces generated by and onto a vehicle during driving. These are a function of the Suspension design and setup. For a race vehicle or team understanding the effects of setup changes allow for optimisation for different conditions and driving styles.

The goal of NU 24 was to find a balanced setup that worked well for all four Dynamic Events at competition: Skid Pad, Acceleration, Autocross, and Endurance.

To understand the effects of Suspension setups and configurations some key concepts must be understood.

2.1. Suspension Overview

A breakdown of the parts in NU 24's Suspension System are shown in Figure 138, which shows the Front Right Suspension Assembly. The Wheels and Tyres are bolted to the Spindle Assembly. When vertical load is applied to the tyre, the Control Arms allow the Upright to shift upwards, compressing the Coilover. Both Control Arms have Spherical Bearings (ABWT5V) which allow multi-directional movement which are shown in Figure 103 inside the Control Arms. This allows the Upright to move up and down as well as pivot around the steering axis.

The Suspension Pickups are welded to and transmit load to the Chassis through the Control Arms.

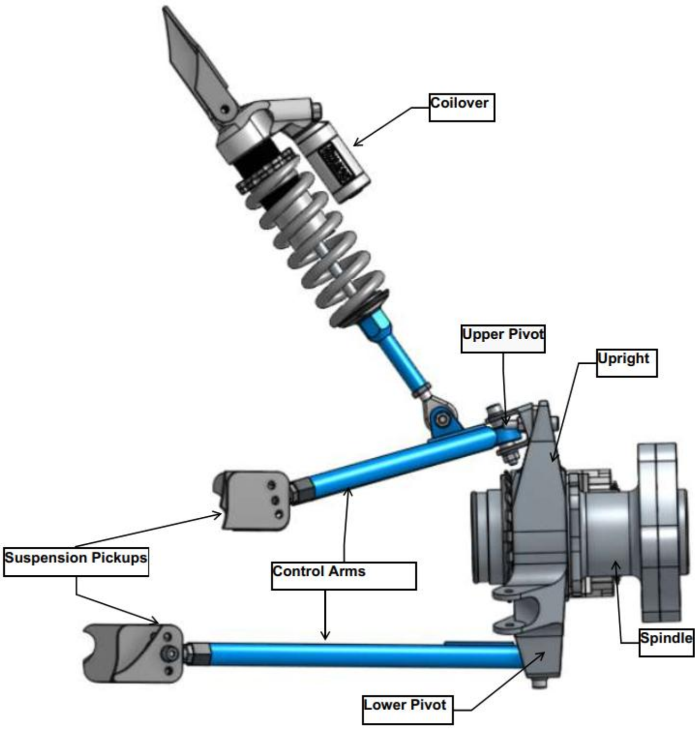


Figure 138. NU 24 Suspension Overview

A vehicle has a track and a wheelbase. These are shown in Figure 139.

Figure 139. Track and Wheelbase

2.2. Roll, Heave, and Yaw

Roll, heave, and yaw all represent the movement of a car under different driving conditions.

Roll is the transfer of load to the outside wheels whilst going around a corner. Heave refers to the transfer of load to the front axle under braking and rear axle under acceleration. Yaw is the rotation of the car around the vertical axis, turning the car. These motions are shown in Figure 140.

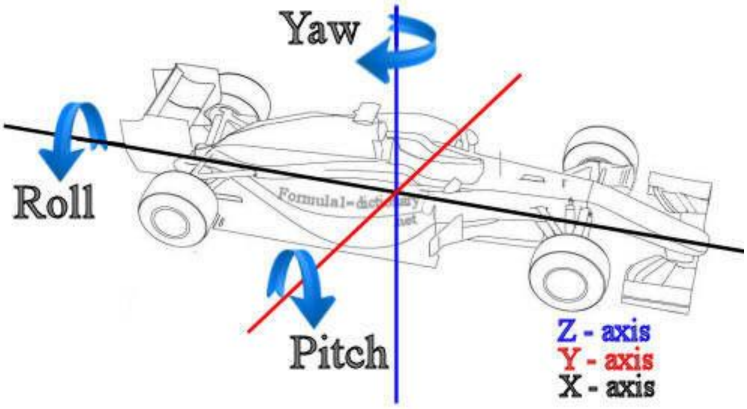


Figure 140. Roll, Heave (Pitch), and Yaw Diagram

2.1. Lateral, Longitudinal, Vertical Acceleration

Lateral Acceleration refers to the acceleration of the car due to yaw. This is cornering acceleration from left to right and right to left.

Longitudinal Acceleration refers to the acceleration due to heave. This is breaking and accelerating loads from front to rear.

Vertical Acceleration refers to the combination of acceleration from heave and roll.

2.2. Forces on a Tyre

The three forces on a tyre are the normal force, F_z, the lateral force, F_y, and the longitudinal force, F_x. This is displayed in Figure 141.

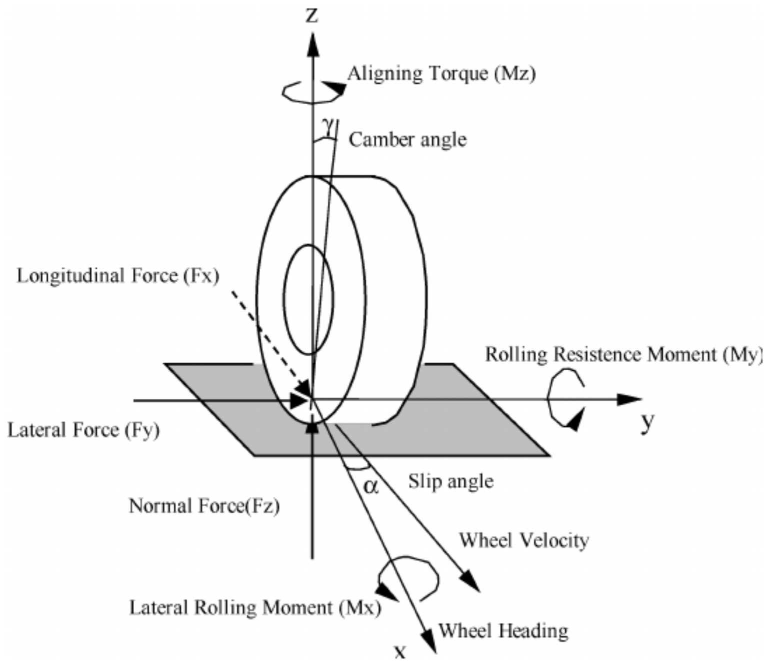


Figure 141. Forces Acting on a Tyre

It must be noted that the more normal load on a tyre the higher lateral force that can be achieved (up to a certain slip angle).

2.3. Castor and Mechanical Trail

Castor, or castor angle, refers to the angle between the steering axis and vertical [41]. The steering axis is the line drawn between the top and bottom pivot points (or ball joints etc). An image of this is shown in Figure 142. Castor angle can be positive, negative, or neutral. Figure 142 shows positive castor.

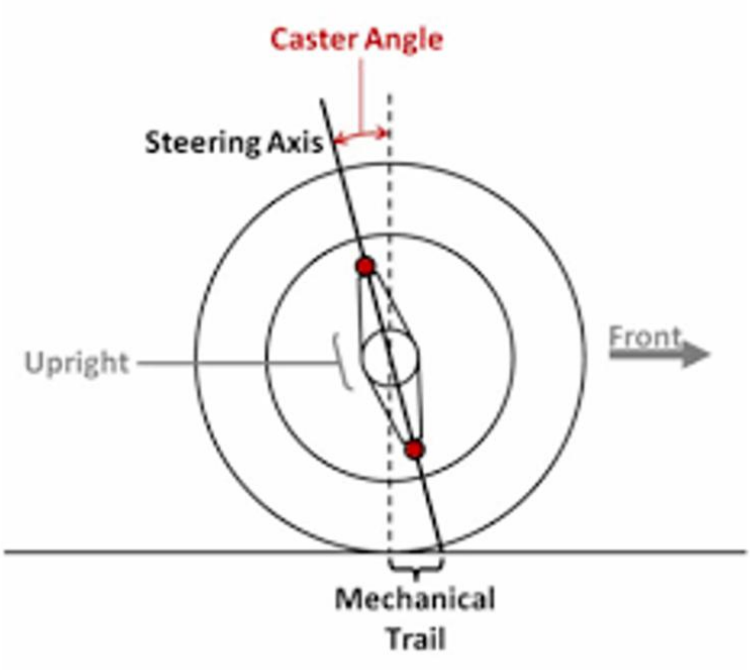


Figure 142. Castor and Mechanical Trail

The steering axis is the axis that the Upright will rotate around under turning.

If the steering axis is all the way to the ground, the distance between the midline of the tyre and this point is the mechanical trail. When positive castor is used, the mechanical trail along with pneumatic trail creates a self-aligning torque. This is because steering axis is placed in front of the contact patch of the tyre and as the car turns the contact patch generates a force to oppose the motion of steering. The self-aligning torque is zero when the car is going straight.

Too much mechanical trail can limit the impact of pneumatic trail [42].

2.1. Contact Patch

The contact patch of a tyre is the area of the tyre that is touching the road surface. The contact patch size and position change with setup factors such as tyre pressure, camber, slip ratio, and inputs into the tyre such as steering or braking.

Pneumatic rail is what, provides the driver ‘feeling’ during steering of a car approaching the limit of grip when cornering at high speeds. It contributes to the self-aligning torque alongside mechanical trail. The effect of pneumatic trail increases with slip angle, as the contact patch moves further back. This does begin to diminish at higher slip ratios [42]. This is shown in Figure 143.

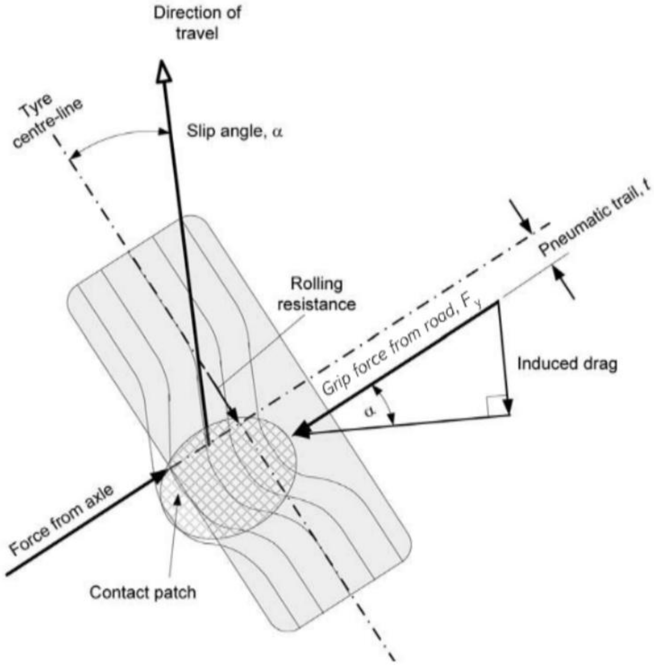


Figure 143. Contact Patch and Forces

2.2. Camber

Camber angle, or inclination angle, refers to the angle of the tyre to the vertical and is shown in Figure 144.

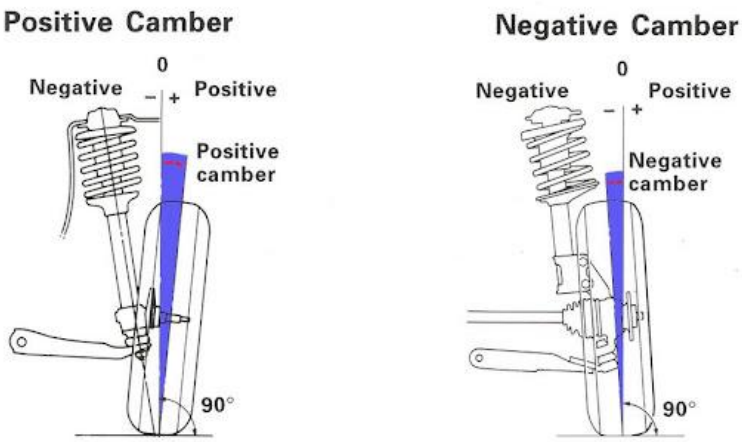


Figure 144. Camber Angle Diagram

Static camber is the amount of camber when the car is not moving. The goal of camber is to maximise lateral grip under turning. This is done by approaching neutral or near neutral camber, i.e. a camber angle of 0°. Camber is generally negative. Camber changes during driving due to steering, bump, roll, and rebound. Control Arm lengths and angles contribute to camber changes in bump and rebound, more negative camber in bump and more positive camber in rebound. Limiting the amount of roll, by an anti-roll bar or stiff springs resists camber gain in roll. The Kingpin Inclination (KPI) or steering axis inclination contributes to camber change of both front inner and outer wheels due to steering inputs.

2.3. Slip Angle

Slip angle is an angle that describes the difference between where the car is travelling and where the wheels are pointing, which is shown in Figure 143. Tyres increase the lateral force output with slip angle (until a point) as shown in Figure 183.

2.4. Slip Ratio

The slip ratio, refers to the difference in speed of a driven wheel and free rolling wheel for a given acceleration or braking event. This occurs as tractive force is applied to the tyres; the front of the contact patch (for acceleration) will compress. This reduces the effective radius of the tyre. This means that the driven wheel must always travel faster than the free rolling wheel. This is shown in Figure 145.

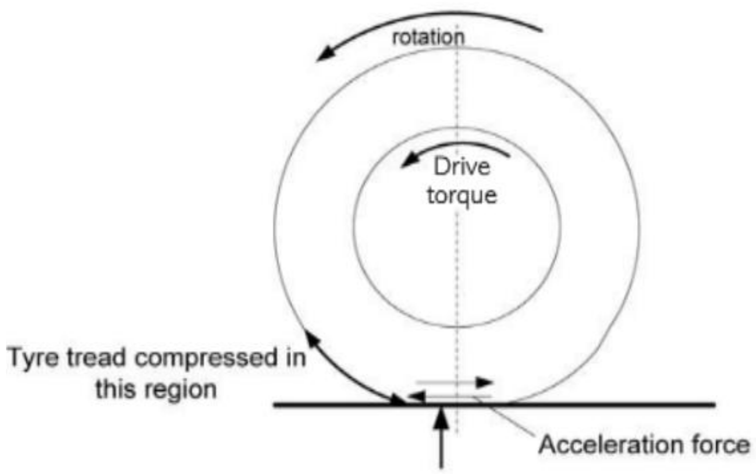


Figure 145. Slip Ratio Diagram [42]

2.5. Kingpin Inclination or Steering Axis Inclination and Scrub Radius

The angle between the line drawn between the Upper and Lower Pivot points of an Upright looking from the front of the car, and vertical is the KPI. The KPI causes camber gain and is responsible for the scrub radius. This is shown in Figure 146.

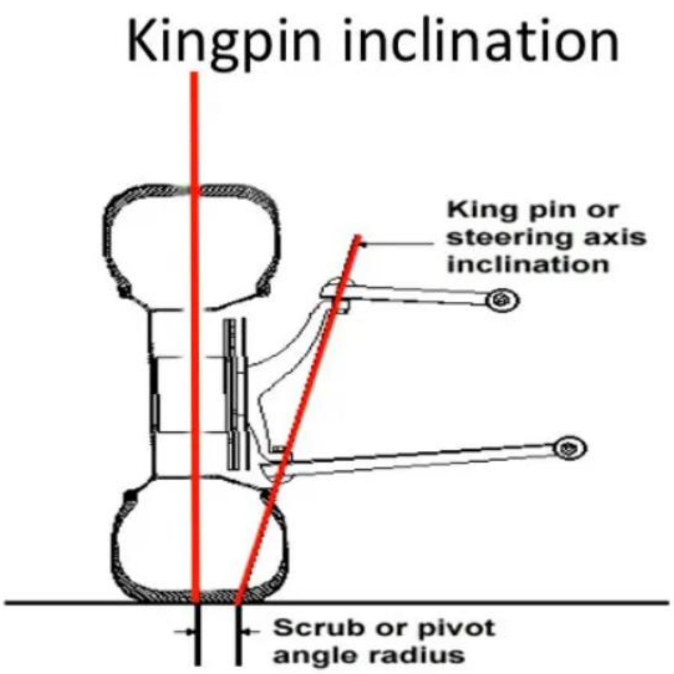


Figure 146. KPI and Scrub Radius [43]

The scrub radius is the distance between the line intersecting both Upper and Lower Pivot points and the contact patch of the tyre. As the KPI describes the pivot point of the steering, more scrub radius creates a moment acting against the steering. This is due to the forces generated by the contact patch of the tyre, which are multiplied at by the scrub radius to give the moment. Due to this scrub radius should always be reduced as much as possible. Excess scrub radius also increases the likelihood of the steering yanking or pulling violently from the drivers' hands due to the mechanical advantage it provides over the steering [42].

Usually, the KPI is selected due to a combination of packaging issues, not being able to fit everything inside the rim, and minimising scrub radius.

2.6. Toe

Toe is the angle of the tyres when looking at the car from a bird's eye view. Toe out refers to the tyres pointing away from the vehicle, whereas toe in refers to the tyres pointing in, towards the centre of the vehicle. This is shown in Figure 147.

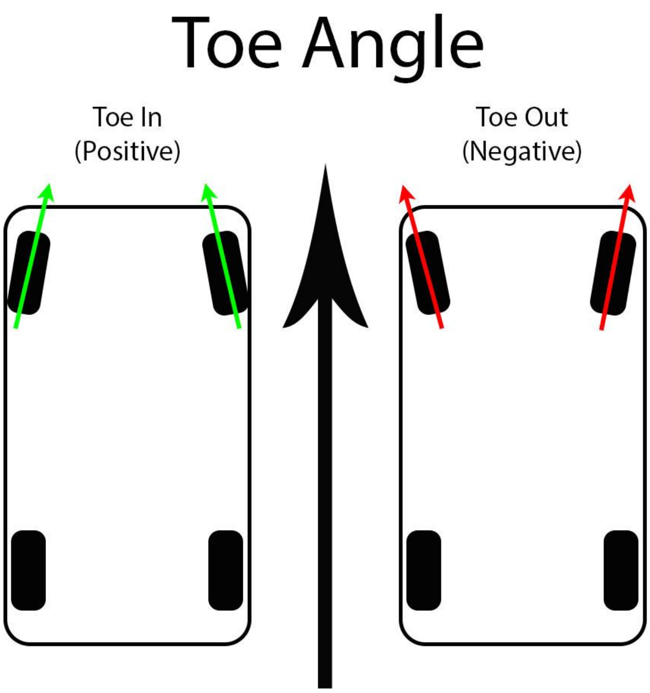


Figure 147. Toe Angle

Toe out helps the inside tyres generate more lateral force as their slip angle increases compared to the outside tyres.

Toe in helps the outside tyres generate more lateral force as their slip angle increases.

2.7. Bump Steer

Bump steer is where due to compression the distance between the Steering Rack and the Upright changes, causing the vehicle to turn in (toe in). To minimise bump steer the Tie Rod must be placed such that its line of action intersects with the instant centre generated by the Upper and Lower Control Arms. This is shown in Figure 148.

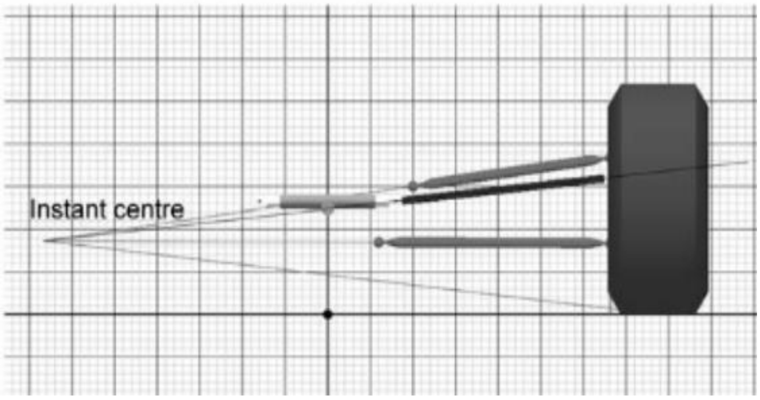


Figure 148. Tie Rod Intersection the Instant Centre to Minimise Bump Steer [42]

2.8. Roll Centres, Roll Axis, Roll Couple

The roll centre is a dynamic point on a singular axle of a vehicle that influences roll couple, which is the moment applied to the car due to lateral acceleration. Roll centres determine the vertical distance between the roll axis and the CoG height. This height is then multiplied by the lateral acceleration of the car. This determines the roll angle of the car during cornering.

A roll centre is found first by finding the instant centre of the Upper and Lower Control Arms. Once this is found a line is drawn from the instant centre to the contact patch of the tyre. If this is repeated for the opposite side of the car, where the two lines (going towards the contact patch) intersect is the roll centre. Note that for a static car, unless the Control Arms are not the same across the track, the roll centre will be located at the half track (centreline) of the car. During cornering and roll however this is not the case. An example roll centre is shown in Figure 149.

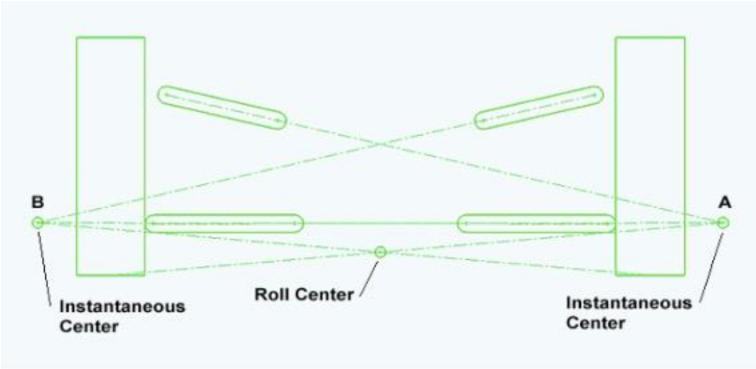


Figure 149. Roll Centre Diagram

The distance from the contact patch to the instant centre is known as the virtual swing arm length (VSAL). The length of the VSAL illustrates the amount of camber change due to roll and bump. Equation 6.1 shows this relationship for roll.

$$Camber\ Gain = \tan^{-1}\left(\frac{1}{VSAL}\right) \tag{6.1}$$

Once the roll centres are found for the front are rear axles, the roll axis can be found by drawings a line between the two. This line represents the line that the sprung mass rotates about during roll.

From this the roll couple can be found. This is simply the distance from the roll axis to the height of the CoG of the vehicle multiplied by the centripetal force (lateral force) to give the roll couple. This is shown in Figure 150.

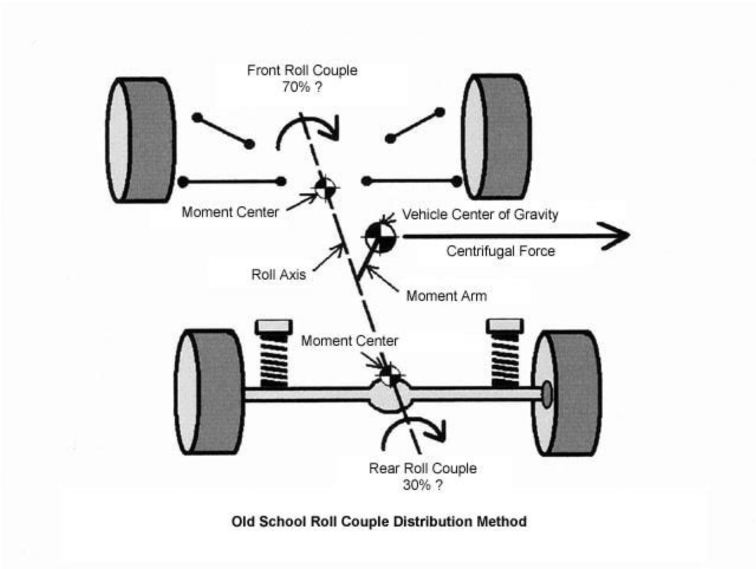


Figure 150. Roll Couple Diagram

Different roll axis heights allow for different impacts to the performance of the car. If the roll axis is lowered the roll couple increases and more roll is induced. If the roll axis is raised higher jacking forces increase. This is where more load is passed through the Control Arms and not the Coilovers. This causes the car to rise during cornering [42].

2.9. Dampers

Dampers are a part of the Coilovers and provide a reaction force dependant on the speed of its displacement. They are vital in controlling the driving characteristics of a vehicle and they control the rate of compression and rebound during driving.

The rate of compression is the speed at which the damper displaces. Less compression and the damper will easily use all its travel. This can make the car feel like it quickly dives through its travel, especially under cornering and braking. Using more compression and the damper will be firmer and use less of its travel. This can feel like the damper does not want to compress and doesn't absorb load well.

The rate of rebound is the speed that the damper returns to its natural position. Less rebound and the damper will return to its natural position quickly. This can feel like the damper is skipping or hopping over the road as it returns extremely quickly. More rebound and this is slower and more controlled. This can feel like it takes a noticeable period for the damper to return to its position.

High and low speed controls are available for most mid to high end dampers. High speed damping refers to events such as hitting potholes and skipping over bumps. Low speed damping refers to slower movements such as roll and heave, under cornering and braking.

2.10. Springs

In a similar way to dampers, springs output a reaction force due to displacement. Springs come in different stiffnesses and are often denoted in lbs/inch or N/mm.

Spring stiffnesses change the lateral and longitudinal weight transfer distribution of a car. For a set of soft springs travelling around a corner, load will be evenly distributed across the inside and outside tyres. For a set of harder springs travelling around the same corner, as the car cannot roll as much, load distribution in biased to the outside wheels.

Anti-roll bars (ARB) can be used to influence the load transfer distribution in a corner. With a stiffer ARB the load will be biased towards the outside tyre. Where ARB’s get interesting is the influence they have on the opposing axle of the car. If an ARB is placed on the rear axle, it will help stop the car from understeering. This is because the load distribution is removed from the rear axle and place more distribution on the front axle.

Preload can be used to affect the output force of springs. Preload is a static tightening of the spring prior to dynamic use. For example, for a linear spring if half an inch of preload is put into a 200 lb/inch spring will mean that it will store a force of 100 lbs. But it also means that it will take 200 lbs to now move the spring another inch.

Preload will make the springs harsher, not stiffer. This means it will take a bigger force to compress a similar amount.

2.11. Motion Ratio

Motion ratio is simply the ratio of the distance travelled for the spring divided by the distance travelled by the wheel. This is shown in Figure 151.

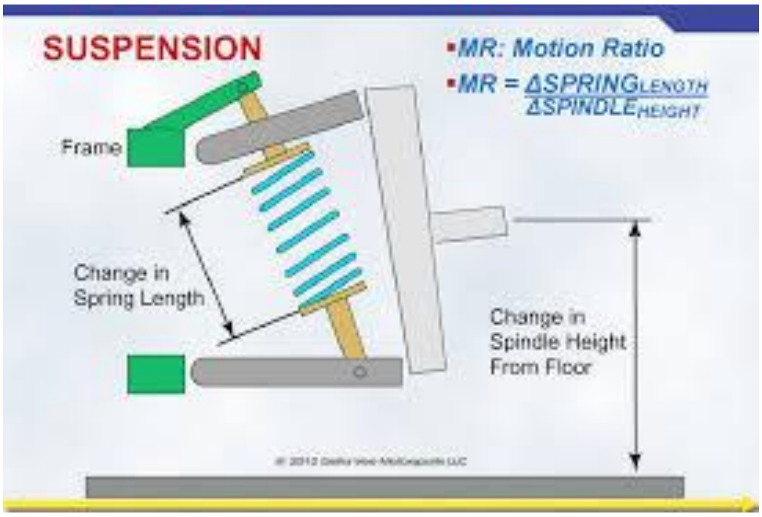


Figure 151. Motion Ratio Definition

2.12. Centre of Gravity

As discussed in 2.8 the CoG of a vehicle is important to the load transfer distribution across all four wheels. A higher CoG will promote roll, where a lower one will not.

Measuring the position of the height of the CoG can be completed using methods such as lifting the front of the vehicle and having the rear two wheels on scales or by measuring the mass of every object and it distance to the floor [44], [42].

Measuring the CoG between the wheelbase and track width is a lot simpler and can be achieved by using four scales [45].

Knowing these values are very important for making setup changes, especially to do with the roll couple.

3. NU 24 Characteristics and Components

3.1. Wheels and Tyres

NU 24 employs Hoosier LC0 16 x 7.5 x 10 tyres as its slick tyres. These tyres are the softest compound tyre that Hoosier sell for FSAE. These are paired with Keizer 10" FSAE 4lug rims.

3.2. Suspension

NU 24 uses Ohlins MKII TTX25 Coilovers. These have a 57 mm stroke and allow for adjustment to high and low speed compression and rebound.

The suspension setup for NU 24 is direct acting. This means that the coilover is directly attached to the control arm. Other suspension setups are pull rod and push rod. These make use a of a bell crank to influence the motion ratio of the suspension. The motion ratio for NU 24 is shown in Table 6.

3.2.1. NU 24 Suspension Static Geometry Values

NU 24's static geometry values are shown in Table 6 as derived by Justin Li [17].

Table 6. NU 24 Suspension Static Geometry Values

Static Variable	Front Suspension	Rear Suspension
Camber (°)	-1.5	-1
Track Width (mm)	1050	1050
Wheelbase (mm)	1550	N/A
Kingpin Inclination (KPI) (°)	9.2	5.8
Scrub Radius (mm)	47	44.9
Castor (°)	6	N/A
Mechanical Trail (mm)	18	N/A
Ackermann (%)	Inconclusive	N/A
Roll Centre Height (mm)	99	72
Virtual Swing Arm Length (mm)	641.9	1001.6
Motion Ratio	0.79	0.74

3.3. Wheelbase and Track Width Changes

The team of 2023, namely Joseph Barker and Justin Li, designed the Chassis and Suspension with the intent of reducing both the track width and the wheelbase of NU 24. This was to increase the agility of the vehicle. Track width especially is of concern for FSAE. A shorter track will increase the load transfer to the outside wheels during cornering but will allow the car to easily fit between cones in slaloms. As all the racing in FSAE is completed through cones, reducing the track will increase the minimum speed through a given slalom as the car will not have to enter as wide to make the corner. The changes are shown in Figure 152 and Figure 153.

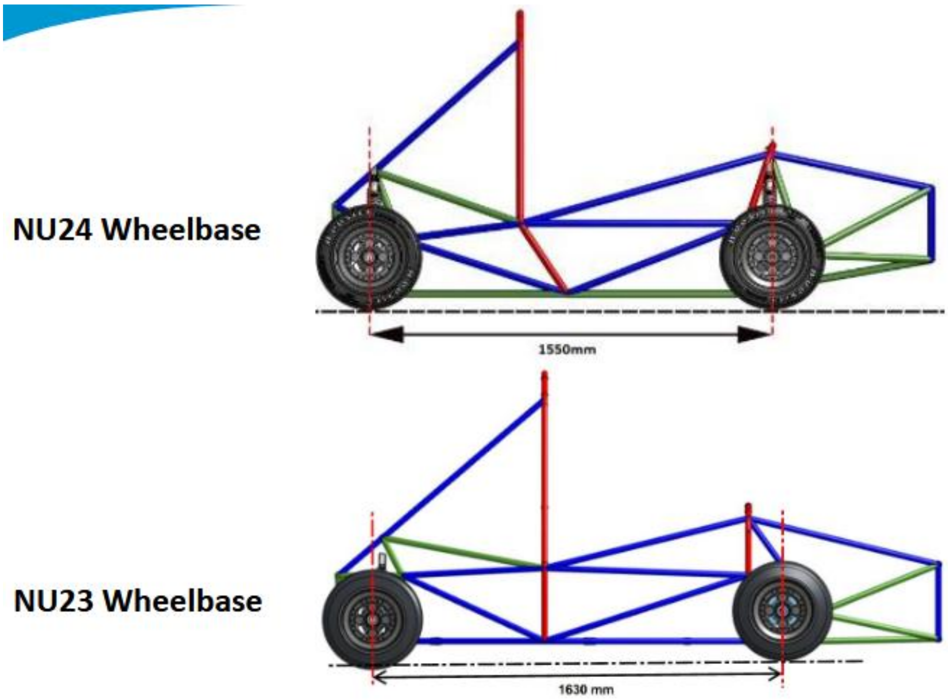


Figure 152. Change in Wheelbase from NU 23 to NU 24

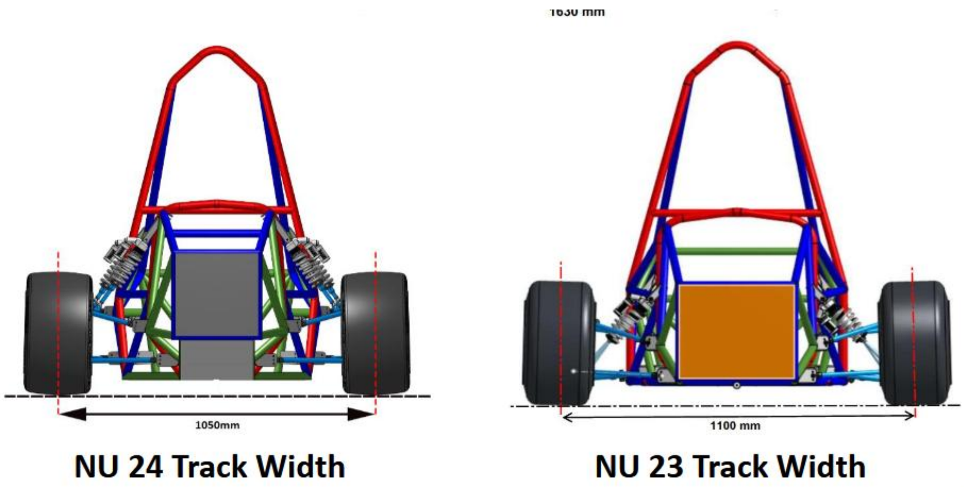


Figure 153. Change in Track Width from NU 23 to NU 24

4. Starter Project - Steering

4.1. 2023 Design – Introduction

The steering design for NU 23, was comprised of a single gear bevel gearbox, a steering rack, and a quick release steering wheel. This is shown below in Figure 154. The system was a change from previous iterations that had used universal joints [13].

Figure 154. NU 23 Steering Design

4.2. NU 24 Steering Components

Drew Bender's system worked well during competition, due to this the 2024 design remained similar. NU 24 was designed with the intention of saving weight. This was seen in the reduction of some parts, such as the support arms, and change in material of some parts. The changes in the initial design of NU 24's steering are explained in 4.1 Design Validation.

NU 24's steering is shown in Figure 155.

Figure 155. NU 24 Steering Design

4.2.1. Steering Wheel Assembly

The steering wheel assembly consists of the steering wheel, quick release, and quick release mount. This is shown in Figure 156.

Figure 156. Steering Wheel Assembly

4.2.2. Steering Wheel Shaft

The steering wheel shaft, made from Mild Steel, is comprised of the steering wheel shaft, quick release, and the keyed flange. This is shown in Figure 157.

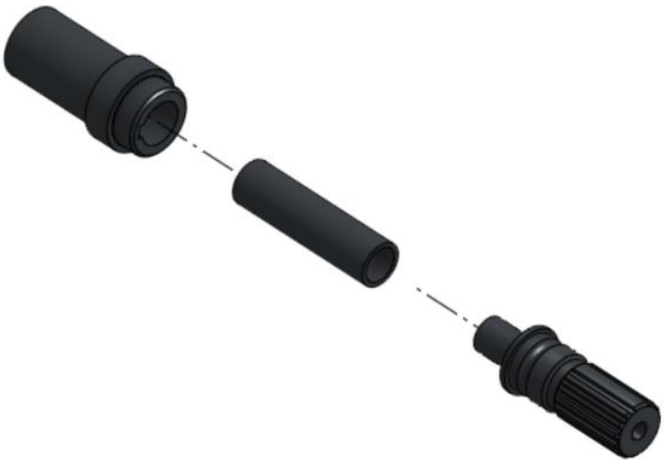


Figure 157. Steering Wheel Shaft

4.2.3. Bearing Block

The bearing block is the assembly of a Computer Numeric Controlled (CNC) milled block of 6061 T6 aluminium that houses a 6905-ZZ NSK bearing that is fit to the keyed flange of the steering wheel shaft. The block is then bolted to the face of the gearbox. This is shown in Figure 158.

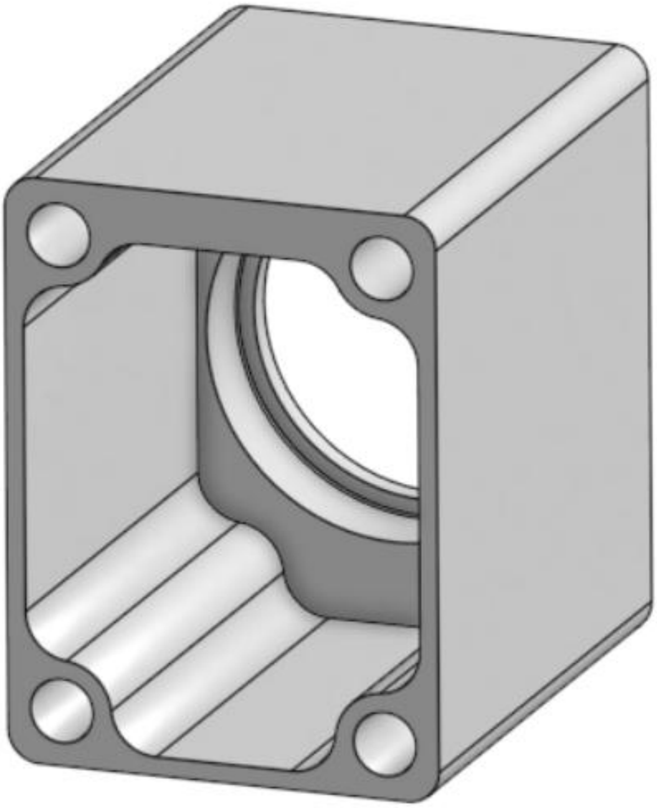


Figure 158. Steering Bearing Block

4.2.4. Gearbox

The bevel gearbox used for the steering is the same as used in 2023. The gearbox is a DZ 20S 3FAB from DZ Transmissioni. It has two keyed shafts that connect to the steering wheel shaft and the steering rack shaft. This is shown in Figure 159.

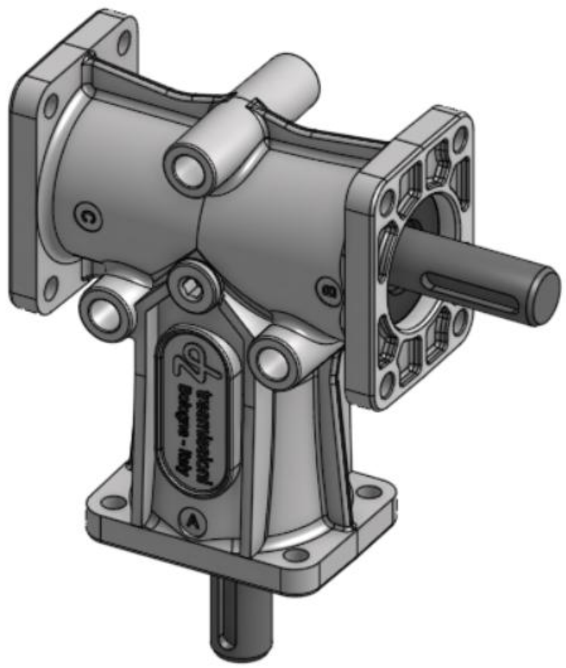


Figure 159. Steering Bevel Gearbox - DZ 20S 3FAB

4.2.5. Steering Rack Shaft

The steering rack shaft is made from 19 × 3.2 mm 6061 T6 Aluminium. It connects the gearbox and the steering rack shaft. It is shown in Figure 160. The keyed shaft, also made from 6061 T6 Aluminium, is machined to remove allow the steering rack shaft to slot up to a ‘butt’ to be welded. This is shown in Figure 161. The connection between the rack shaft and the steering rack is by the rack connection, which is machined similarly to the keyed shaft. It has 2 offset pairs of holes that connect to the steering rack. These holes are made to suit the steering rack.

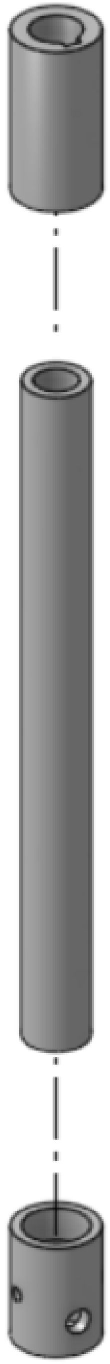


Figure 160. Keyed Shaft, Steering Rack Shaft, Rack Connect

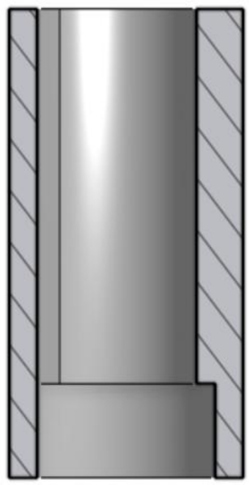


Figure 161. Section view of the Keyed Shaft

4.2.6. Steering Rack

The steering rack is a NARRco Rack Mk II. The rack has a rack speed of 87.88 mm per rotation [46]. The steering rack assembly also includes two rack spacers that are made from 3D printed PETG. This is done to satisfy rule V.3.2.4 [7] which requires steering to have positive steering stops. The steering rack assembly is shown in Figure 162.

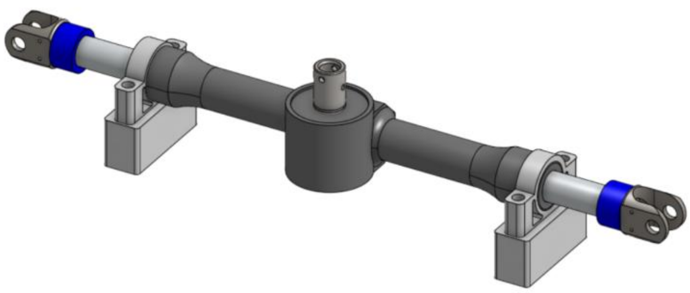


Figure 162. Steering Rack Assembly

4.2.7. Tie Rods

The tie rods were made from Ø16 × 1.6 mm 4130 grade steel. At either side of the rod there are welded hex inserts that are tapped to M8 × 1.25 mm. This is to suit the 8 mm rod ends that connect to both the uprights of the car and clevises of the steering rack. To facilitate the fit between the rod ends and the uprights outboard suspension spacers are used. Similarly for the steering rack clevis a misalignment spacer is used. This is shown in Figure 163. Opposite sides of each tie rod have right hand and left-hand threads respectively. This allows for the adjustment of the toe, which is the angle of the wheel if looking at them from a bird's eye view, by turning the tie rod whilst it is still bolted into the car.

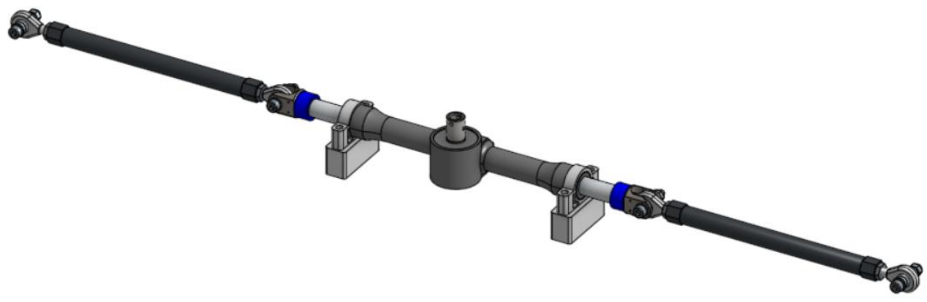


Figure 163. Tie Rods and Steering Rack

4.2.8. Rack Shim

The rack shims provide the height of the steering rack when bolted into the car. These are made from aluminium and are shown in Figure 162.

4.2.9. Mounting Plate and Support Arms

The steering support arms are made from Ø5/8" × 0.065" CHS grade 4130 steel and are shown in Figure 164. These are notched at one side to fit the chassis nodes where they are welded, which is shown in Figure 165. The mounting plates are made from 3 mm MS and have a circular hole in the centre of them. This was introduced to allow easy placement and correct clocking of the support tubes in the mounting plate as opposed to making jigs or providing complex dimensions for the machinist in Prototyping Workshop to follow.

Figure 164. Support Arms and Mounting Plate connected to the Bevel Gearbox

Figure 165. Notching of the Support Arms to the Chassis

4.2.10. Shaft Cover

To ensure compliance with FSAE rule T.1.3.3, which states all moving parts inside the cockpit must be covered by a solid material, a Steering Shaft Cover was designed and 3D printed, bolted to the bottom of the Steering Gearbox. The Shaft Cover is shown in Figure 166.

Figure 166. Steering Shaft Cover

4.3. Design Changes

There were changes from the initial design completed by Drew Bender in early 2024. They are as follows:

- Aluminium supports to steel
- Keyed shaft weight reduction
- Changes in dimensions for the tie rods, the steering wheel shaft, the steering rack shaft, and rack connect
- Adding the holes to the mounting plates to allow for easier welding
- Removal of the centre support as it impacted the DEN

The aluminium Support Arms were designed to be aluminium as shown in Figure 167.

Figure 167. Initial Steering Support Arm Design

The three Support Arms had Clevises welded into them. These were going to be bolted to pickups welded onto the Front Hoop of the Chassis. These are shown in Figure 168.

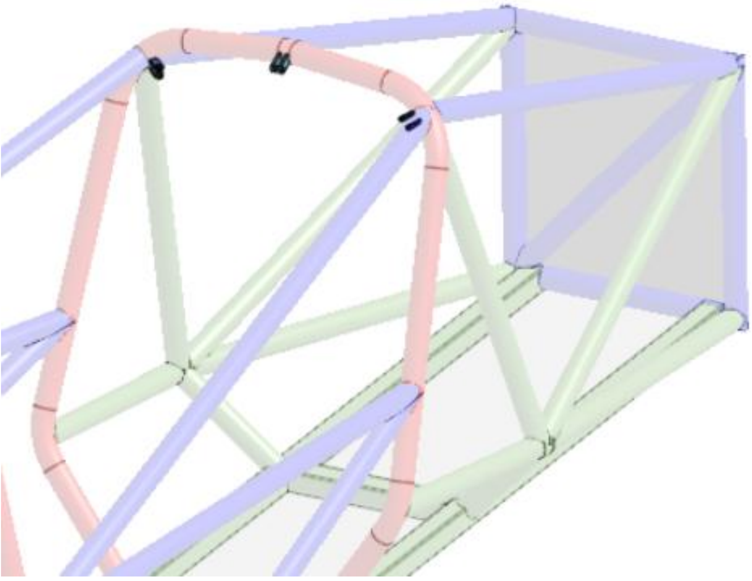


Figure 168. Steering Clevis Tabs

Upon removing the third Centre Support as its position was not feasible as the DEN could not move, there was a concern of the rigidity of the mounting system, owing to the stack up of bolts and clevises, and the lower Young's Modulus of aluminium when compared to steel. Due to this the Support Arms were changed to steel and were instead welded to the Chassis. This would lower part count and massively reduce manufacture complexity and assembly complexity owing to the clocking (angle) of the clevises to allow easy removal and installation of the Steering Gearbox. As a result of this change, no manufacturing drawings were ever made for the two steel Support Arms. The Prototyping Workshop, who had already begun manufacturing, instead used the CAD to manufacture the Support Arms. As the angle of the Support Arms to Front Hoop did not change, the Mounting Plate welding drawings were still utilised.

The Keyed Flange had some excess material removed as there only a bearing lip surface was required shown in Figure 169. This removal of material does increase the torsional load at the end of the flange but was negligible. This is shown in section in section 4.1.

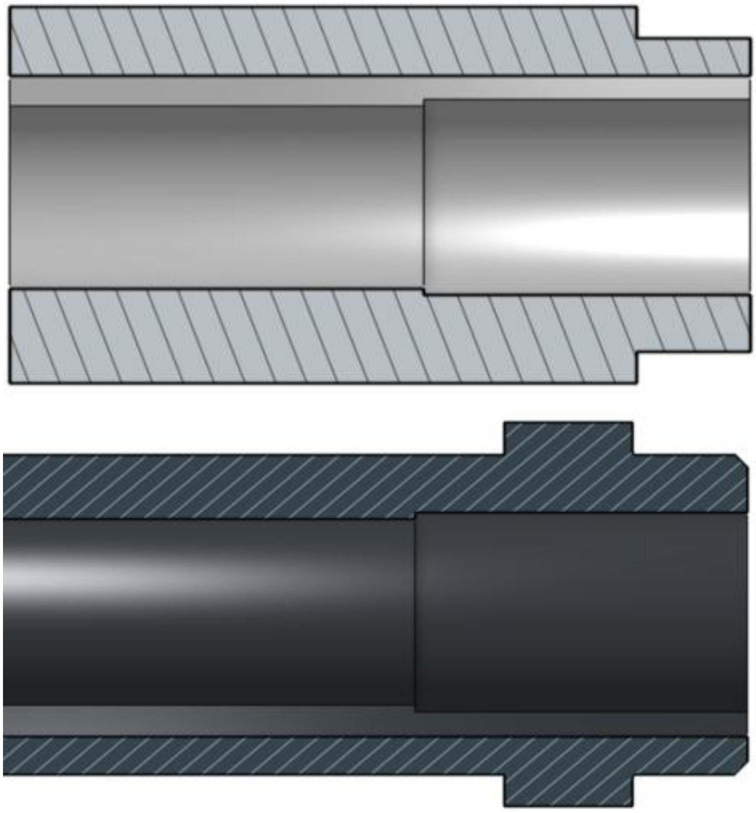


Figure 169. Changes to the Keyed Flange

4.1. Design Validation

Prior to preparation to manufacture of the steering system, design validation was carried out to ensure the viability of the design provided by Drew Bender. This was carried out as a combination of Finite Element Analysis (FEA) and hand calculations.

Hand calculations were mostly used to validate designs. Due to the similar castor, KPI, scrub radius and mechanical trail, the author assumed the steering of NU 24 would experience similar forces compared to NU 23. The changes in these values are shown in Table 7.

Table 7. Changes in KPI, Scrub Radius, Castor, Mechanical Trail from NU 23 to NU 24

Static Values	**Front Suspension NU 23**	**Front Suspension NU 24**	**Rear Suspension NU 23**	**Rear Suspension NU 24**
KPI [degrees]	9	9.2	6.7	5.8
Scrub Radius [mm]	32.5	47	47	44.9
Castor [degrees]	5.3	6	N/A	N/A
Mechanical Trail [mm]	17	18	N/A	N/A

In early 2024 there was no data on the steering torque load. Due to this the author had to assume a load condition to evaluate the stress in each part. An estimate of 50 Nm was used referencing Drew Bender's estimation [1]. The hand calculations are shown in 11.1 Appendix A - Steering Hand Calculations. None of steering assembly were near their limit, with the lowest safety factor being 2.

Due to the limited track time in 2024, the actual steering load is not known. Strain Gauges should be placed on the Tie Rods for a day of hard driving to estimate steering loads. This will allow more accurate design decisions. If it is advised that the loads in the steering are less than the estimate for steering torque, then parts are being overbuilt. Overbuilt steering parts can be a good thing, as weak steering systems, especially Tie Rods, are prone to snapping due to collisions or large impacts from the road, such as potholes.

FEA was completed on the Steering Support Arm Mounts. This was problematic as the model for the steering mounts had cutouts to ease manufacture. This means that the Support Arm and

Mounting Plate were not intersecting consistently which create high stress concentrations in the results. Due to this the FEA was not trusted. The Steering Gearbox was included in the FEA as it is just a solid model. This will not accurately define the body but give an insight into the stress distribution of the mounts. The interacting surface of the Mounting Plate to the Gearbox was given a No Separation contact, and beam models used to represent bolts. The load case was selected to compare to the EV.Three Steering System, which was tested by 30 kg of force in the longitudinal and vertical directions. It should be noted that these values are likely excessive. The set up for the FEA is shown in Figure 170 and the results are shown in Figure 171.

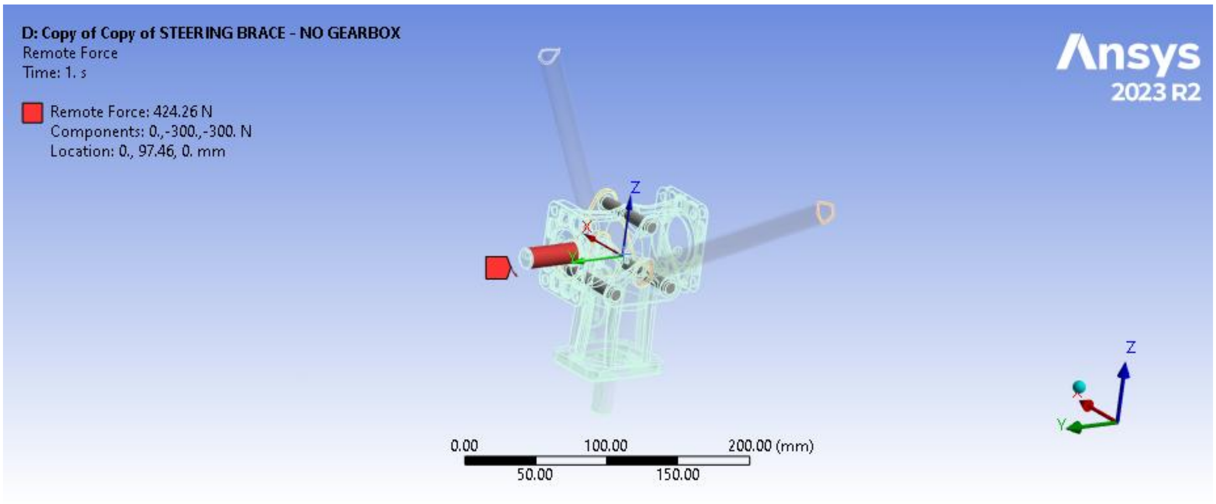


Figure 170. Support Arm FEA Setup

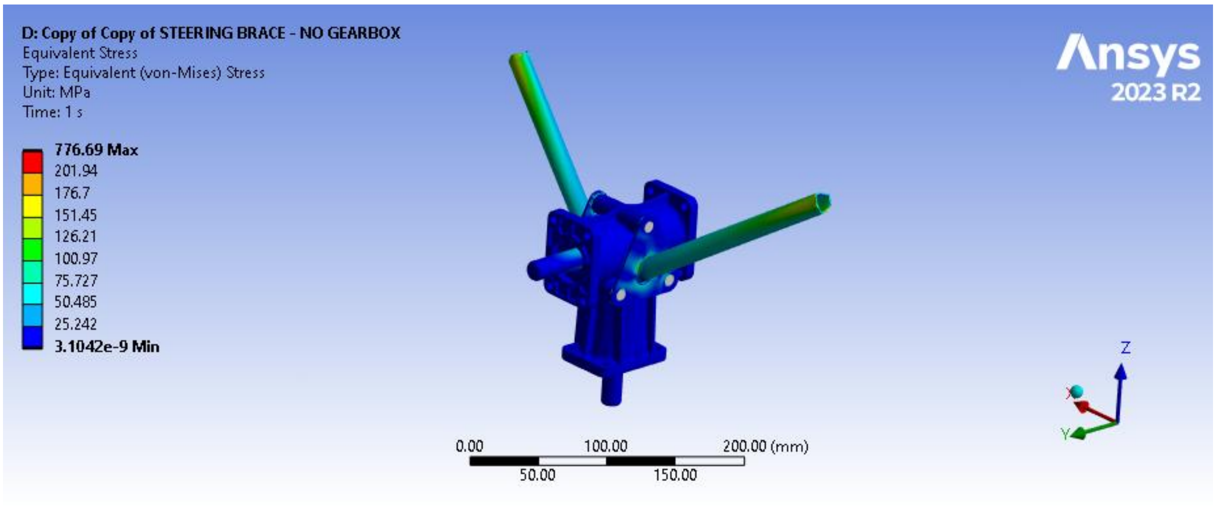


Figure 171. Support Arm FEA Results

It should be noted that the scale for the results in Figure 171 was adjusted to show the stress distribution contour. As the stress concentrations were so high the maximum stress was 776 MPa.

4.2. Manufacturing

The manufacturing process incredibly simple and endured no setbacks thanks to the Prototyping Workshop. The manufacturing drawings are shown in 11.2 Appendix B – Steering Manufacture Drawings. It should be noted that these drawings were the first the author created, and many details, such as the bearing tolerances, that would be done differently if redone.

The only change that occurred during manufacture was the change from aluminium Support Arms to steel. Outside of this every was manufactured easily.

The Tie Rods and Steering Wheel Shaft were made from Ø16 x 1.6 mm Chromoly Steel. This was left over from a previous Chassis order. The Tie Rod hexagonal ends were welded into the Tie Rod tubes before drilling and tapping to avoid distortion in the threads.

The Bearing Block was a success, weighing in at just 156 g. This is shown in Figure 172.

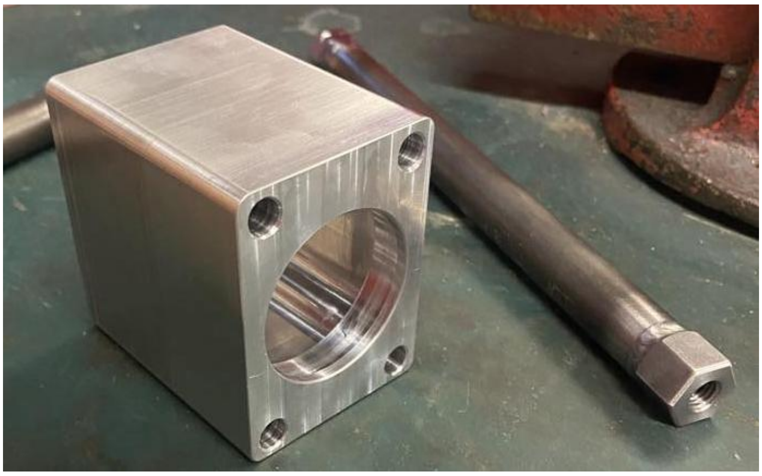


Figure 172. Manufactured Bearing Block and Tie Rod

Following the manufacture and weldment of the Steering Wheel Shaft, Steering Rack Shaft, and the Rack Shim the Support Arms could be welded in. The Steering Rack and Gearbox were assembled in the Chassis. MIG wire was then used to restraint the Steering Column assembly before it was welded in situ. The setup is shown in Figure 173 and the welded Support Arms in Figure 174.

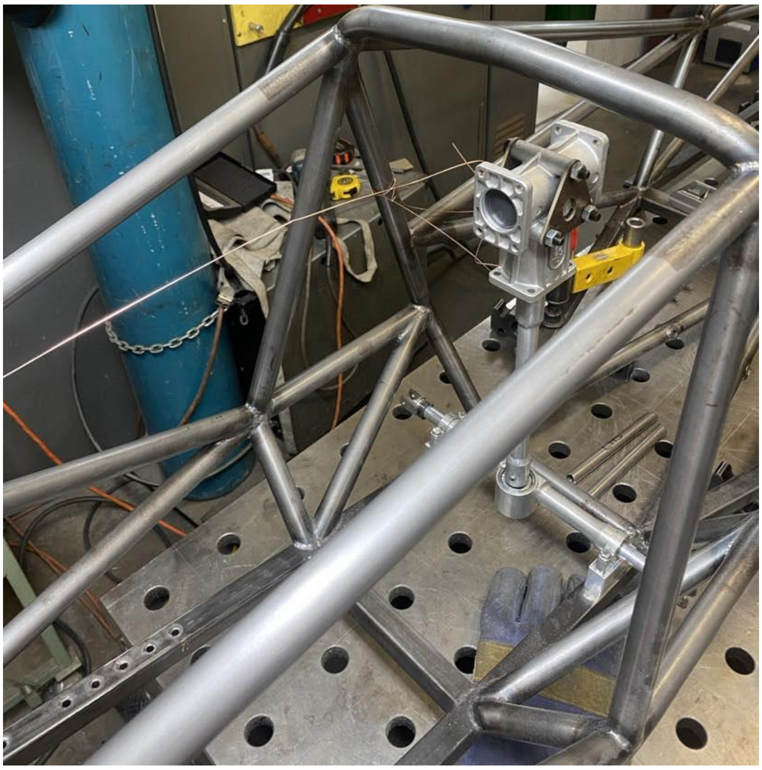


Figure 173. Support Arm Weldment Setup

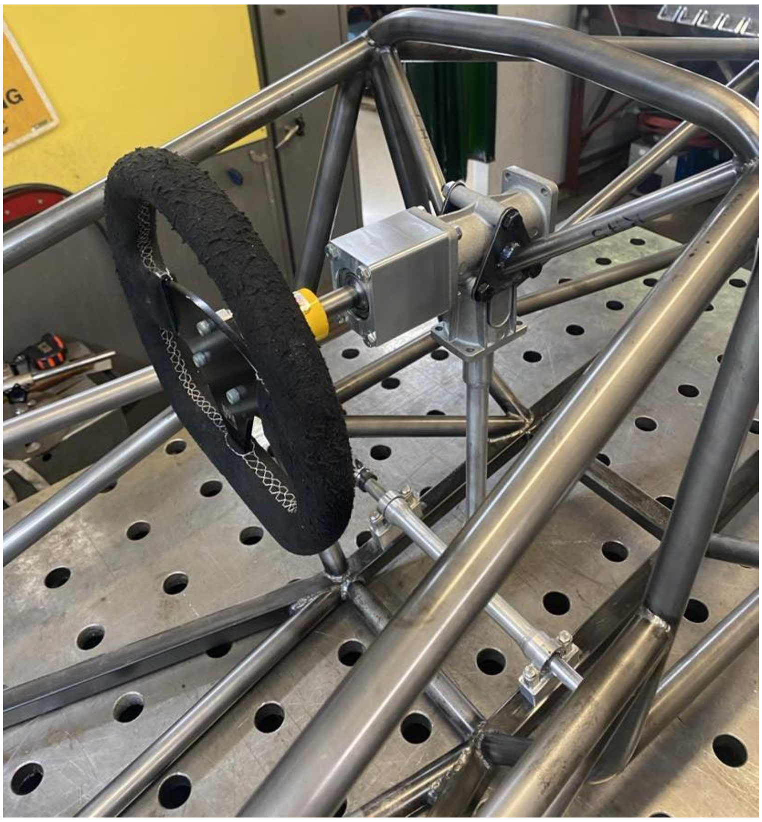


Figure 174. Assembled Steering in the Chassis

It should be noted that the Quick Release Shaft was welded last. This allowed the machinist to verify that the Steering Wheel angle lined up with the Steering Rack being in its neutral position.

The Steering was completed and as such removed until the Chassis and Suspension were returned from the Prototyping Workshop following manufacture. On June 7th NU Racing had a rolling Chassis as shown in Figure 175.

Figure 175. NU 24 as a Rolling Chassis

5. Track Layouts

NU Racing completes track days at SMSP and at the University of Newcastle's ICT Carpark.

5.1. SMSP

At SMSP there are two tracks that NU Racing can book, the Skid Circuit and the Figure 8 Circuit. The Skid Circuit is by far the most valuable track. SMSP is where major testing is completed and where all vehicle setup physical testing occurs.

5.1.1. Skid Circuit

The Skid Circuit at SMSP is a large open concrete track (150 m × 60 m) that allows for testing for each dynamic event. It is long enough that Acceleration runs can be completed comfortably. There is more than enough space to set up Skid Pad. Due to its size Autocross can be set up to include high speed sections to imitate competition (Three sections > 85 km/h). Endurance runs can be completed on the same setup as Endurance.

For Autocross and Endurance testing on the Skid Circuit in 2024 the track made by 2023 Chief Engineer, Jye Hollier, was used [3]. This is shown in Figure 176.

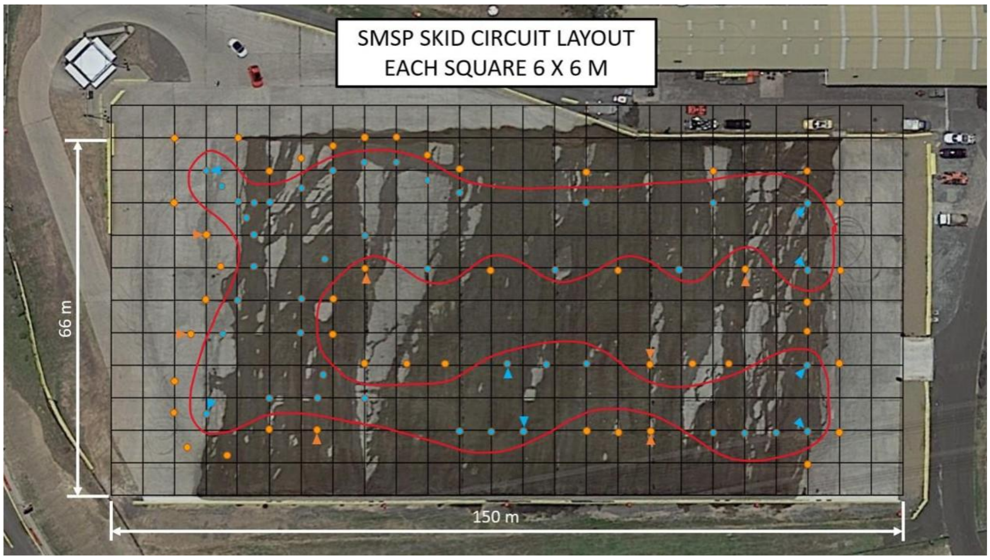


Figure 176. Skid Circuit Track Layout [3]

5.1.2. Figure 8 Circuit

The Figure 8 Circuit at SMSP is much less useful. Skid Pad and Acceleration cannot be practised at this track. Autocross can be practised, however there is only one high-speed section (max speed 83 km/h), and the Autocross pace is not incredibly faster than an Endurance run on this track (30.54 s lap compared to 33 s lap for Endurance). Due to poor booking by NU Racing this was the circuit NU Racing used the most in 2024.

As this track as never been utilised by NU Racing before for testing, as the Skid Circuit is preferred, the author created a track layout. This is shown in Figure 177.

Figure 177. Figure 8 Circuit Layout

When creating a track layout, it is vital to minimise risk where possible. Adding features to the track that slow the driver down before approaching walls and the pits is one method to accomplish this. On the far left of the Figure 8 Circuit, which is driven clockwise, there is a long concrete barrier, and as such the author added slaloms in the middle of the previous corner to reduce the speed carried towards the wall.

5.2. ICT Carpark

The ICT Carpark on campus is primarily used for vehicle shakedowns after an electrical change or upgrade. If there is a failure, the proximity to TA allows the team to take the car back to the workshop, or to easily grabs tools and equipment to fix the issue.

Jye Hollier also designed the track for ICT and is shown in Figure 178.

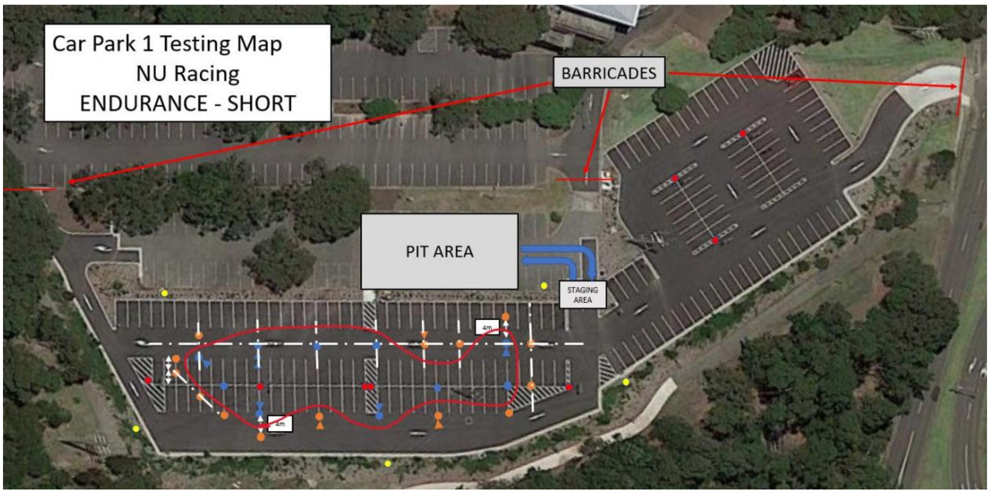


Figure 178. ICT Carpark Track Layout

Due to the small size of the track, only Endurance simulations can be completed at ICT.

6. Physical Testing

As track time was limited in 2024 due to the failure of the CM200DZ Motor Controller which limited available track time to two months. Due to the large volume of commission and testing of different PCB’s and Electrical Nodes on NU 24, the time for Physical Testing to gain understanding of and tune NU 24’s Suspension was extremely limited. As a result of the year, only two track days were dedicated for testing and tuning. They were as follows:

- Test Day 1 – November 7th, 2024
  - Spring Rate testing
  - Completed with Autocross driving
- Test Day 2 – November 11th, 2024
  - Static Camber Requirement, Tyre Pressure testing
  - Completed with Skid Pad driving

The limit of track days affected the ability to develop an understanding of change over multiple track days and meant that results of testing were not as controlled as they should have been. Tyre life, weather, and track condition all largely impacted the testing and without repeated tests it was hard to gauge definitive change. Tyre life especially had a large effect. If a tyre was near the end of its lifespan, it would not create any lateral grip. The age of a tyre should always be recorded.

Amongst other track days changes to the low and high-speed compression of the Ohlins MKII TTX25 dampers were made. Both low and high speed were turned clockwise ¼ turn from the values that are written on the dampers. This decreased the rate of compression, especially under braking and made NU 24 feel more controlled under braking.

6.1. Spring Rate Testing

To test the spring rates of NU 24 the plan was to run different spring configurations between two experienced drivers completing Autocross laps, measure each lap, and the driver feedback. The run plan is shown in Table 8.

Table 8. Run Plan for Spring Rate Testing

Run Plan	**Front Spring Stiffness [lb/inch]**	**Rear Spring Stiffness [lb/inch]**
1st Run	450	450
2nd Run	650	650
3rd Run	450	650

It should be noted that the track day was rained out. The full plan included 650 lb/inch front and 450 lb/inch rear.

6.1.1. First Run

The first run, 450 lb/inch front and rear, was completed and the times shown in Table 9.

Table 9. Spring Test First Run

Lap Number	Driver 1	Driver 2
1	33.352	32.08
2	32.202	31.402
3	32.144	31.318
4	32.644	30.672
5	33.132	
Average	32.6948	31.368

Both drivers noted that the car was understeer prominent. No other notes were made by either driver.

6.1.2. Second Run

The second run was completed, 650 lb/inch front and rear, and the times shown in Table 10.

Table 10. Spring Test Second Run

Lap Number	Driver 1	Driver 2
1	33.353	31.964
2	32.735	32.106
3	32.417	31.415
4	32.159	31.074
5	33.294	32.102
6	32.675	-
Average	32.77217	31.7322

Both drivers disliked this spring rate configuration. They described the car feeling skittish and hard to trust. There was visible oversteer in the slaloms of the track.

6.1.3. Third Run

The third run was completed, 450 lb/inch front and 650 lb/inch rear, and the times shown in

Table 11. Spring Test Third Run

Lap Number	Driver 1	Driver 2
1	32.379	30.716
2	31.435	30.182
3	-	29.832
Average	31.907	30.24333

Driver 1 stated he felt a difference but felt neutral about it, however this was when the rain began so he didn't get another lap in. Driver 2 loved the setup, stating that the car felt pointy and willing to commit to corners. Their lap times reflected this.

6.1.4. Setup Performance and Discussion

The average lap time from each configuration is shown in Table 12, showing that the 450 lb/inch front and 650 lb/inch rear was almost a second faster than its alternates.

Table 12. Spring Rate Configuration Lap Time Average

Spring Rate Configuration	450 lb/inch F&R	650 lb/inch F&R	450 lb/inch F, 650 lb/inch R
Average Time	32.0314	32.2522	31.0752

It should be noted that there was time left between each run to attempt to let the tyres cool down.

The massive difference in average lap time reflected the feedback given from the drivers and the confidence this configuration gave them.

The reason that the 450 lb/inch front and 650 lb/inch rear setup worked so well mainly lies in the fact that NU 24 has a locked rear axle. Because of this in corners the inside rear wheel is still travelling at the same speed as the outer wheel, which pushes the front axle through the corner, generating understeer. The stiffer springs on the rear axle change the load transfer distribution between the rear tyres. As the stiffer springs do not comply, the load will travel to the outside wheel. Because of this the rear inside wheel loses normal force (F_z) and capacity to generate longitudinal force (F_x). This means that is has less ability to push the car through the corner, reducing understeer. Another effect of this is because the inside rear is unloaded, the front axle gains some of the load distribution. This means that there is more normal force (Fz) which give both front tyres the ability to generate more lateral force (F_y) for a given slip angle and overall yaw.

If more Skid Pad time it would have been beneficial to test these spring rates in this event as well. The spring rates have a large impact on the event due to its ‘steady state’ characteristics, especially due to the final set up picking up the inside wheel which would massively reduce understeer.

Due to these results the 450 lb/inch front and 650 lb/inch rear setup was used for the rest of the year.

6.2. Static Camber Testing

The second testing day consisted of changing the static camber of NU 24 to accommodate for camber gain. This was done during Skid Pad testing as it allowed for easily repeatable drives, the tyres to work at semi steady state, and quick timing between changes.

NU 24 makes use of camber shims to change the static camber of each wheel individually. Removing these shims adds negative camber, whilst adding the shims adds positive camber. A camber plate is shown in Figure 179. These come in two sizes, 6 mm shims and 1.6 mm, and give 0.5° and 2° of camber reduction respectively [16].

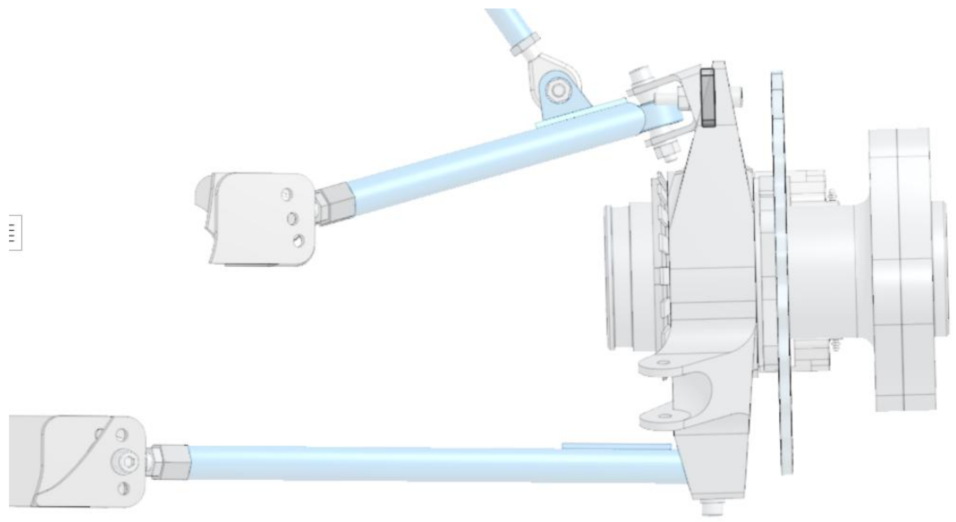


Figure 179. 6 mm Camber Shim

As camber gain occurs during roll, bump, and steering, negative camber is required such that the tyre never goes into positive camber during driving. The result of this is that the camber approaches neutral for the outside wheels during cornering, where more lateral force is desired.

In an ideal world static camber testing during Autocross runs would also be completed. This would allow an indication of the camber gain generated due to the different driving style.

During Skid Pad 2 g’s of lateral acceleration were generated by NU 24.

Gathering temperature data of the surface of the tyre during a driving event can give estimates of the size of the contact patch of the tyre. To achieve maximum lateral and longitudinal forces we need to use as much of the tyre as possible (this is always true but is very general). Temperature distributions can show the area of the tyre being used throughout a race run.

As NU Racing does not have access to infrared tyre temperature sensors, such as the Izz Racing Sensors that connect to CAN and capture live data of tyre temperatures [47], a FLIR Thermal Imaging gun is used. This is not ideal as it allows the tyres to cool before gathering data and shows an average of the tyre temperatures (imagine a car turning left then right repeatedly then looking at the tyre temps). This is not great practise but is limited due to budget and time.

The spreadsheet shown in Figure 180 shows for each driver the setup change, feedback, comments, and average lap times. This resource was made after the Spring Rate Testing and only used for the camber testing.

Timing, Feedback, and Setup Sheet - Skid Pan

Date Revised: 8/11/24

Driver	Date	Change	Feedback	Scale (from 1-1	Average Lap Time	Fastest Lap	Cone Strikes
Alec	11/11/2024	Front -1.5 rear -1	No Comment	No Scale	5.57		1
Alec	11/11/2024	front -1 rear -0.5	Added 1 small camber plate to each corner		5.3		0
Alec	11/11/2024	front -0.5 rear 0	Added 2 small camber plates to each corner		5.55		1
Fisher	11/11/2024	Front -1.5 rear -1	No Comment		5.41		0
Fisher	11/11/2024	front -1 rear -0.5	Added 1 small camber plate to each corner		5.27		0
Fisher	11/11/2024	front -0.5 rear 0	Added 2 small camber plates to each corner		5.26		0
Timothy	11/11/2024	Front -1.5 rear -1	No Comment		5.57		0
Timothy	11/11/2024	front -1 rear -0.5	Added 1 small camber plate to each corner		5.59		0
Timothy	11/11/2024	front -0.5 rear 0	Added 2 small camber plates to each corner		5.37		3
Cam	11/11/2024	Front -1.5 rear -1	No Data				1
Cam	11/11/2024	front -1 rear -0.5	Added 1 small camber plate to each corner		5.44		1
Cam	11/11/2024	front -0.5 rear 0	Added 2 small camber plates to each corner		5.49		1?

Averages - Set Up

Setup	Average Feedback	Average Scale	Average Lap
No Shim			5.516666667
1 Shim			5.4
2 Shim			5.4175

Averages - Driver

Driver	Setup	Average Feedback	Average Scale	Average Lap
Alec				5.47
Fisher				5.31
Timothy				5.51
Cam				5.47

Figure 180. Setup and Feedback Sheet

The initial setup of NU 24 was -1.5 ° for the front wheels and -1 ° for the rear wheels. Drivers were sent out and completed Skid Pad laps, taking minimum 30 seconds between attempts. After each driver, of which there were 4, the camber was reduced by 0.5 ° using small chamber shims. The average times for each setup are shown in Figure 180. It must be noted both laps per circle (left and right) are used to calculate the average. This is not ideal but is due to the limitations of MoTeC i2. The author was able to make the formula shown in Figure 181 to calculate average Skid Pad laps.

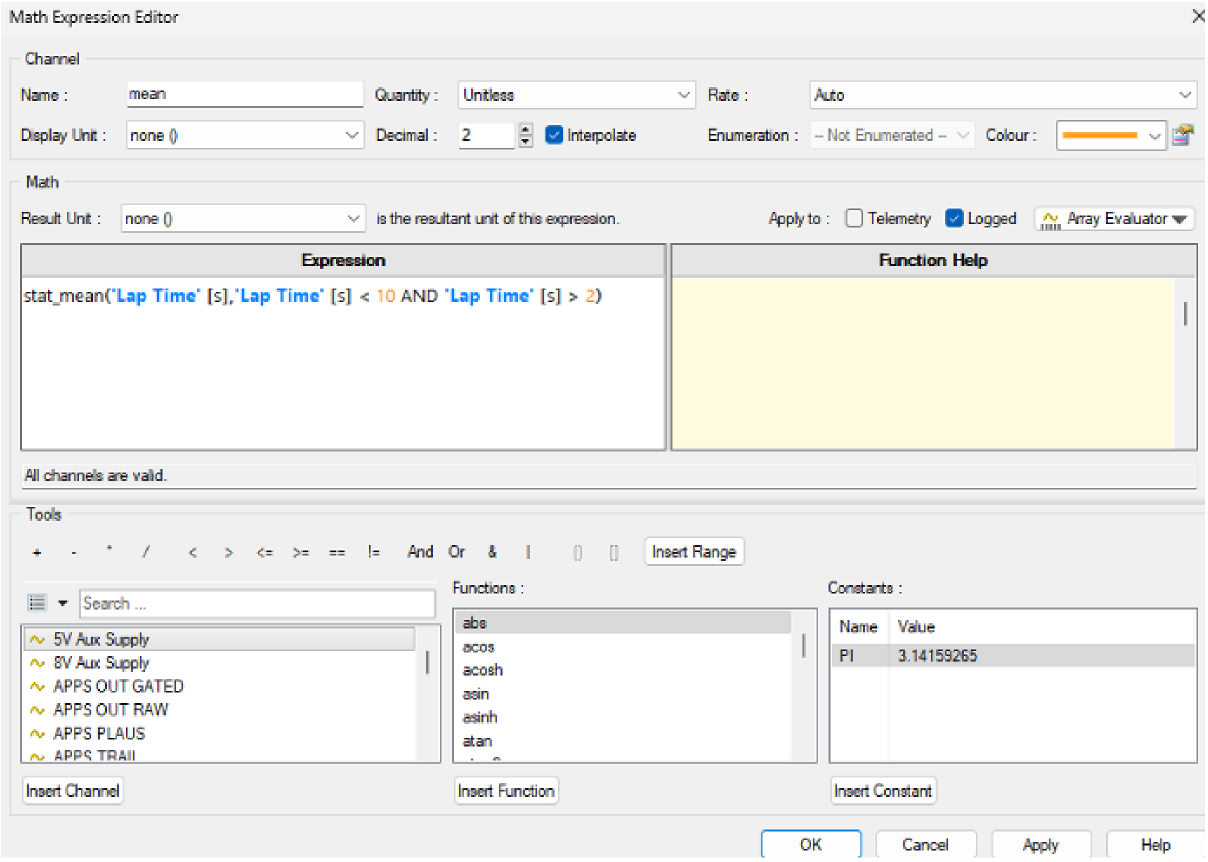


Figure 181. Skid Pad Average Lap Time Formula for MoTeC i2

The lap time data shows that the second set up with the front camber at -1° and rear at -0.5° was the fastest setup.

Drivers Alec, Timothy, and Fisher all thought that the second set up was the easiest and felt the fastest to drive. The first felt slow to get the car onto the limit, and the last felt like it overtook the limit. The Last driver Cam, who missed the first run, thought that the last set up was the best, despite his times not reflecting this.

The thermal imaging data did show some useful data but could often have lapses of usefulness. This is again attributed to this not truly capturing the live data. Figure 182 shows the migration of the temperature distribution of the front left tyre due to static camber changes. When there is lots of negative camber is heats the inside edge of the tyre, similarly for positive camber heating the outside of the tyre. It can be seen that temperature goes from the inside of the tyre to the outside of the tyre as the static camber changes.

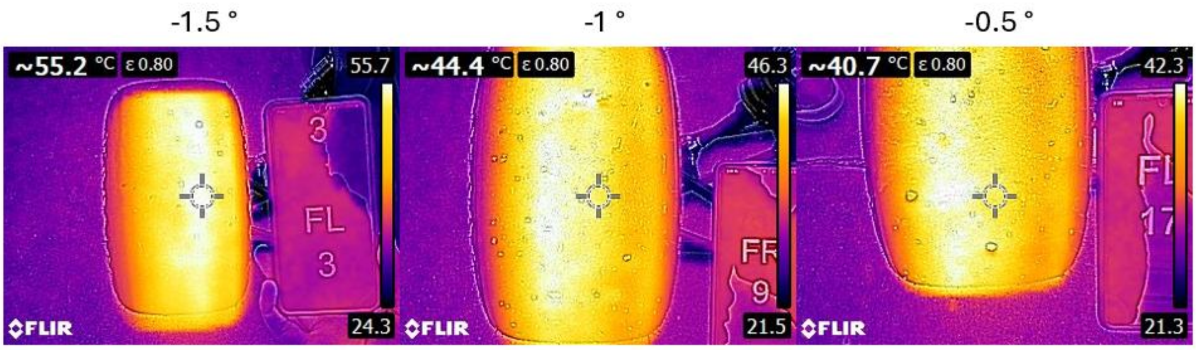


Figure 182. Migration of Temperature due to Static Camber Changes

Images of each tyre were taken twice per run per driver. These images were used to validate lap times and give insight into what was happening to each tyre.

As this was the only day dedicated to static camber testing, the author was not able to test the adjusting camber front to rear (i.e. only changing the number of camber shims to the rear or the front). It is not known if this would have generated a large difference.

Due to the results in Figure 180, the static camber run at for the rest of the year was -1° front and -0.5° rear.

6.3. Untested Parameters

Due to the time lost testing the following parameters never had dedicated testing completed:

- Static Toe
- Tyre Pressures
- Ride Height

These can all have a large impact on the characteristics of a car, especially ride height. Not being able to thoroughly test these was a huge loss.

Static Toe was not sufficiently tested, as such it was not used at competition and the toe across the front and rear was 0. This means that tyres were aligned straight.

Tyre pressures were left at 14 psi all year. Dedicated tyre temperature testing would have provided an idea of if this pressure was too high or too low.

Ride height was changed, but did not undergo testing. The ride height was set as low as it could be without the Accumulator Mounting Bolts hitting the ground, as these are the lowest part of the primary structure as shown in Figure 77. Changing the mounting for the Accumulator will allow future vehicles to be run lower and tested effectively. This will not occur in 2025 as the Accumulator from NU 24 is being reused.

7. Tyre Data

Tyre data refers to the data provided by the Tyre Testing Consortium (TTC) that provides values for FSAE tyre forces dependent on different conditions such as normal force, slip angle, camber etc. This allows the use of the data to influence the design of the suspension, and aid vehicle set up and optimisation. This data is available to universities which have paid a once off fee (which NU Racing has) and allows for unlimited accounts to be made to view the data.

Due to the large change in scope of the author during 2024, tyre data was never utilised. Contrary to the belief of the 2023 team, there recorded tyre data for the Hoosier LC0 tyre in our size. Utilising this will be able to give an insight into the performance capabilities of the tyre and how it can be utilised.

The author managed to create a MATLAB script, based off the work of Matt Reggers [13], that separates the data and can plot it depending on different conditions. This script is available on the NU Racing GitHub and should be utilised and improved upon. The script is also shown in 11.3 Appendix C – TTC Tyre Data MATLAB Script. Matt Reggers report should also be referenced to understand the script [13]. An example plot is shown in Figure 183.

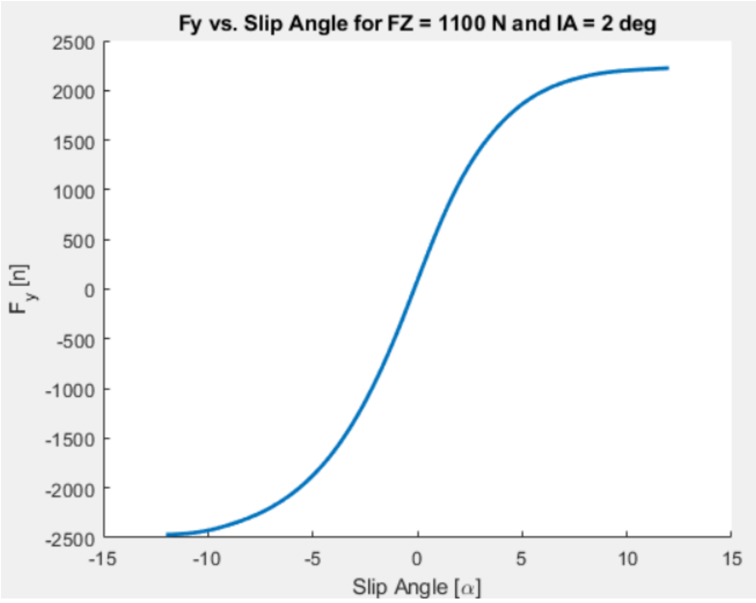


Figure 183. Example Tyre Data for the Hoosier LC0 16x7.5x10

8. Data Management

It is critical for the Vehicle Dynamics Engineer to be able to accurately gather data and driver feedback to effectively make decisions. Detailed spreadsheets indicating setup changes, driver feedback, lap times, and MoTeC data is vital to this. Without measuring change, knowing what is positively or negatively effecting the handling of the car is near impossible. An example of a spreadsheet made by the author is in Figure 180.

Another important step is to ensure that MoTeC i2 data reflects the setup changes as well. When reviewing data in 2024 it became clear that the author was not informing the dedicated data engineer of what descriptions to put into the log files. This makes reviewing of data much more difficult. Regular data logging is also recommended to ease confusion.

9. Competition Performance

9.1. Design Event

The first job at competition for the Vehicle Dynamics Engineer was to complete the Design Event. This is where you have one hour to present NU 24 to a panel of judges and explain the design process and decisions that culminated in NU 24. The Design Event is broken up into different categories and is worth 150 competition points.

The author, along with junior member Cooper Chomicki, completed the Vehicle Performance part of the Design Event.

The event went extremely well with the points from Vehicle Performance shown in Figure 184.

Points Available	Points Scored	Good	Needs improvement
30	24.9	Terrific understanding of the fundamentals of vehicle dynamics when working with limited resources and budget. Great emphasis on utilisation of key mechanical parameters that led to an effective use of testing time	Not much simulation driving design selection (doesn't necessarily need to be complex or off the shelf with one million settings. Basic parameter sensitivity analysis needs to be completed to evaluate the car in competition conditions i.e. all events.

Figure 184. Vehicle Performance Design Event Score and Feedback

It also showed the author that simulation needs to be used more by NU Racing. The author received the email address of the design judge who said they would be more than happy to assist with where to start with vehicle simulations (2025 member should reach out to the author). It is highly recommended that prior to this a good understanding of Vehicle Dynamic concept is achieved.

The Design Event Booklet created by the author is shown in 11.4 Appendix D – Design Event Booklet.

9.2. Vehicle Setup

The setup for NU 24 for competition is shown in Table 13. This was only changed for Acceleration where the front tyre pressures were changed to 20 psi to reduce rolling resistance.

Table 13. NU 24 Setup Prior to Competition

Setup Parameter	Value
Static Camber Front (°)	-1
Static Camber Rear (°)	-0.5
Tyre Pressure (psi)	14
Spring Stiffness Front (lb/inch)	450
Spring Stiffness Rear (lb/inch)	650
Ride Height (mm)	39
Static Toe Front and Rear (mm)	0

9.3. Prior to Each Event

Before each event the tyre pressures were checked and ensured to be 14 psi. The team members operating the push bar throughout competition were told to carry a rag and clean the tyres at the gate before the vehicle drove off. This is incredibly important for Skid Pad, Acceleration, and Autocross as there will be so much grip lost over a short run.

9.4. Skid Pad

The Skid Pad track was declared a damp track, which meant it was up to each team what tyre compound was used. Due to the standing water on the track NU Racing elected to use their wet tyres for the first driver. The wet tyres were from 2022, and as racing tyres do, were dry rotted and not effective in the slightest. New wet tyres were desired, but due to budget cuts was not purchased (cost for four tyres is approximately $2000). This greatly hampered the effectiveness of the first driver as a respectable time was sincerely not possible.

Due to this it was immediately decided that the second driver would drive on dry tyres. The track was still wet in places and made the drive quite challenging. NU 24 noticeably had very little grip. The driver was able to place the car on the podium at the end of the run, but as discussed in 12.2.1 Skid Pad in the Chief Mechanical Engineer report, the team finished ninth with every team that was faster than the second driver competing after them in dryer conditions.

The driver times are shown in Table 14.

Table 14. NU 24 Skid Pad Competition Times

Driver	Run 1	Run 2
1st	6.58035	6.80095
2nd	5.7538	5.61245

It should be noted that fastest run for NU 23 in completely dry weather was only 0.3 s faster than the time recorded by NU 24.

This was a harsh blow to the team, as testing times had indicated a time of 5.25 s was easily achievable. During testing the second driver had an average time, including the first laps for each circle (which are slower and not counted), of 5.26 s. This time would have placed the team second in Skid Pad. Measured times as low as 5.18 s were measured in the limited two track days that the 2nd driver drove the event.

The failure to not have wet tyres, and bad luck, resulted in a massive point loss in the event.

9.5. Acceleration

Acceleration was a huge win. The times are shown in

Table 15.

Table 15. NU 24 Acceleration Competition Times

Driver	Run 1	Run 2

1	4.159	3.9677
2	3.9397	4.1008

The Drivetrain changes and weight loss of over 20 kg are key to these results.

Having neutral front and rear static toe assisted in this event. Any value of toe would have caused more rolling resistance, which is not desirable in this event. The only concern this causes is toe can help with straight line stability, but with no issues from the drivers throughout testing and the event it was left as neutral.

Increasing the front tyre pressures to 20 psi also reduced the rolling resistance of the front tyres, which are not driven.

9.6. Autocross

Only one run was completed of Autocross due to an AMS fault. Due to this it is hard to quantify how many points we expected to gain. It was known that for the second run of the first driver, they were up approximately 3 seconds according to the data engineer on their initial time through only halfway through the lap. If this lap was finished, only being 3 seconds faster, NU 24 would have been the 4th fastest EV of the 1st drivers as shown by Table 16.

Table 16. 2024 1st Driver Autocross Times

Team	Run 1	Run 3	Fastest Lap
Auckland EV	01:39.0	01:35.3	01:35.3
Curtain EV	01:39.9	01:37.7	01:37.7
Monash EV	01:47.4	01:38.0	01:38.0
Western Australia EV	01:51.8	01:44.6	01:44.6
New South Wales EV	01:52.7	01:45.5	01:45.5
Newcastle EV	01:45.7	-	01:45.7
Queensland EV	02:03.4	01:46.2	01:46.2
Wollongong EV	02:02.1	01:46.4	01:46.4
RMIT EV	02:03.6	01:49.5	01:49.5
Adelaide EV	01:58.6	02:02.1	01:58.6
Taipei EV	02:06.7	02:03.6	02:03.6
ANU IC	02:39.2	02:12.3	02:12.3
Griffith EV	03:13.0	-	03:13.0

Our second driver, who had driven Autocross in 2023 and 2022 was notably quicker than the first driver and a faster time would have been expected.

As Autocross results are hard to replicate due to the track layout. As such the true Autocross pace of NU 24 will never be known.

The first driver noted that the lap was especially damp and lacked any grip, this is clearly visible on the GoPro footage. By the time the second drivers had went out the track had notably gotten dryer, and most teams made large improvements in lap time, some teams up to 10 seconds, but most around. This however cannot be attributed to just the track as the second driver is usually the fastest.

9.7. Endurance

Endurance gave a glimpse of the speed of NU 24. The lap times of both drivers are shown in Table 17. This shows that both drivers had times faster than the Autocross fastest time. This is mostly due to track condition and temperature. The Autocross track in the morning was greasy and damp, whereas for Endurance it was hot and very dry.

Table 17. NU 24 Endurance Competition Lap Times

Times (Driver 1)	01:51.8	01:49.2	01:46.6	01:44.3	01:43.5	01:43.4	01:44.3	01:44.0	01:43.3
Times (Driver 2)	01:50.2	01:47.0	01:43.2	01:41.6	01:41.9	02:09.6	01:41.2	01:40.9	01:42.1

Both drivers drove incredibly well and consistently. The author, the second driver, claims the Spring Stiffness configuration was vital during this drive as it allowed the car to be driven quickly through slaloms due to the front-end grip, without needing to brake and waste energy, which affects the Efficiency score.

10. Conclusions and Recommendations

The vehicle setup on NU 24, whilst not having the points from Skid Pad and Autocross, proved that it was balanced for all four dynamic events. The blistering Acceleration run paired with the consistent high pace of the Endurance lap times shows that NU 24 was predictable and fast.

A lack of dedicated track days to study setup changes hampered the year. It is unknown if the setup NU 24 ran at competition was its fastest version, however it was very clear that it was the fastest version based on the testing completed.

In 2025 NU 24 must be thoroughly studied through changing setups. All parameters of the Suspension are connected, and everything is a compromise. Spending track days just making deliberate and measured changes to gather data will prove vital once testing for NU 25 commences. This is especially important as static geometry values of the Suspension will be that same as NU 24.

The Skid Circuit at SMSP must be booked early in the year. In 2024 this did not happen and as such there were only three track days where Skid Pad was completed. The circuit also allows for genuine, high-speed Autocross runs when compared to the Figure 8 Circuit. The Skid Circuit is beyond integral to NU Racing testing.

Place linear potentiometers on each coilover (shock pots). This will allow the data gathering of wheel loads and a ride height estimate of each corner. For two years these have been given to a NU Racing member and not completed. They need to be used in 2025 as it is such an easy method to gather more data that will affect setup decisions. A steering angle sensor will allow for the comparison of drivers for the purpose of selection and should be used as well.

Feedback from the design event was that NU Racing must begin to use simulations to make design decisions. Decisions such as the change in track, wheelbase, and weight. A point mass simulation is suggested as the starting point.

Utilise tyre data. The script provided by the author works and is ready to be utilised. Evolve the script and use the data to attempt to make connections between real life and the data, especially if used in conjunction with shock pots. If utilised correctly it will also allow for the creation of a tyre model (such as a Pacejka model) which will allow further simulation.

To gain a thorough understanding of Vehicle Dynamics read Race Car Design by Derek Seward and Race Car Vehicle Dynamics by Milliken and Milliken. They are a great starting point. It will give the reader the ability to calculate ride and roll rates, which can help calculating roll and wheel weights of the car. This will assist in effectively using tyre data.

If the budget allows purchase infrared tyre temperature sensor, such as the Izze Racing ones [47], that allow for live data collection on tyre temperatures. This will greatly help to understand the temperature distribution over the tyre surface during driving and help make educated decisions when selecting the tyre pressures and static camber.

The author hopes that 2025 has a dedicated Vehicle Dynamics Engineer that wants to make NU 25 the fastest car that NU Racing has ever built. Dedicate time to understanding key concepts and how parameters all affect each other. Dedicate the most time to physical testing, organise your data, listen to the driver feedback, look at the lap times, and make well informed decisions. Use simulation more than NU Racing ever has.

11. Appendix

11.1. Appendix A - Steering Hand Calculations

Steering Wheel Shaft

Parameters		
D	16	mm
d	12.8	mm
T	50	Nm
Totals		
J	3798.622828	mm^4
r	8	mm
τ	105.3013205	Mpa

Yield Strength of Mild Steel

350 Mpa

203

Safety Factor

1.93

Steering Rack Shaft

Parameters		
D	19	mm
d	12.6	mm
T	50	Nm
Totals		
J	10319.7649	mm^4
r	9.5	mm
τ	46.0281802	Mpa

Yield Strength of 6061 T6

240 MPa

139.2 MPa

Safety Factor

3.02

.

Keyed Shaft

Parameters		Units		Ixx	15965.073	Units		Iyy	16669.9089	Units
D	25	mm		Area total	304.65	mm^2		Area total	304.7	mm^2
d	15	mm		ΣAi * yi	3727.86	mm^3		ΣAi * yi	3808.2	mm^3
b	5	mm		ybar	12.2364	mm		ybar	12.5	mm
c	1.901	mm								
Torque	50	Nm		I_pipe	16689.71	mm^4		I_pipe	16689.7	mm^4
Radius	12.5	mm		I_keyway	724.64	mm^4		I_keyway	19.8	mm^4
Totals										
J	32634.9819	mm^4								
τ	19.151	Mpa								

Yield Stress of 6061 T6
240 Mpa
139.2

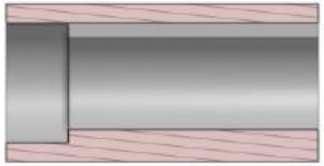
Safety Factor
7.26846317

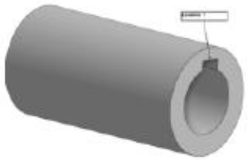
Parameters		Units		Ixx	11320.7782	Units		Iyy	11320.7782	Units
D	25	mm		Area total	176.71	mm^2		Area total	176.7	mm^2
d	20	mm		ΣAi * yi	2208.93	mm^3		ΣAi * yi	2208.9	mm^3
b	0	mm		ybar	12.5000	mm		ybar	12.5	mm
c	0	mm								
Torque	50	Nm		I_pipe	11320.78	mm^4		I_pipe	11320.8	mm^4
Radius	12.5	mm		I_keyway	0.00	mm^4		I_keyway	0.0	mm^4
Totals										
J	22641.5564	mm^4								
τ	27.604	Mpa								

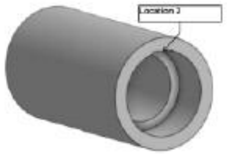
Yield Stress of 6061 T6
240
139.2

The keyway no longer exists on this section of pipe

Safety Factor
5.042727448







Keyed Flange

Parameters		Units
A	129.583	mm^2
r	9.665	mm
T	50	Nm
F	5173.305742	N
Stress	39.92271936	Mpa

Keyed Shaft

Parameters		Units
A	116.17	mm^2
r	9.665	mm
T	50	Nm
F	5173.30574	N
Stress	44.5322006	Mpa

Rack Connect Combined Area

Parameters		Units
A	99	mm^2
r	19	mm
T	50	Nm
F	2631.57895	N
Stress	26.5816055	Mpa

Tie Rod

Parameters		Units
Pinion Gear Diameter	28.06596702	mm
Torque	50	Nm
Force	3563.034188	N
Tie Rod OD	16	mm
Tie Rod ID	12.8	mm
Area	72.38229474	mm^2
Stress in the Tie Rod	49.22521731	Mpa
Bolt Diameter	6	mm
Bolt Area	34.1376	mm^2
Stress	104.3727206	Mpa


SPECIFICATIONS

Kinematic Length

Max Linear Travel Per Side

Max Axial Load Rating

Max Off-Axis Load Rating (Per Side)

Max Deflection @ Max Travel and Max Off-Axis Load

Max Steering Torque

Assume the torque and force in the datasheet are related by the diameter of the pinion gear

Max Torque	93.6	Nm
Max Force	6670	Nm
Radius of Pinion Gear	14.03298351	mm

Note: this is close to what I can see from the model

Note max torque nad max force

Keyed Flange

Location 3

Parameters		Units		**Ixx**	36303.6835	Units		**Iyy**	37250.4311	Units
D	30	mm		Area total	518.00	mm^2		Area total	518.0	mm^2
d	15	mm		ΣAi * yi	7664.14	mm^3		ΣAi * yi	7770.0	mm^3
b	5	mm		ybar	14.80	mm		ybar	15.0	mm
c	2.429	mm								
Torque	50	Nm		I_pipe	37275.73	mm^4		I_pipe	37275.7	mm^4
Radius	15	mm		I_keyway	972.05	mm^4		I_keyway	25.3	mm^4
Totals										
J	73554.1146	mm^4								
τ	10.197	Mpa								

Keyed Flange

Location 2

Parameters		Units		Ixx	15965.073	Units		Iyy	16669.9089	Units
D	25	mm		Area total	304.65	mm^2		Area total	304.7	mm^2
d	15	mm		ΣAi * yi	3727.86	mm^3		ΣAi * yi	3808.2	mm^3
b	5	mm		ybar	12.24	mm		ybar	12.5	mm
c	1.901	mm								
Torque	50	Nm		I_pipe	16689.71	mm^4		I_pipe	16689.7	mm^4
Radius	12.5	mm		I_keyway	724.64	mm^4		I_keyway	19.8	mm^4
Totals										
J	32634.9819	mm^4								
τ	19.151	Mpa								

Yield Stress of Mild Steel

350

203

Safety Factor

10.5998421

Keyed Flange

Location 1

Parameters		Units		Ixx	15140.93	Units		Iyy	15938.0	Units
D	25	mm		Area total	280.31	mm^2		Area total	280.3	mm^2
d	16	mm		ΣAi * yi	3418.76	mm^3		ΣAi * yi	3503.8	mm^3
b	5	mm		ybar	12.1965	mm		ybar	12.5	mm
c	1.901	mm								
Torque	50	Nm		I_pipe	15957.77	mm^4		I_pipe	15957.8	mm^4
Radius	12.5	mm		I_keyway	816.84	mm^4		I_keyway	19.8	mm^4
Totals										
J	31078.89749	mm^4								
τ	20.110	Mpa								

Yield Stress of Mild Steel

350

203

Safety Factor

10.0944259

11.2. Appendix B – Steering Manufacture Drawings

Item	Name	Quantity
1	STEERING RACK	1
2	TIE ROD	2
3	STEERING COLUMN	1
4	STEERING WHEEL	1

DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D

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TITLE: STEERING

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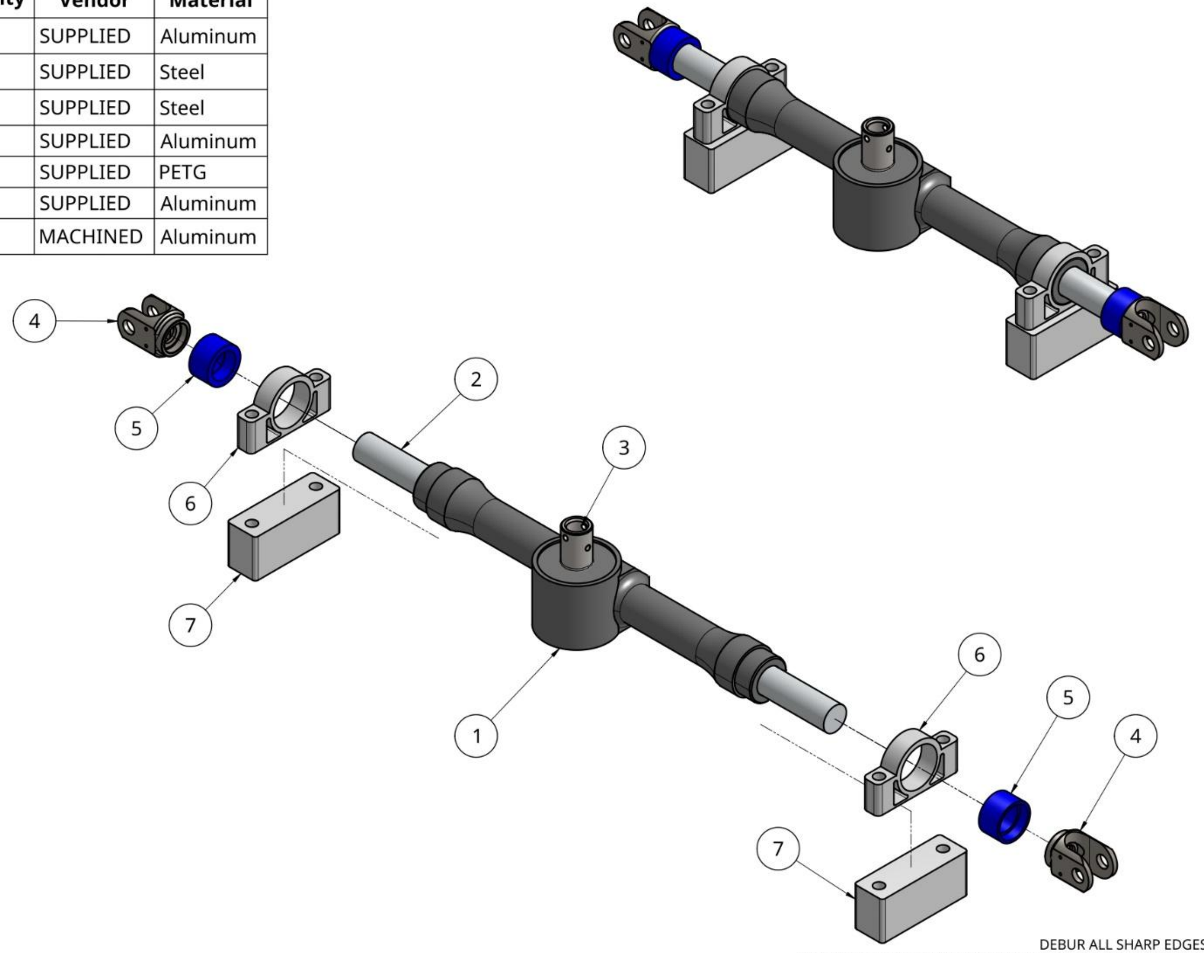
QUANTITY: 1	DRAWN	LACHLAN FISHER		2024-03-06	SCALE: 1:5
MATERIAL: SEE TABLE					SHEET: 1/29 A3

Item	Name	Quantity	Vendor	Material
1	PINION BEARING HOUSING	1	SUPPLIED	Aluminum
2	STEERING RACK	1	SUPPLIED	Steel
3	STEERING PINION	1	SUPPLIED	Steel
4	RACK CLEVIS	2	SUPPLIED	Aluminum
5	RACK SPACER	2	SUPPLIED	PETG
6	RACK PILLOW BLOCK	2	SUPPLIED	Aluminum
7	RACK SHIM	2	MACHINED	Aluminum



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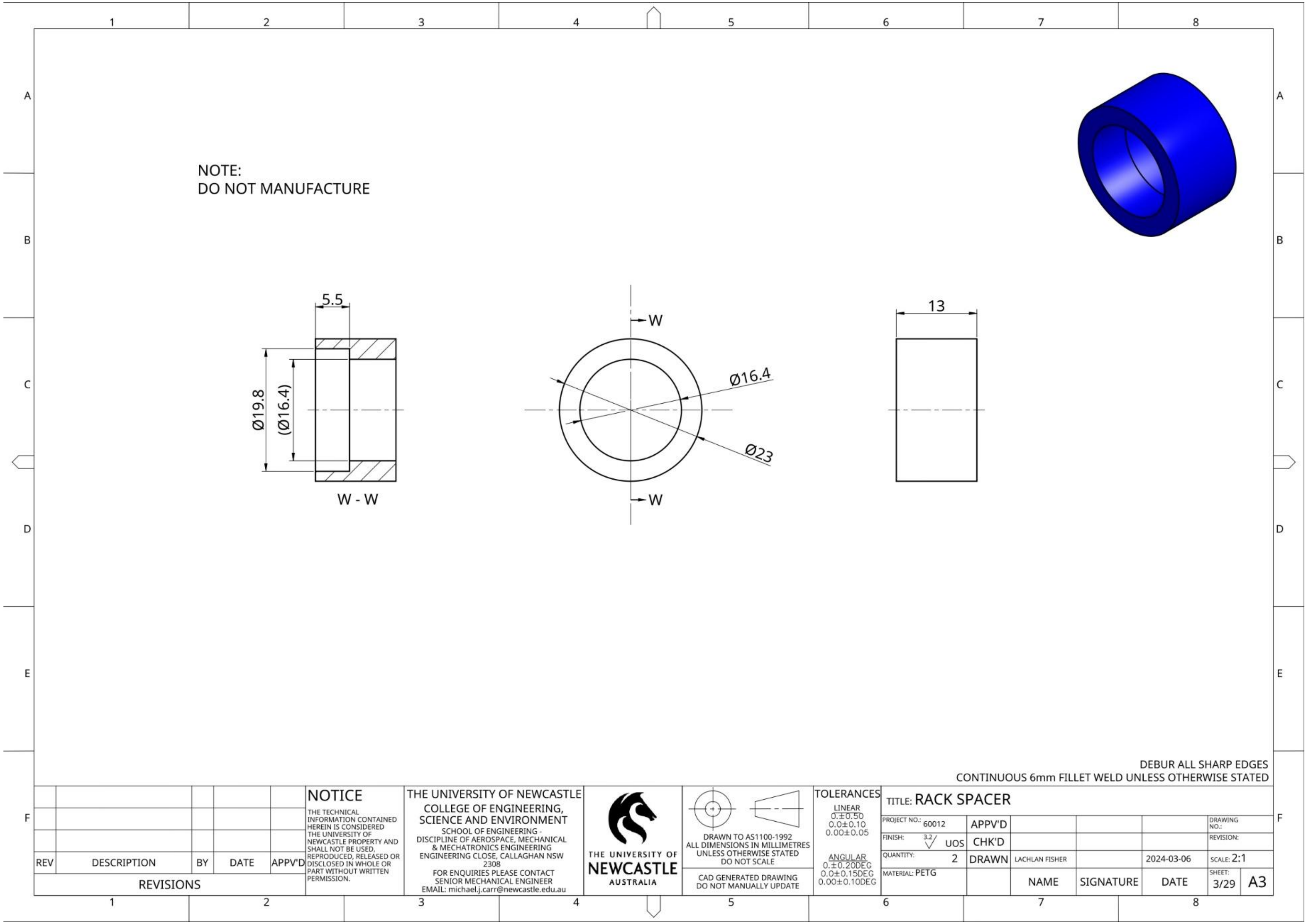
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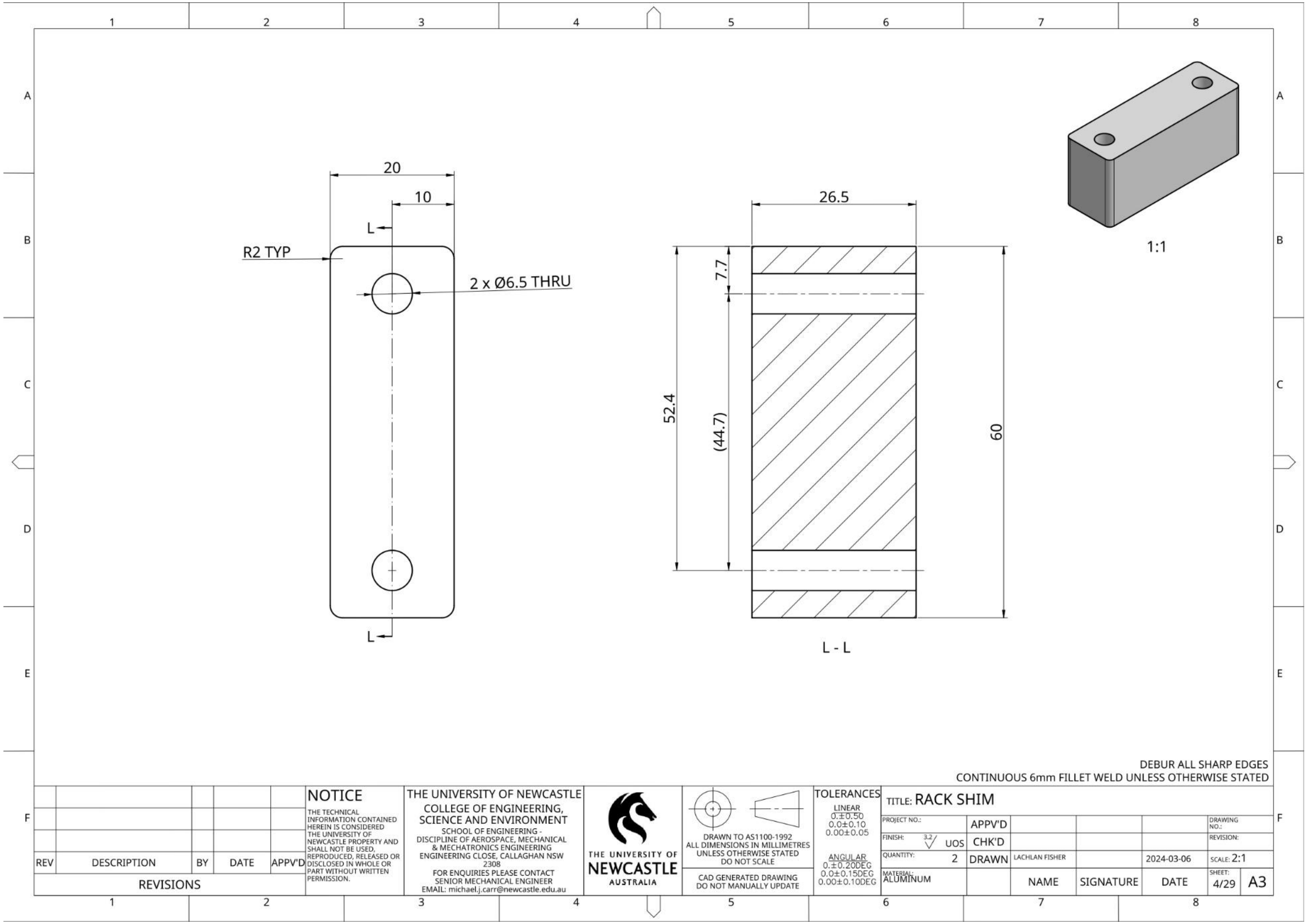
PROJECT NO.: 60012
FINISH: 3.2 UOS
QUANTITY: 2
MATERIAL: PETG
APPV'D
CHK'D
DRAWN LACHLAN FISHER 2024-03-06
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 3/29
A3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TOLERANCES
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ANGULAR
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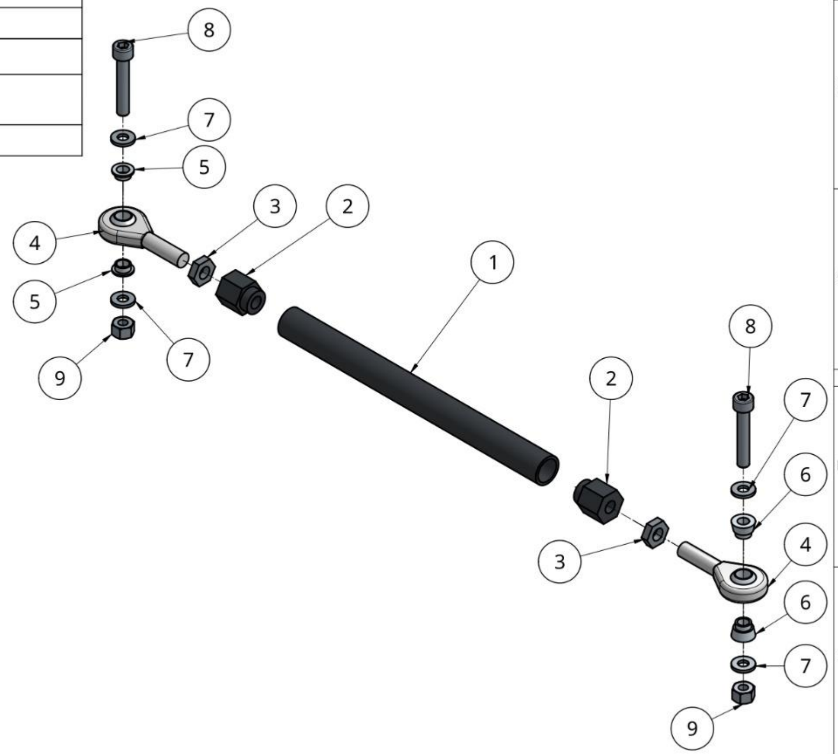
TITLE: RACK SHIM
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 2
MATERIAL: ALUMINUM
APPV'D
CHK'D
DRAWN
LACHLAN FISHER
2024-03-06
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 4/29
A3

Item	Name	Quantity	Vendor	Material
1	TIE ROD SHAFT	1	MACHINED	Carbon Steel
2	SUSPENION HEX	2	MACHINED	Carbon Steel
3	M8 HALF NUT	2	SUPPLIED	300 Series Stainless Steel
4	ROD END MALE 8mm	2	SUPPLIED	300 Series Stainless Steel
5	MISALIGNMENT SPACER	2	SUPPLIED	Stainless Steel
6	OUTBOARD SUSPENSION SPACER	2	SUPPLIED	Stainless Steel
7	PLAIN WASHER M6	4	SUPPLIED	Steel Class 12.9
8	SOCKET HEAD CAP SCREW M6 x 1 x 35	2	SUPPLIED	Steel Class 12.9
9	NYLOC HEX NUT M6	2	SUPPLIED	Steel Class 12.9



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ANGULAR
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TITLE: TIE ROD
PROJECT NO.: | APPV'D
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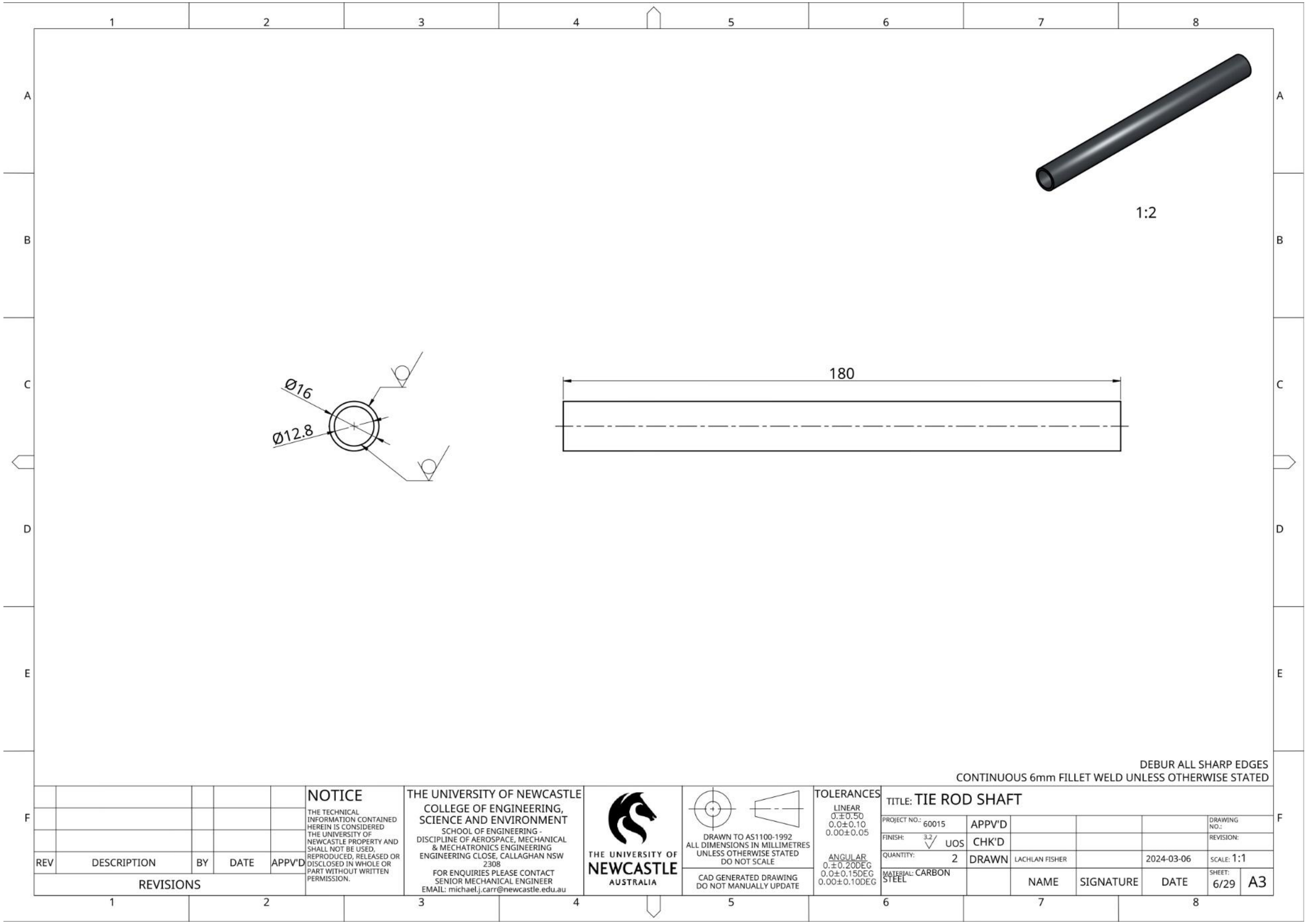
QUANTITY: 2 | DRAWN | LACHLAN FISHER | | 2024-03-06
MATERIAL: SEE TABLE | NAME | SIGNATURE | DATE
DRAWING NO.:
REVISION:
SCALE: 1:2
SHEET: 5/29 | A3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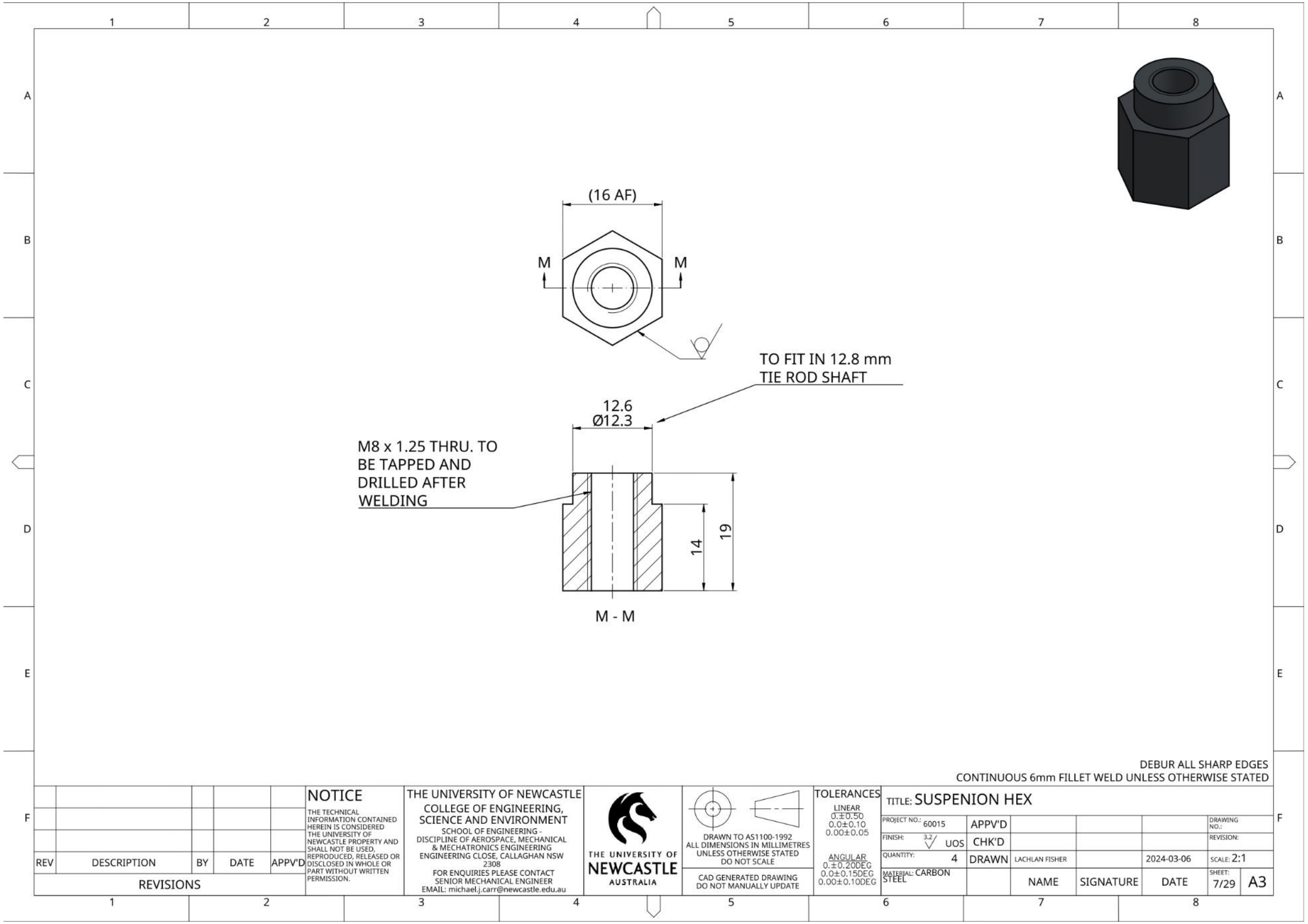
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: TIE ROD SHAFT
PROJECT NO.: 60015
FINISH: 3.2 UOS
QUANTITY: 2
MATERIAL: CARBON STEEL
APPV'D
CHK'D
DRAWN LACHLAN FISHER 2024-03-06
NAME SIGNATURE DATE
DRAWING NO.:
REVISION:
SCALE: 1:1
SHEET: 6/29
A3



(16 AF)
M
M
TO FIT IN 12.8 mm
TIE ROD SHAFT
12.6
Ø12.3
M8 x 1.25 THRU. TO
BE TAPPED AND
DRILLED AFTER
WELDING
14
19
M - M
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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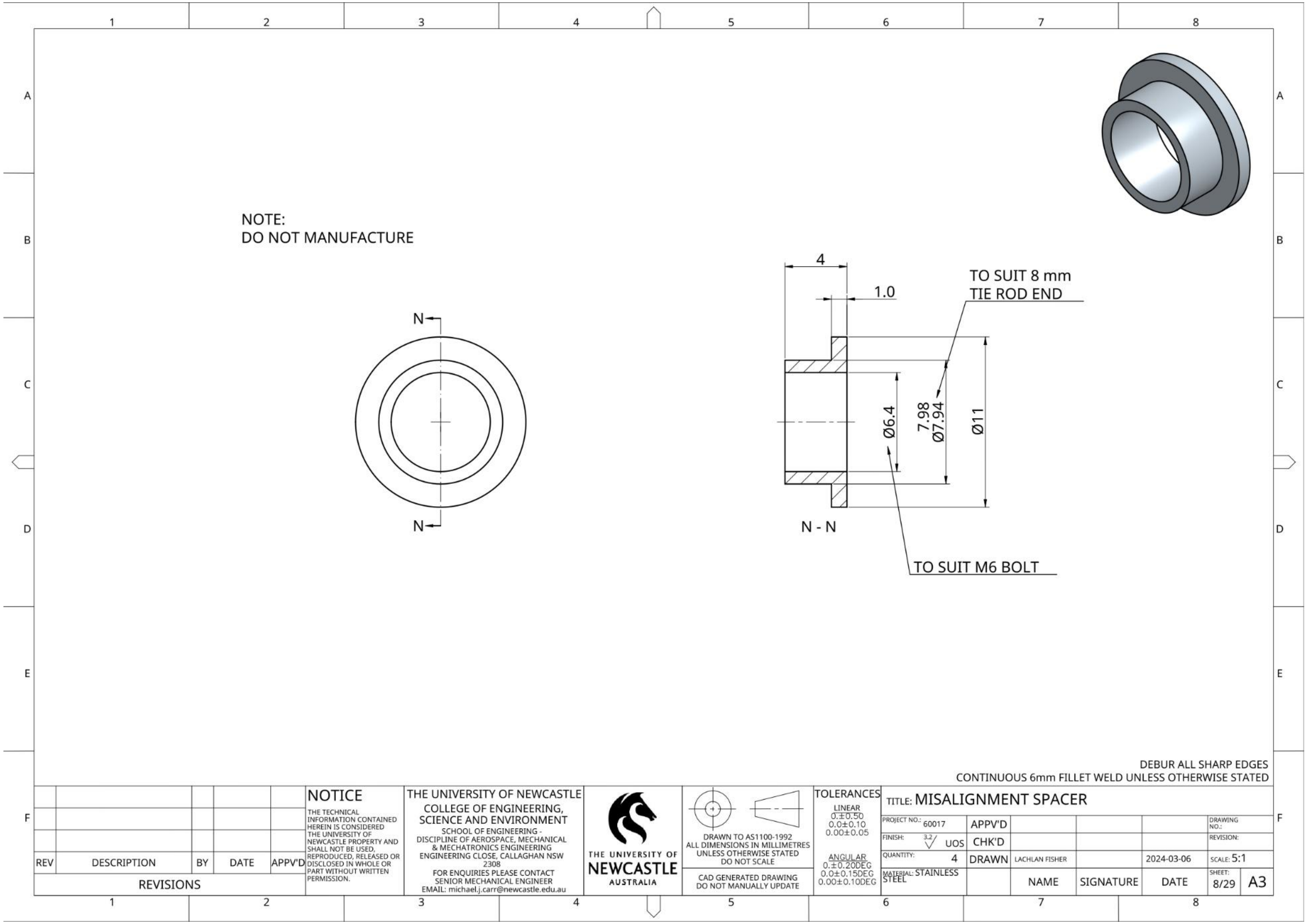
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: SUSPENION HEX
PROJECT NO.: 60015
APPV'D
FINISH: 3.2 UOS
CHK'D
QUANTITY: 4
DRAWN
LACHLAN FISHER
2024-03-06
MATERIAL: CARBON STEEL
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 7/29
A3


NOTE:
DO NOT MANUFACTURE
N
N
4
1.0
TO SUIT 8 mm
TIE ROD END
Ø6.4
7.98
Ø7.94
Ø11
N - N
TO SUIT M6 BOLT
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
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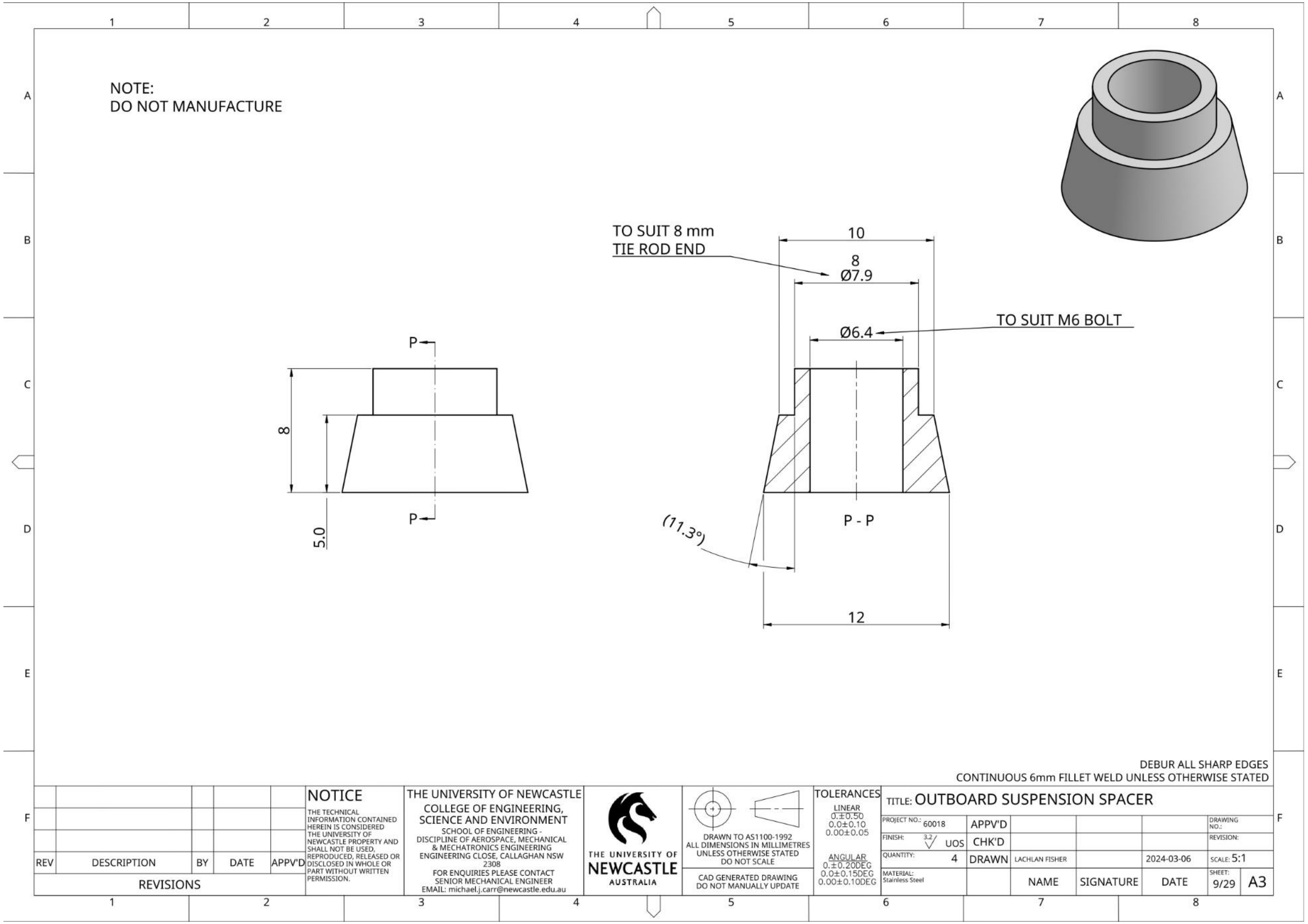
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: MISALIGNMENT SPACER
PROJECT NO.: 60017
FINISH: 3.2 UOS
QUANTITY: 4
MATERIAL: STAINLESS STEEL
APPV'D
CHK'D
DRAWN LACHLAN FISHER 2024-03-06
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 5:1
SHEET: 8/29
A3



NOTE:
DO NOT MANUFACTURE
TO SUIT 8 mm
TIE ROD END
10
8
Ø7.9
TO SUIT M6 BOLT
Ø6.4
P
P
8
5.0
(11.3°)
P - P
12
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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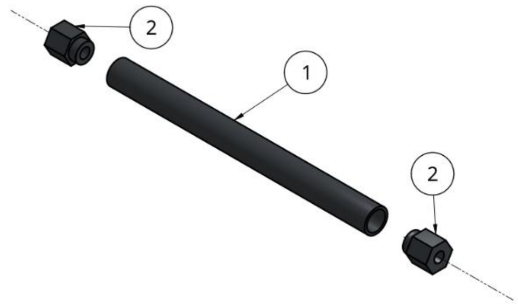
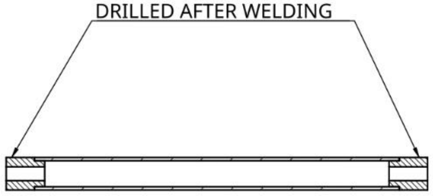
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: OUTBOARD SUSPENSION SPACER
PROJECT NO.: 60018
APPV'D
FINISH: 3.2 UOS
CHK'D
QUANTITY: 4
DRAWN
LACHLAN FISHER
2024-03-06
MATERIAL: Stainless Steel
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 5:1
SHEET: 9/29
A3

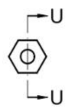
Item	Name	Quantity	Vendor	Material
1	TIE ROD SHAFT	1	MACHINED	Carbon Steel
2	SUSPENION HEX	2	MACHINED	Carbon Steel

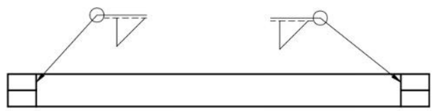


ASSEMBLE UNTIL
SHOULDERS BUTT UP THEN
WELD



U - U





DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D
REVISIONS				

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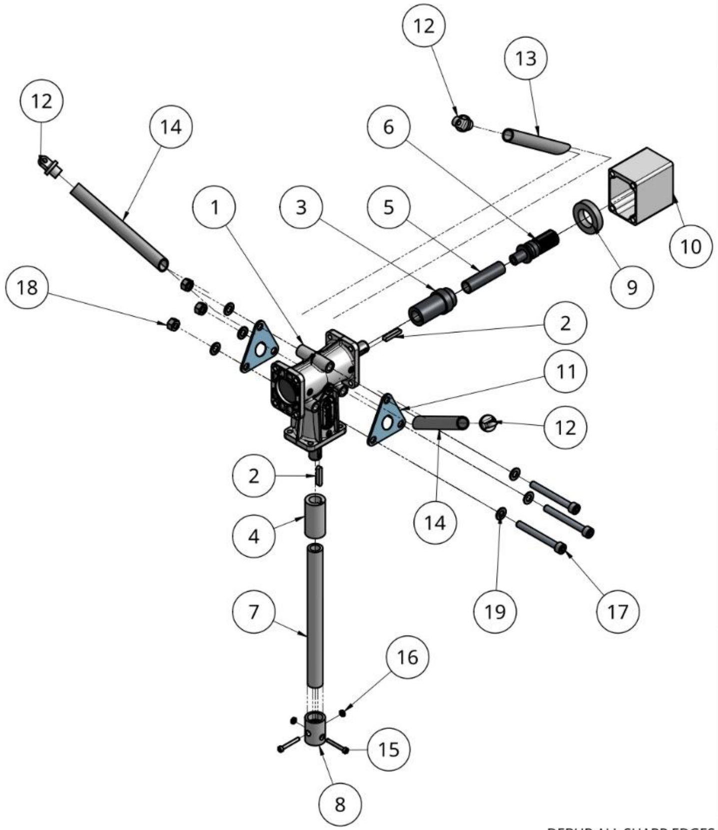
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: TIE ROD ASSEMBLY

PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D				REVISION:
QUANTITY: 2	DRAWN	LACHLAN FISHER		2024-03-06	SCALE: 1:2
MATERIAL: SEE TABLE		NAME	SIGNATURE	DATE	SHEET: 10/29 A3

Item	Name	Quantity	Vendor	Material
1	GEARBOX - DZ20S 3FAB	1	SUPPLIED	Aluminum
2	KEY	2	SUPPLIED	Carbon Steel
3	KEYED FLANGE	1	MACHINED	Carbon Steel
4	KEYED SHAFT	1	MACHINED	Aluminum- 6061 T6
5	STEERING WHEEL SHAFT	1	MACHINED	Carbon Steel
6	QUICK RELEASE SPLINE	1	MACHINED	Carbon Steel
7	STEERING RACK SHAFT	1	MACHINED	Aluminum 6061-T6
8	RACK CONNECT	1	MACHINED	Aluminum - 6061 T6
9	BEARING	1	SUPPLIED	Steel
10	BEARING BLOCK	1	MACHINED	Aluminum - 6061 T6
11	MOUNTING PLATE	2	SUPPLIED	Aluminum - 6061
12	CLEVIS	3	MACHINED	Aluminum - 6061 T6
13	CENTRE SUPPORT ARM	1	MACHINED	Aluminum - 6060 T5
14	SIDE SUPPORT ARM	2	MACHINED	Aluminum - 6060 T5
15	SOCKET HEAD CAP SCREW M4 x 0.7 x 30	2	SUPPLIED	Steel Class 12.9
16	NYLOC NUT M4 x 0.7	2	SUPPLIED	Steel Class 12.9
17	SOCKET HEAD CAP SCREW M8 x 1.25 x 70	3	SUPPLIED	Steel Class 12.9
18	NYLOC NUT M8 x 1.25	3	SUPPLIED	Steel Class 12.9
19	PLAIN M8 WASHER	6	SUPPLIED	Steel



DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D
REVISIONS				

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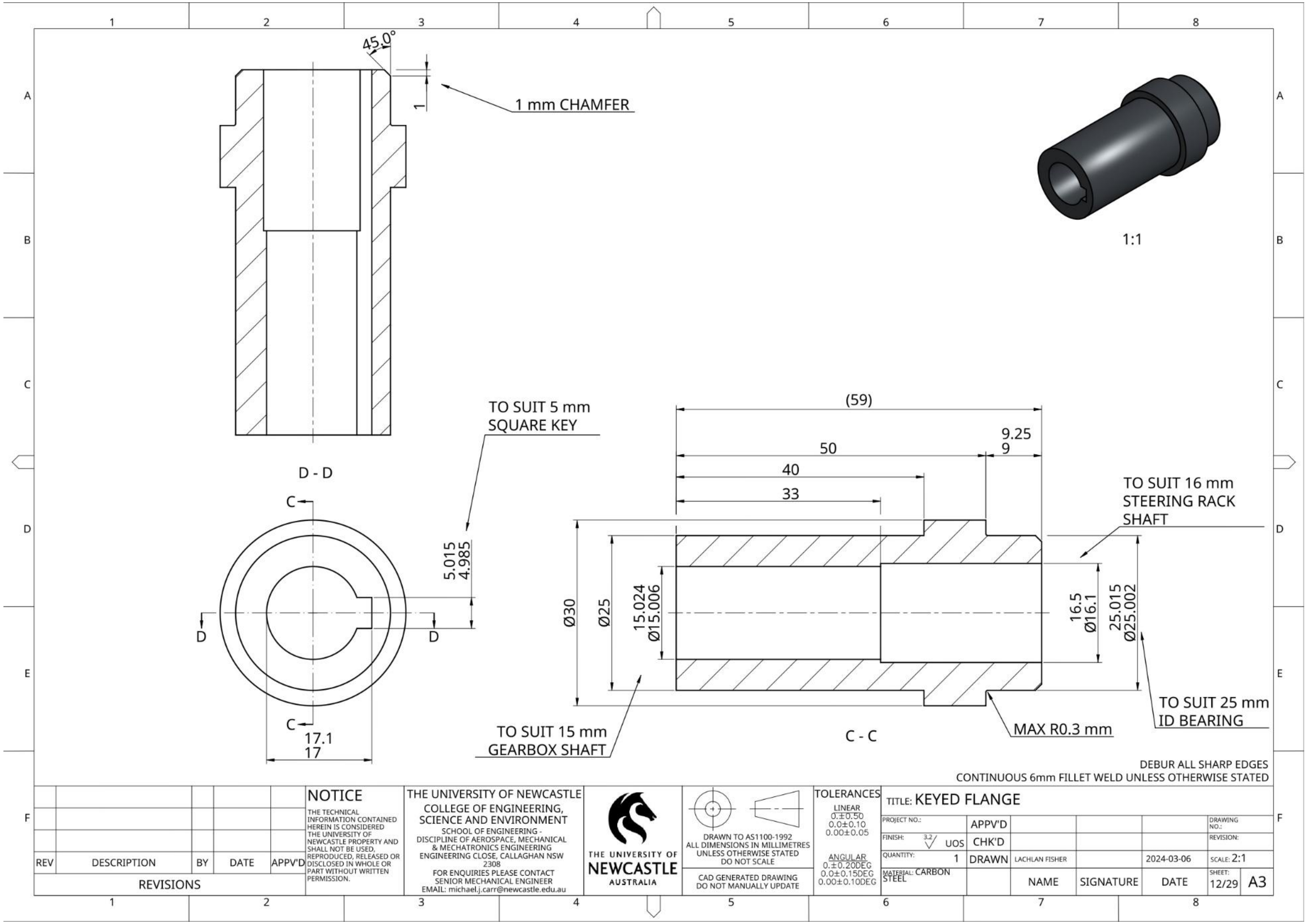
DO NOT SCALE

CAD GENERATED DRAWING DO NOT MANUALLY UPDATE

TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: STEERING COLUMN

		NAME	SIGNATURE	DATE	
PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D				REVISION:
QUANTITY: 1	DRAWN	LACHLAN FISHER		2024-03-06	SCALE: 1:5
MATERIAL: SEE TABLE					SHEET: 11/29 A3


45.0°
1 mm CHAMFER
1
D - D
TO SUIT 5 mm
SQUARE KEY
5.015
4.985
17.1
17
C - C
(59)
50
40
33
9.25
9
TO SUIT 16 mm
STEERING RACK
SHAFT
Ø30
Ø25
15.024
Ø15.006
16.5
Ø16.1
25.015
Ø25.002
TO SUIT 15 mm
GEARBOX SHAFT
MAX R0.3 mm
TO SUIT 25 mm
ID BEARING
1:1
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
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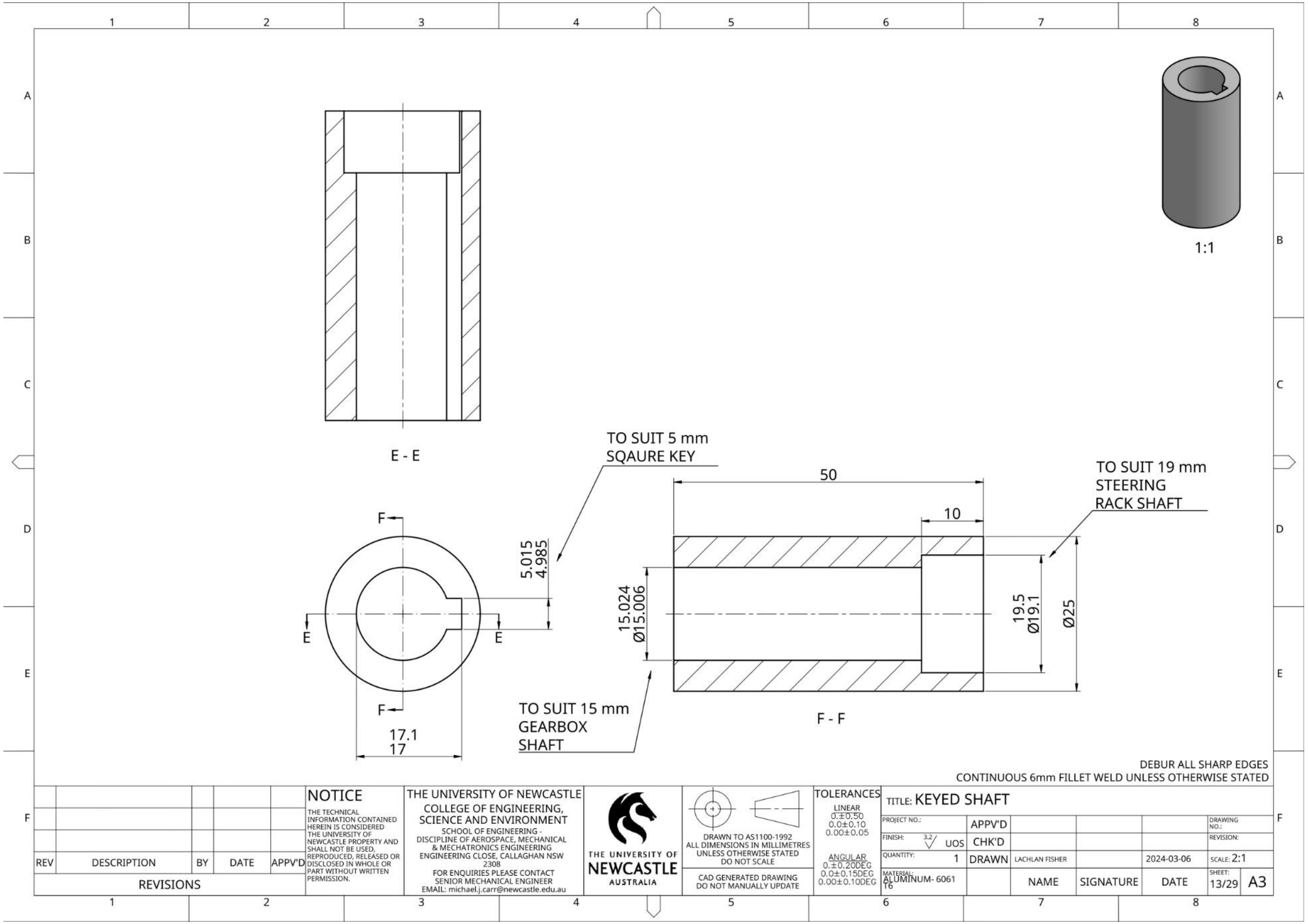
ALL DIMENSIONS IN MILLIMETRES
UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: KEYED FLANGE
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: CARBON STEEL
APPV'D
CHK'D
DRAWN LACHLAN FISHER 2024-03-06
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 12/29
A3



E - E
TO SUIT 5 mm SQAURE KEY
50
10
TO SUIT 19 mm STEERING RACK SHAFT
5.015
4.985
15.024
Ø15.006
19.5
Ø19.1
Ø25
F - F
TO SUIT 15 mm GEARBOX SHAFT
17.1
17
1:1
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV DESCRIPTION BY DATE APPV'D
REVISIONS
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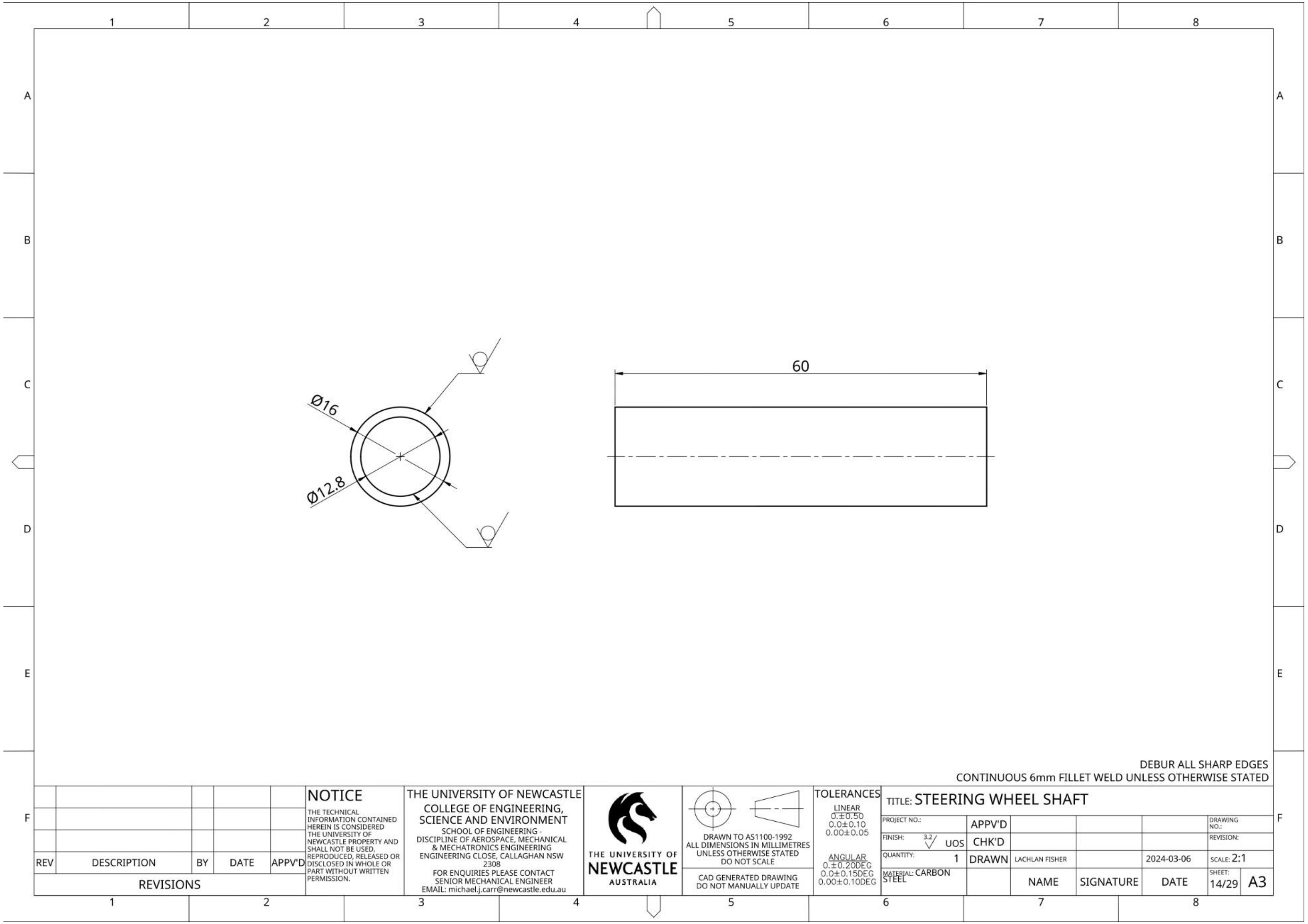
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: KEYED SHAFT
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINUM- 6061 T6
APPV'D
CHK'D
DRAWN LACHLAN FISHER 2024-03-06
NAME SIGNATURE DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 13/29 A3


Ø16
Ø12.8
60
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV DESCRIPTION BY DATE APPV'D
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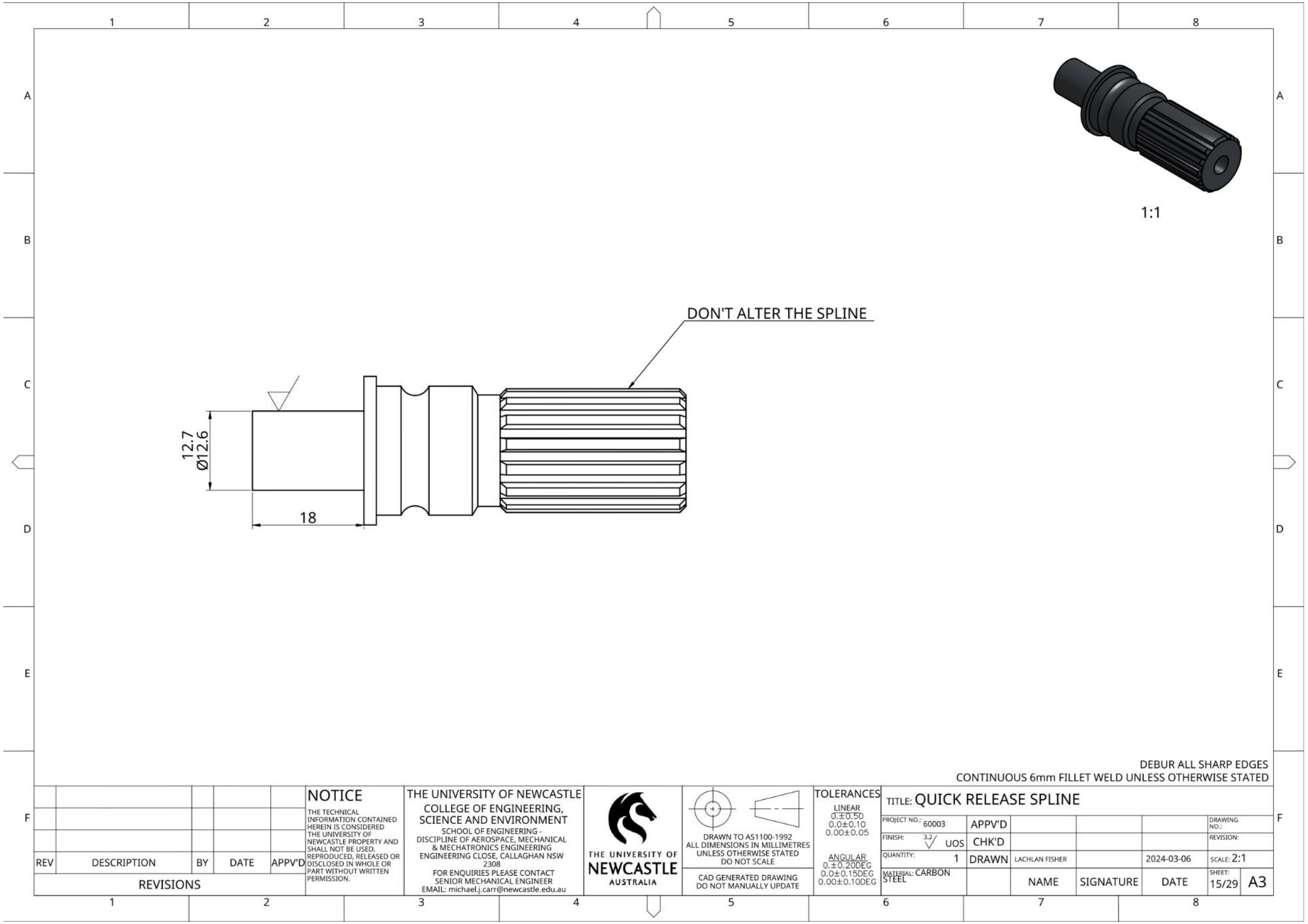
UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: STEERING WHEEL SHAFT
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: CARBON STEEL
APPV'D
CHK'D
DRAWN LACHLAN FISHER 2024-03-06
NAME SIGNATURE DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 14/29
A3


1:1
DON'T ALTER THE SPLINE
12.7
Ø12.6
18
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
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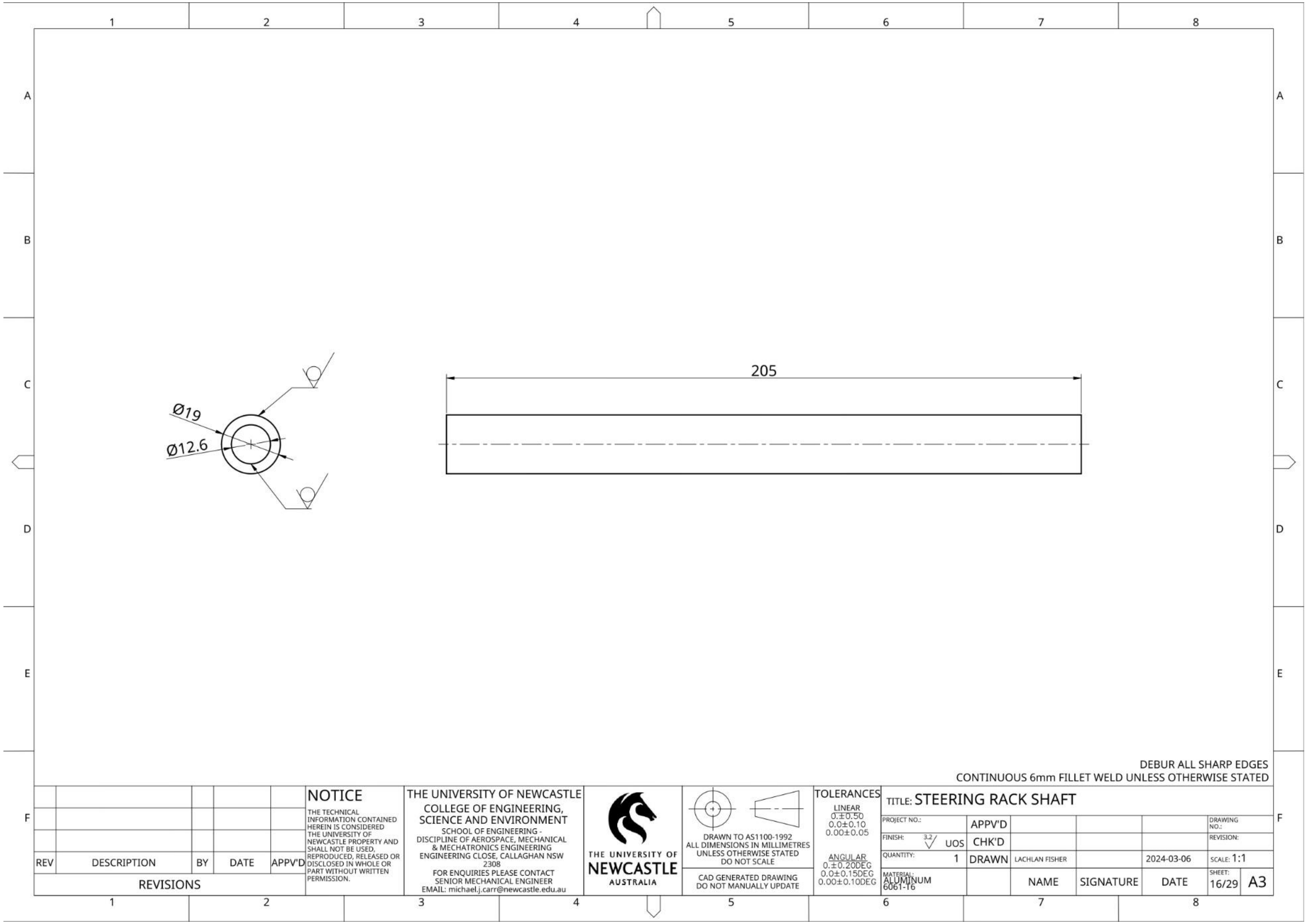
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: QUICK RELEASE SPLINE
PROJECT NO.: 60003
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: CARBON STEEL
APPV'D
CHK'D
DRAWN LACHLAN FISHER 2024-03-06
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 15/29
A3


Ø19
Ø12.6
205
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
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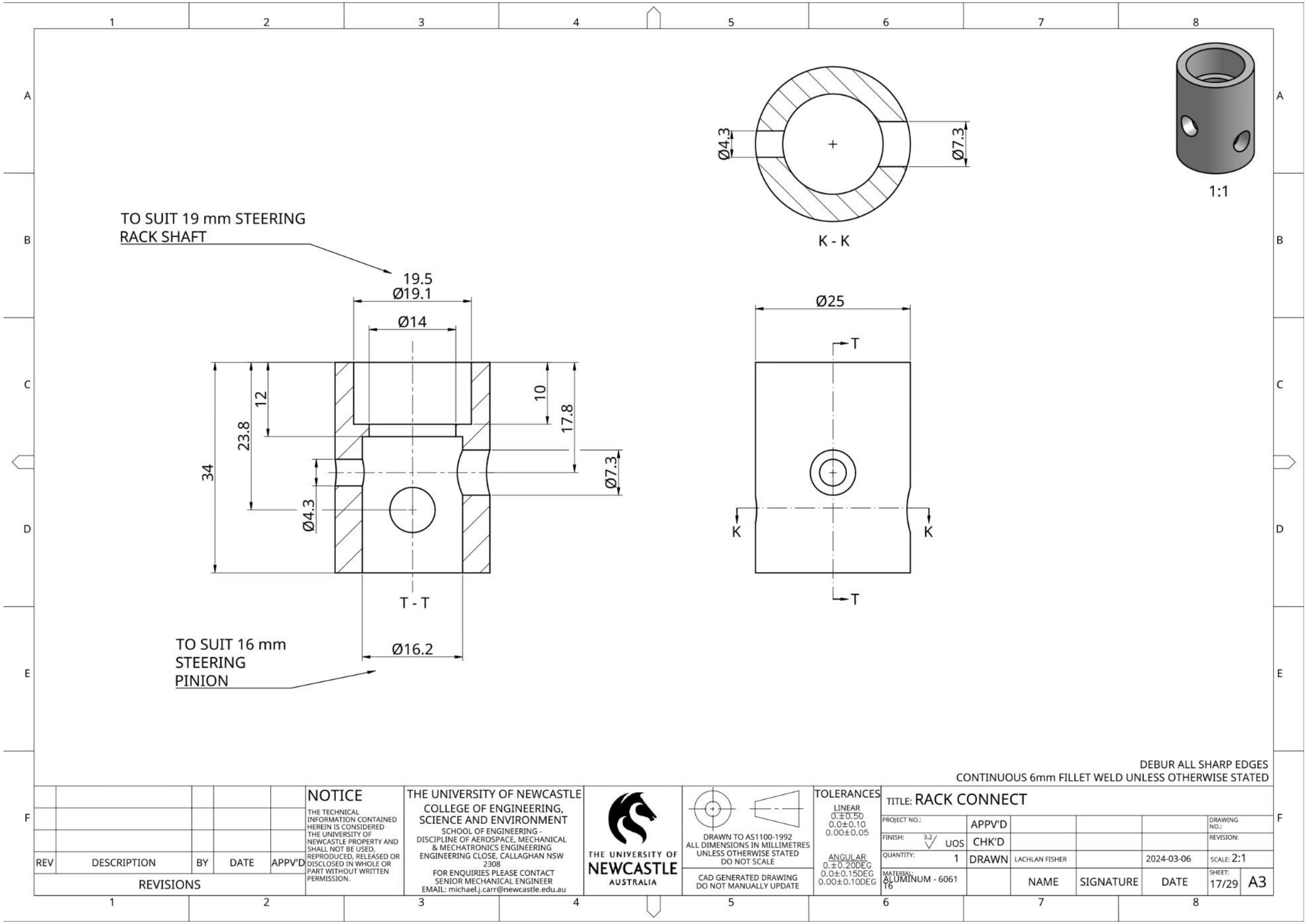
UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: STEERING RACK SHAFT
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINUM 6061-T6
APPV'D
CHK'D
DRAWN LACHLAN FISHER 2024-03-06
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:1
SHEET: 16/29
A3



TO SUIT 19 mm STEERING RACK SHAFT
19.5
Ø19.1
Ø14
12
23.8
34
10
17.8
Ø7.3
Ø4.3
T - T
TO SUIT 16 mm STEERING PINION
Ø16.2
Ø4.3
Ø7.3
K - K
Ø25
T
K
1:1
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
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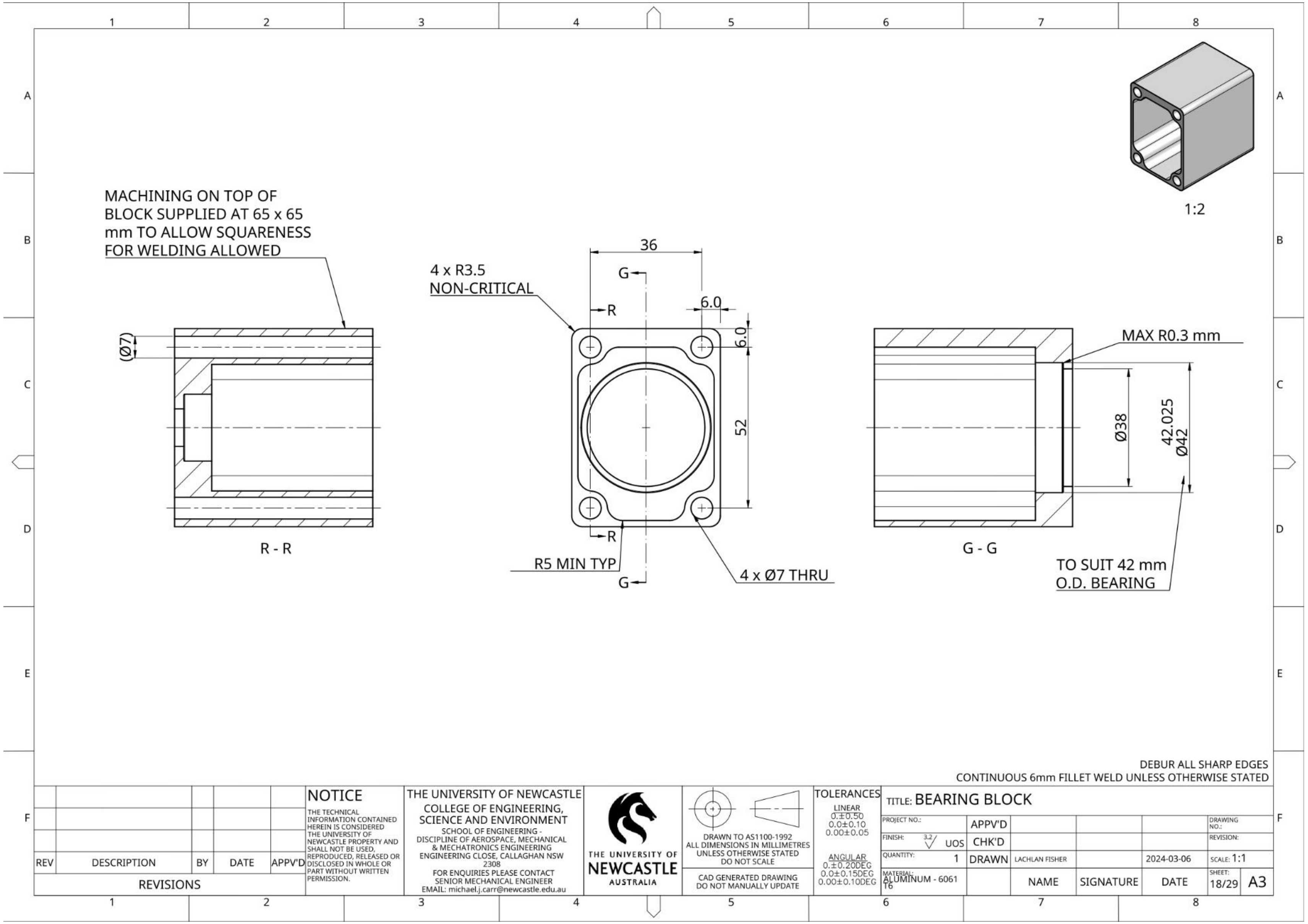
DRAWN TO AS1100-1992
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: RACK CONNECT
PROJECT NO.:
APPV'D
FINISH: 3.2 UOS
CHK'D
QUANTITY: 1
DRAWN
LACHLAN FISHER
2024-03-06
MATERIAL: ALUMINUM - 6061 T6
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 17/29
A3



1:2
MACHINING ON TOP OF BLOCK SUPPLIED AT 65 x 65 mm TO ALLOW SQUARENESS FOR WELDING ALLOWED
(Ø7)
R - R
4 x R3.5 NON-CRITICAL
36
6.0
6.0
52
R
G
R5 MIN TYP
4 x Ø7 THRU
MAX R0.3 mm
Ø38
42.025
Ø42
G - G
TO SUIT 42 mm O.D. BEARING
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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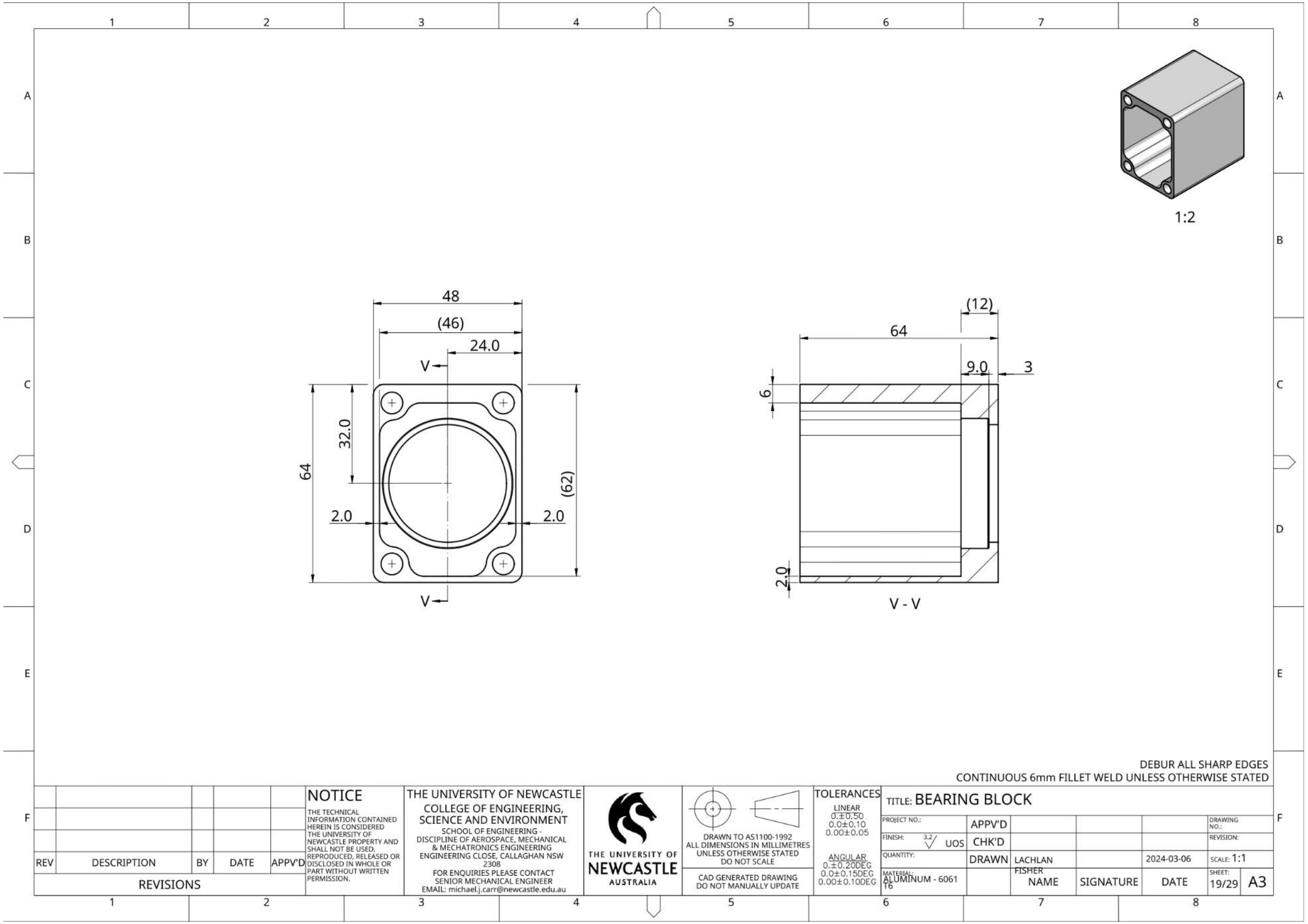
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: BEARING BLOCK
PROJECT NO.:
APPV'D
FINISH: 3.2 UOS
CHK'D
QUANTITY: 1
DRAWN
LACHLAN FISHER
2024-03-06
MATERIAL: ALUMINUM - 6061 T6
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:1
SHEET: 18/29
A3


1:2
48
(46)
24.0
V
32.0
64
(62)
2.0
2.0
V
(12)
64
9.0
3
6
2.0
V - V
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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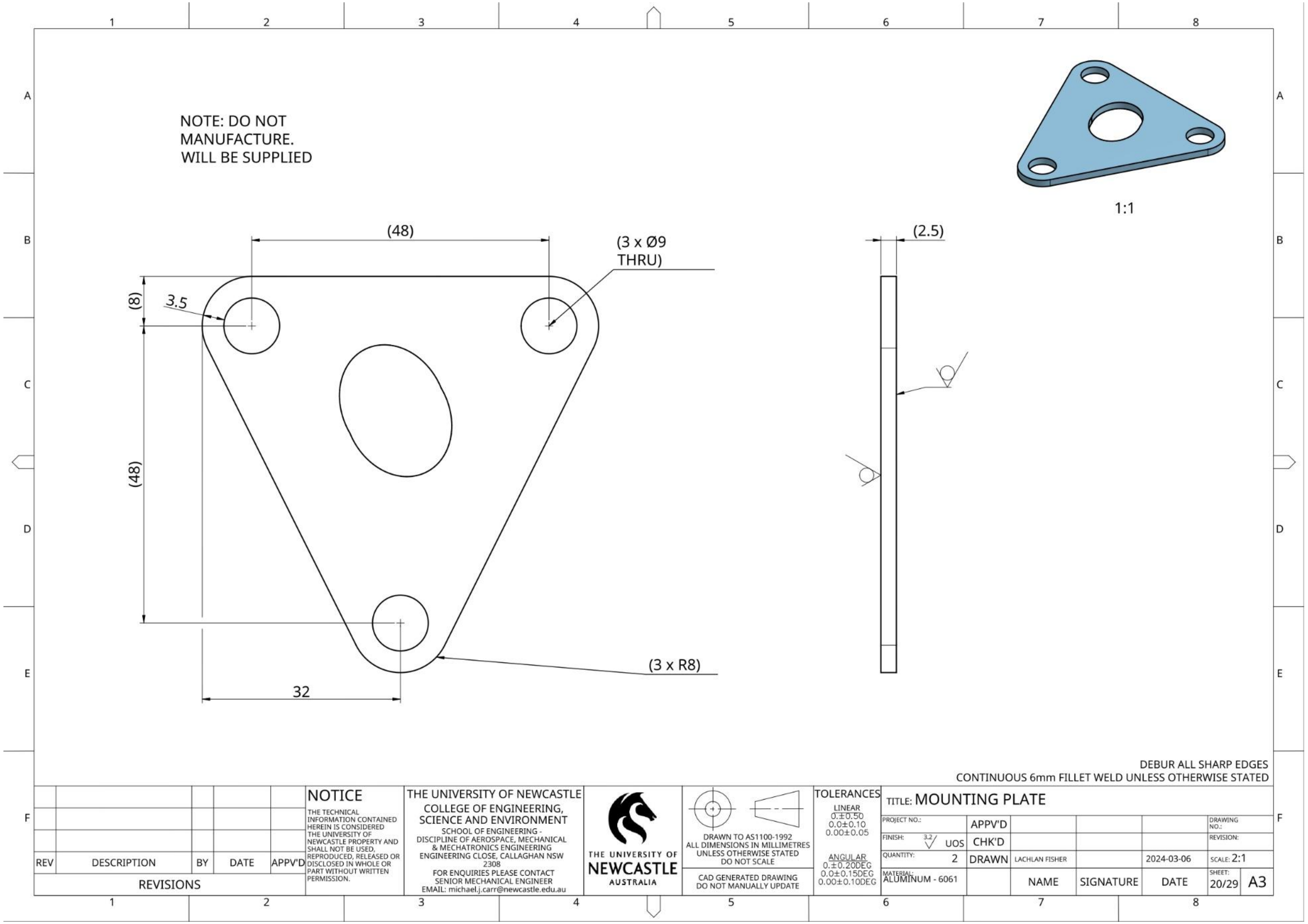
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: BEARING BLOCK
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY:
MATERIAL: ALUMINUM - 6061 T6
APPV'D
CHK'D
DRAWN
LACHLAN FISHER
NAME
SIGNATURE
2024-03-06
DATE
DRAWING NO.:
REVISION:
SCALE: 1:1
SHEET: 19/29
A3


NOTE: DO NOT
MANUFACTURE.
WILL BE SUPPLIED
(48)
(3 x Ø9
THRU)
(8)
3.5
(48)
32
(3 x R8)
(2.5)
1:1
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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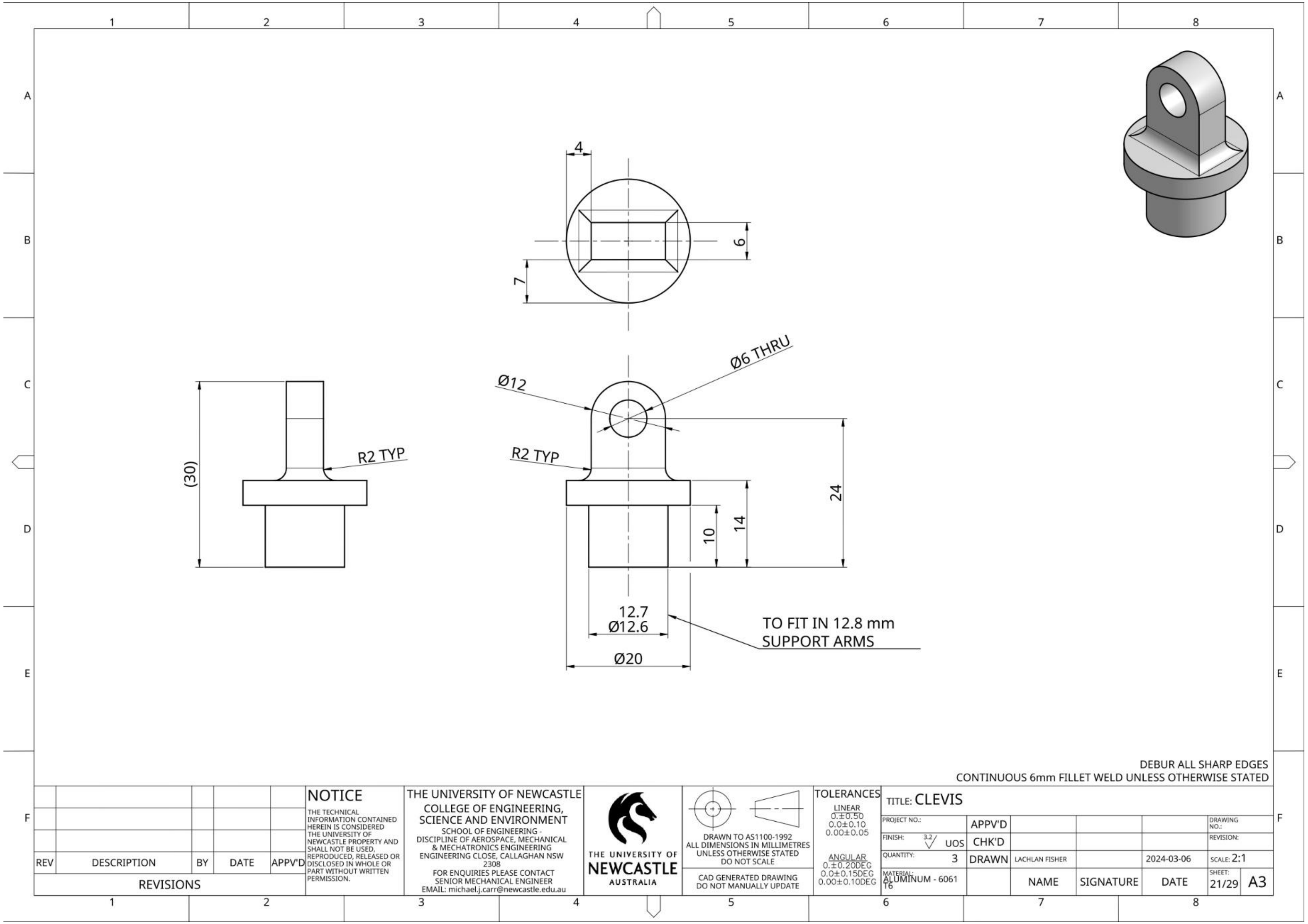
ALL DIMENSIONS IN MILLIMETRES
UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: MOUNTING PLATE
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 2
MATERIAL: ALUMINUM - 6061
APPV'D
CHK'D
DRAWN
LACHLAN FISHER
2024-03-06
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 20/29
A3


4
6
7
Ø6 THRU
Ø12
R2 TYP
R2 TYP
(30)
24
14
10
12.7
Ø12.6
Ø20
TO FIT IN 12.8 mm
SUPPORT ARMS
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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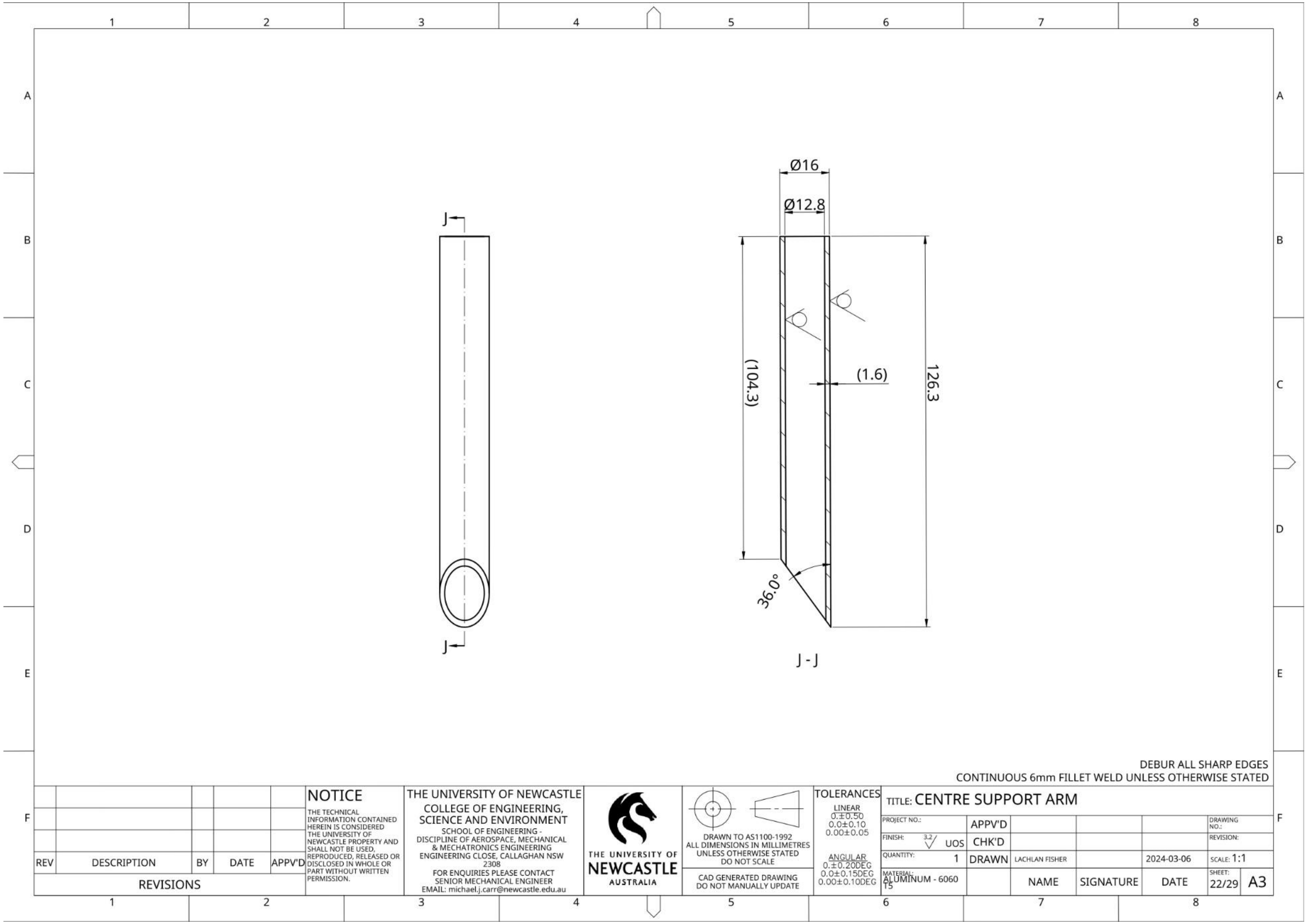
UNLESS OTHERWISE STATED
DO NOT SCALE
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: CLEVIS
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 3
MATERIAL: ALUMINUM - 6061 T6
APPV'D
CHK'D
DRAWN
LACHLAN FISHER
2024-03-06
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 2:1
SHEET: 21/29
A3


Ø16
Ø12.8
J
J
(104.3)
(1.6)
126.3
36.0°
J - J
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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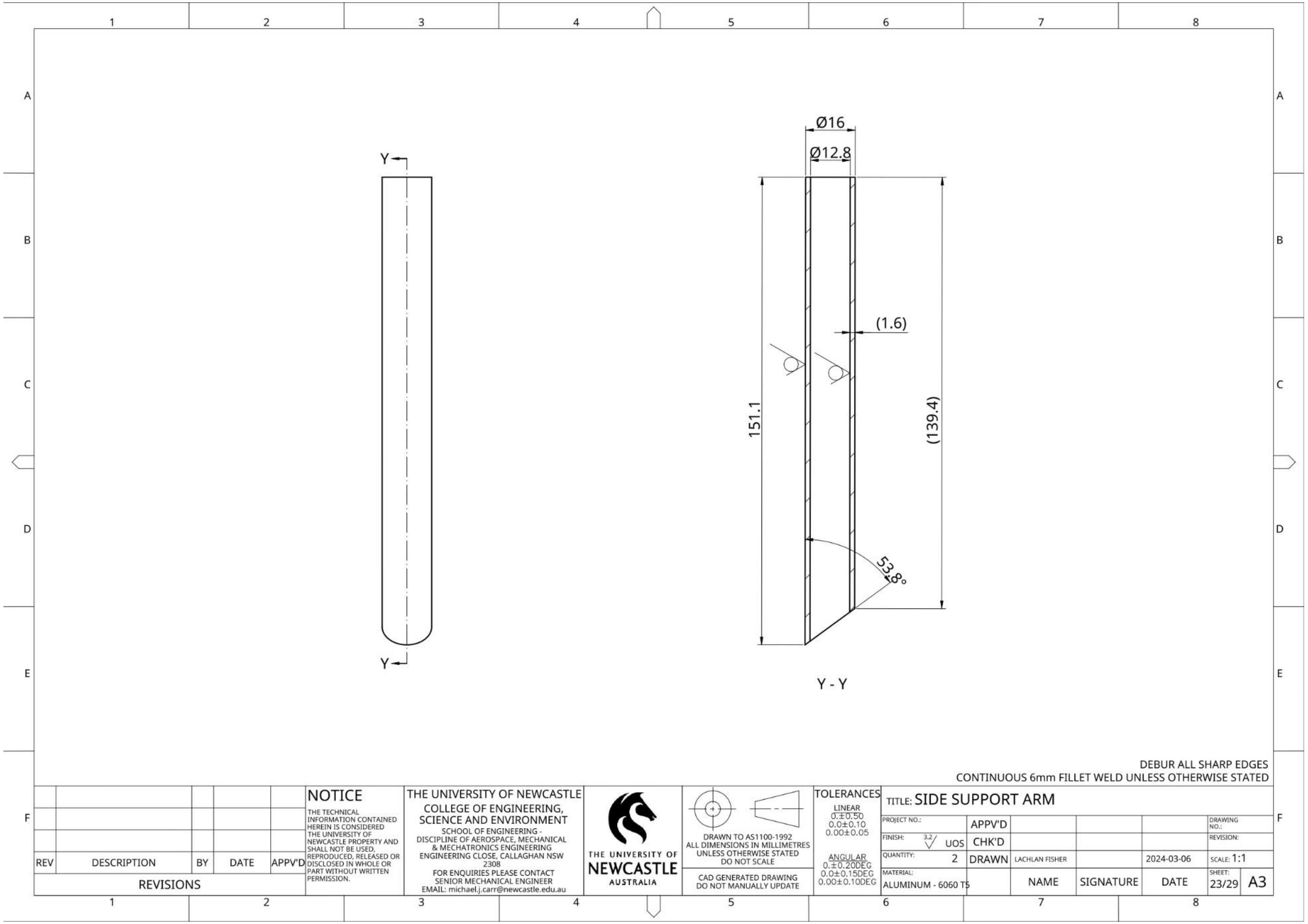
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: CENTRE SUPPORT ARM
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 1
MATERIAL: ALUMINUM - 6060 T5
APPV'D
CHK'D
DRAWN
LACHLAN FISHER
2024-03-06
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:1
SHEET: 22/29
A3


Y
Y
Ø16
Ø12.8
(1.6)
151.1
(139.4)
53.8°
Y - Y
DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED
REV
DESCRIPTION
BY
DATE
APPV'D
REVISIONS
NOTICE
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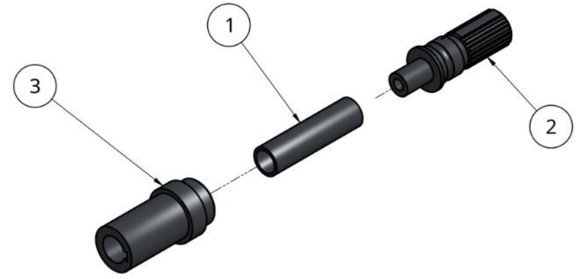
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG
TITLE: SIDE SUPPORT ARM
PROJECT NO.:
FINISH: 3.2 UOS
QUANTITY: 2
MATERIAL: ALUMINUM - 6060 T5
APPV'D
CHK'D
DRAWN
LACHLAN FISHER
2024-03-06
NAME
SIGNATURE
DATE
DRAWING NO.:
REVISION:
SCALE: 1:1
SHEET: 23/29
A3

Item	Quantity	Vendor	Material
1	1	MACHINED	Carbon Steel
2	1	MACHINED	Carbon Steel
3	1	MACHINED	Carbon Steel

ASSEMBLE UNTIL
SHOULDERS BUTT UP.
REFERENCE DIMENSIONS
FOR CLARITY



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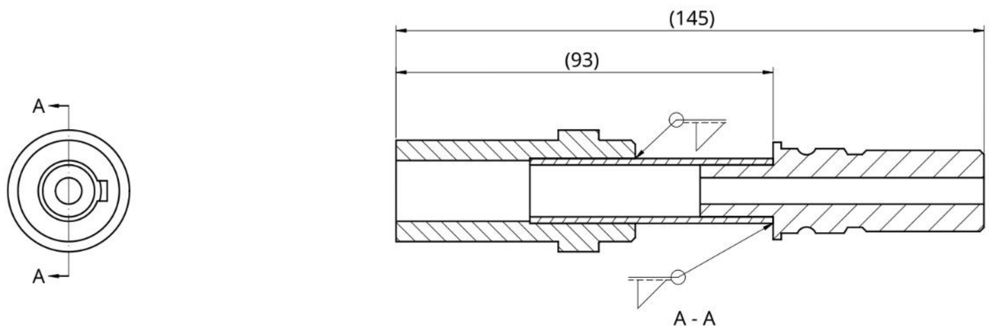

A - A

DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D
REVISIONS				

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UNLESS OTHERWISE STATED
DO NOT SCALE

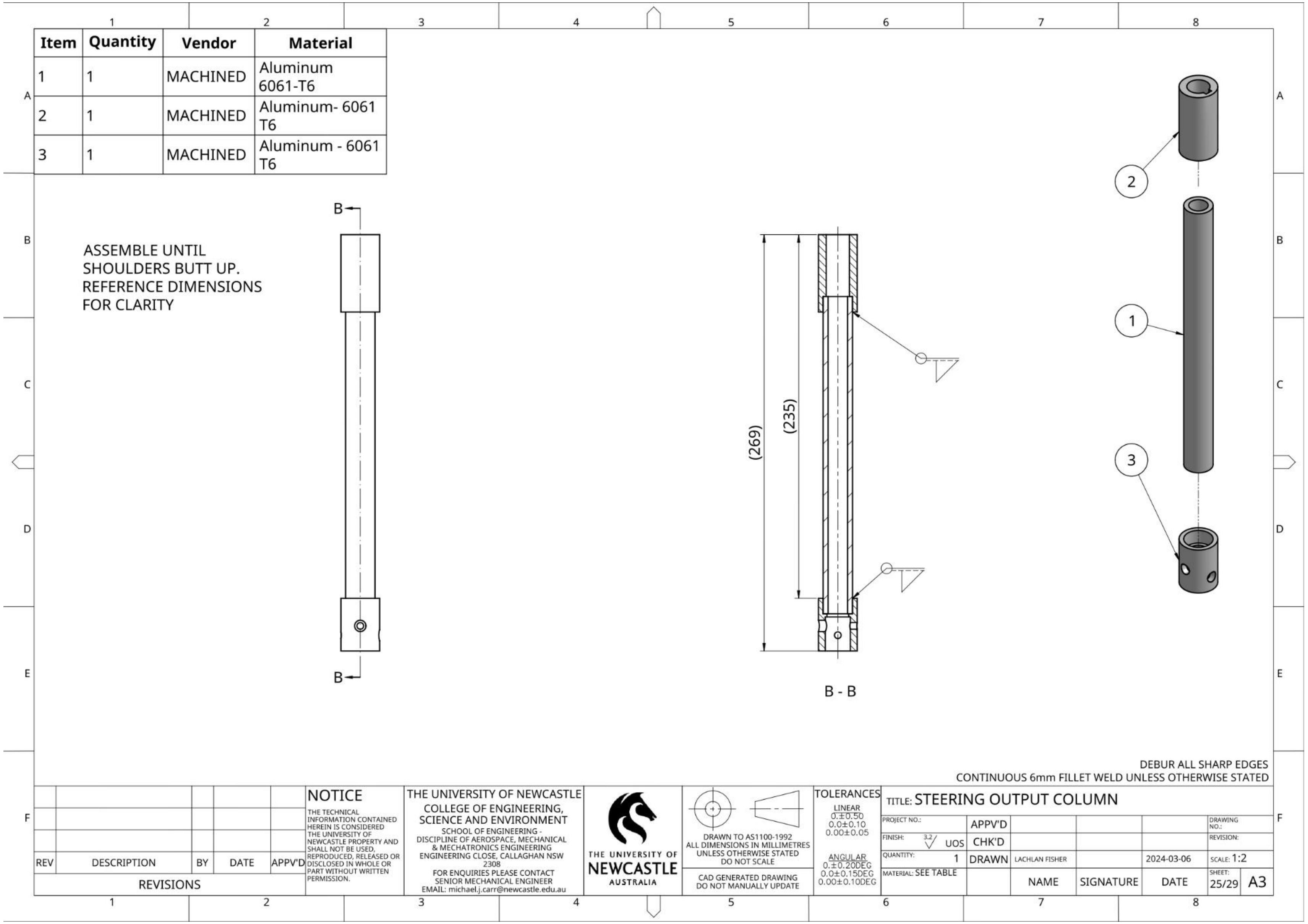
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE

TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

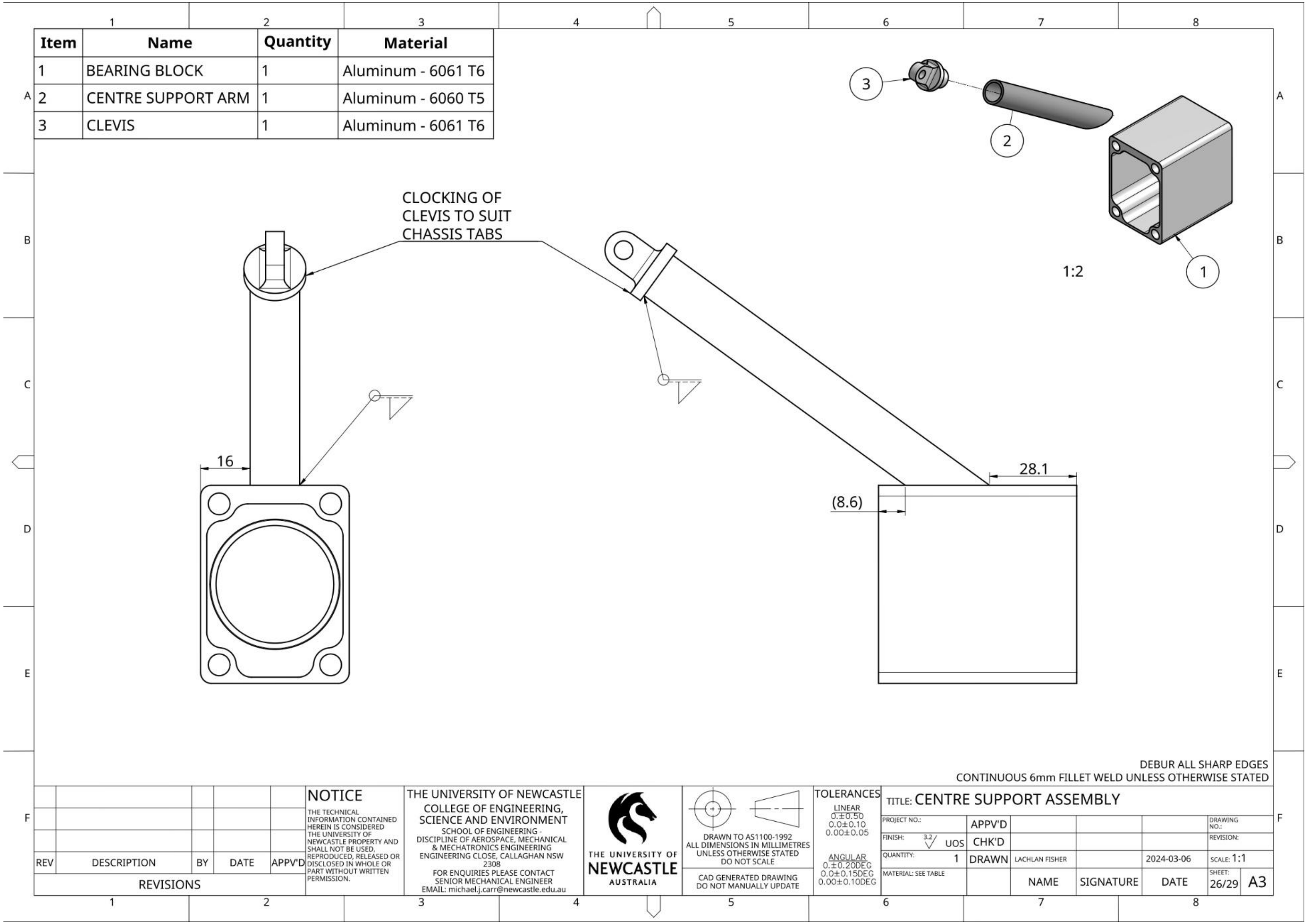
TITLE: STEERING INPUT SHAFT

PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D				REVISION:
QUANTITY: 1	DRAWN	LACHLAN FISHER		2024-03-06	SCALE: 1:1
MATERIAL: SEE TABLE		NAME	SIGNATURE	DATE	SHEET: 24/29 A3

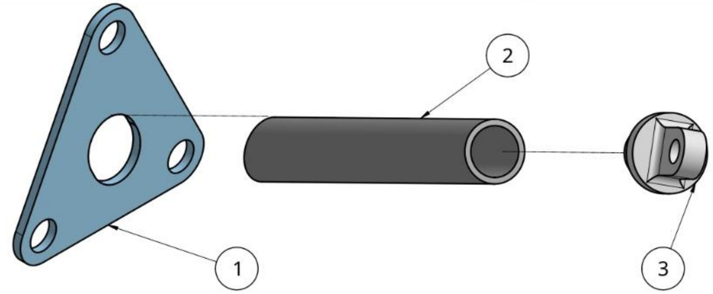
Item	Quantity	Vendor	Material
1	1	MACHINED	Aluminum 6061-T6
2	1	MACHINED	Aluminum- 6061 T6
3	1	MACHINED	Aluminum - 6061 T6

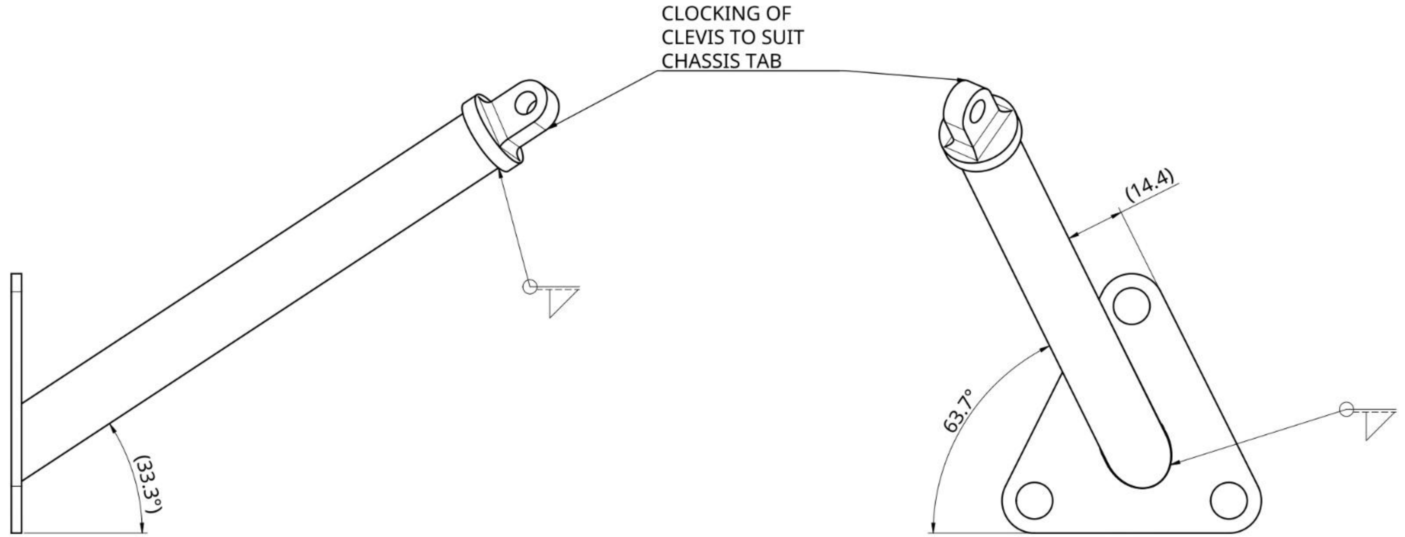


Item	Name	Quantity	Material
1	BEARING BLOCK	1	Aluminum - 6061 T6
2	CENTRE SUPPORT ARM	1	Aluminum - 6060 T5
3	CLEVIS	1	Aluminum - 6061 T6



Item	Name	Quantity	Vendor	Material
1	MOUNTING PLATE	1	SUPPLIED	Aluminum - 6061
2	SIDE SUPPORT ARM	1	MACHINED	Aluminum - 6060 T5
3	CLEVIS	1	MACHINED	Aluminum - 6061 T6





DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D
REVISIONS				

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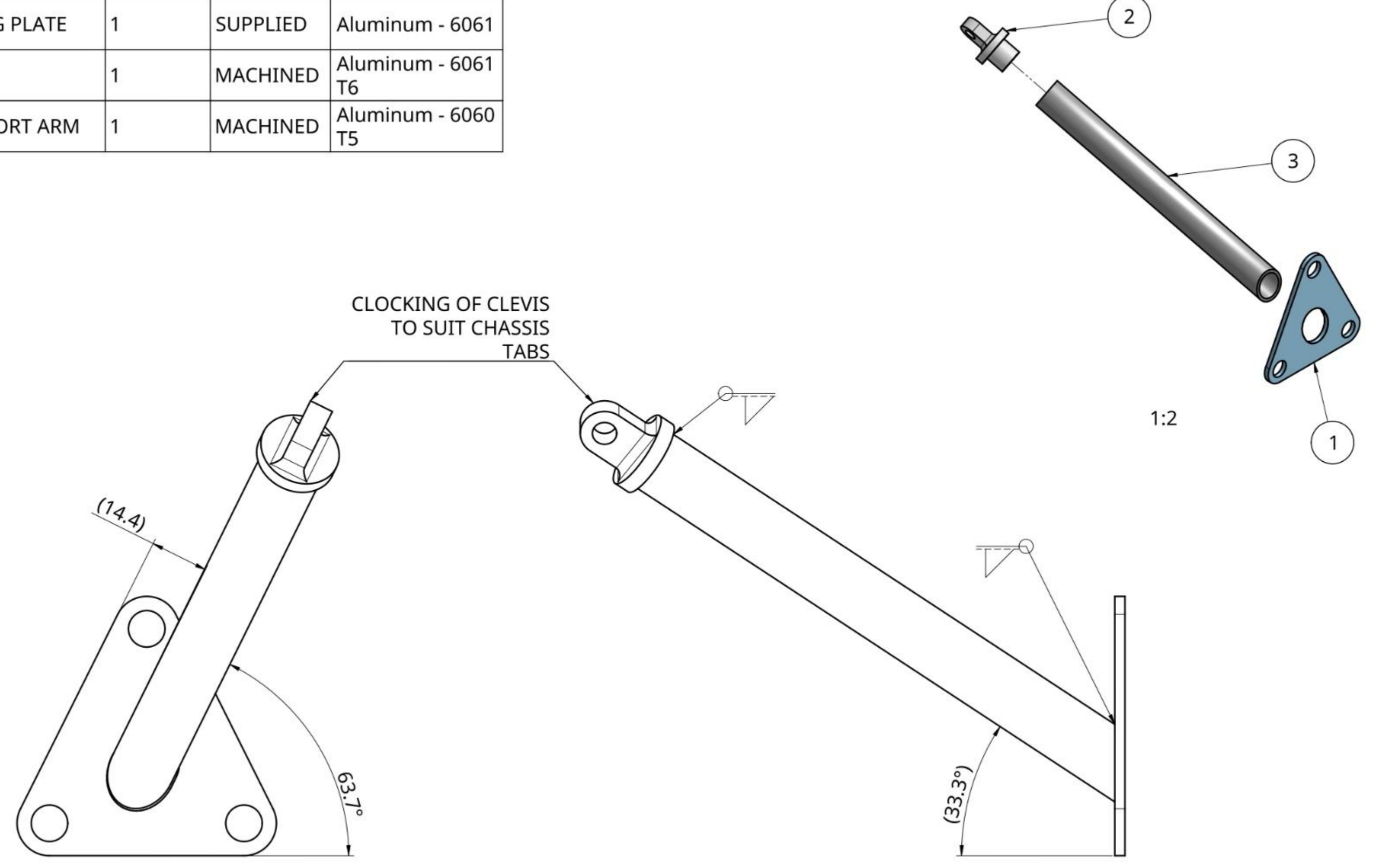
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE

TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: LEFT SUPPORT ASSEMBLY

PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D				REVISION:
QUANTITY: 1	DRAWN	LACHLAN FISHER		2024-03-06	SCALE: 1:1
MATERIAL: SEE TABLE		NAME	SIGNATURE	DATE	SHEET: 27/29 A3

Item	Name	Quantity	Vendor	Material
1	MOUNTING PLATE	1	SUPPLIED	Aluminum - 6061
2	CLEVIS	1	MACHINED	Aluminum - 6061 T6
3	SIDE SUPPORT ARM	1	MACHINED	Aluminum - 6060 T5



DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D

REVISIONS

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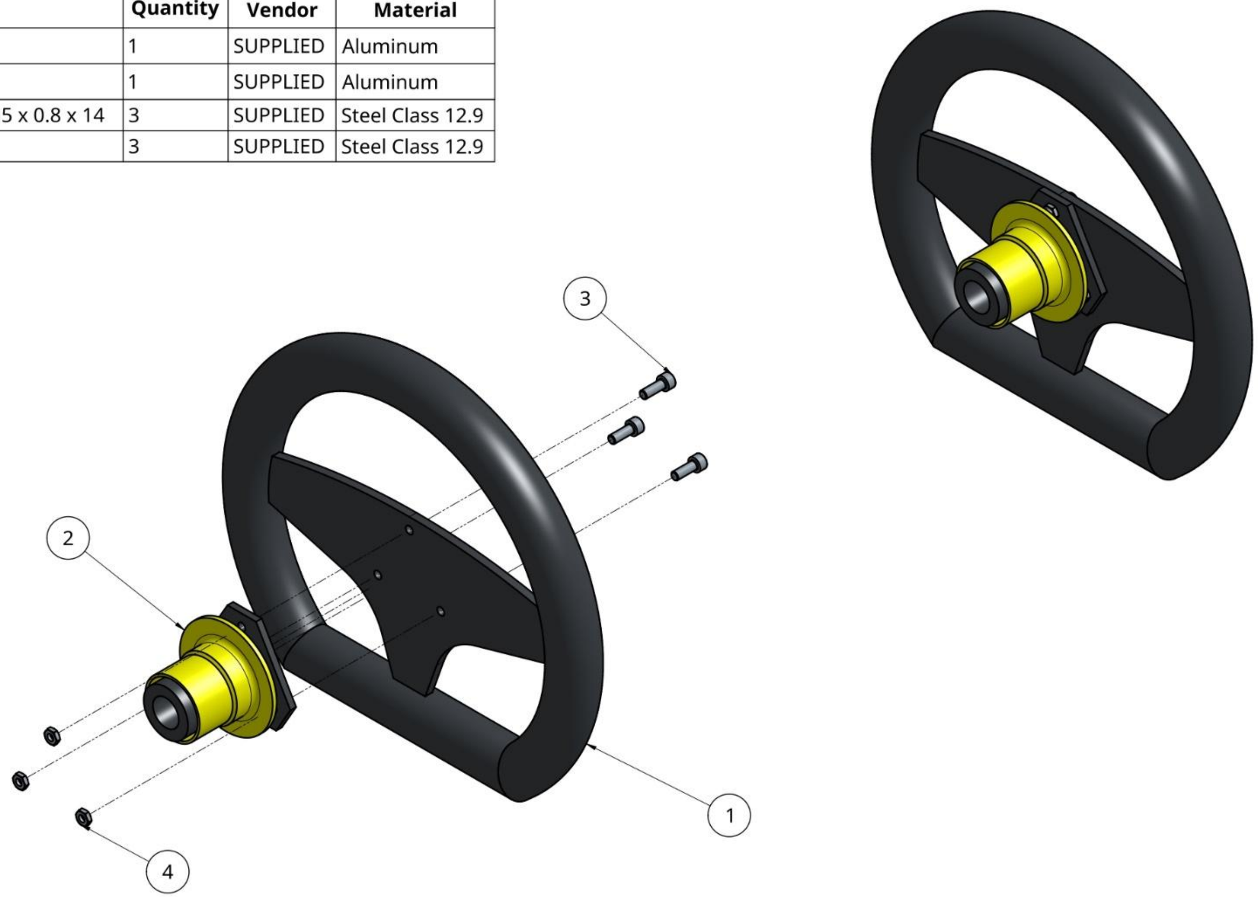
DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE

TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: RIGHT SUPPORT ASSEMBLY

PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D				REVISION:
QUANTITY: 1	DRAWN	LACHLAN FISHER		2024-03-06	SCALE: 1:1
MATERIAL: SEE TABLE		NAME	SIGNATURE	DATE	SHEET: 28/29 A3

Item	Name	Quantity	Vendor	Material
1	STEERING WHEEL	1	SUPPLIED	Aluminum
2	QUICK RELEASE	1	SUPPLIED	Aluminum
3	SOCKET HEAD CAP SCREW M5 x 0.8 x 14	3	SUPPLIED	Steel Class 12.9
4	HEX NUT M5 x 0.8	3	SUPPLIED	Steel Class 12.9



DEBUR ALL SHARP EDGES
CONTINUOUS 6mm FILLET WELD UNLESS OTHERWISE STATED

REV	DESCRIPTION	BY	DATE	APPV'D
REVISIONS				

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DO NOT SCALE
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE

TOLERANCES
LINEAR
0.±0.50
0.0±0.10
0.00±0.05
ANGULAR
0.±0.20DEG
0.0±0.15DEG
0.00±0.10DEG

TITLE: STEERING WHEEL

		NAME	SIGNATURE	DATE	
PROJECT NO.:	APPV'D				DRAWING NO.:
FINISH: 3.2 UOS	CHK'D				REVISION:
QUANTITY: 1	DRAWN	LACHLAN FISHER		2024-03-06	SCALE: 1:2
MATERIAL: SEE TABLE					SHEET: 29/29 A3

11.3. Appendix C – TTC Tyre Data MATLAB Script

Table of Contents

Load Data

```
load RunData_Cornering_Matlab_SI_10inch_Round8\B1965run15.mat
```

Create Segments Dependent on No. of Sweeps

```
%plot(SA)  % Sanity Check of the Data (seeing it sweep from 12 to -12

crossings = find(abs(diff(SA>0))==1);    % finds where the data changes
across a steering angle of 0
crossings = crossings(2:2:end);          % replaces the array with every
second element (shows a full sweep not just 12 to 0 degrees)
crossings = [1; crossings; numel(SA)]; % numel counts the number of elements
in the array %this makes the 1 - all the elements of crossing - last data
point
segsizes = diff(crossings)+1;
```

Create Empty Arrays to Store Data

```
nsegments = numel(crossings)-1;       % number of bins for different sweeps
FYBin = NaN(max(segsizes), nsegments);  % empty array to store Lateral Force
FZBin = NaN(max(segsizes), nsegments);  % empty array to store Normal Force
MXBin = NaN(max(segsizes), nsegments);  % empty array to store Overturning
Moment
SABin = NaN(max(segsizes), nsegments);  % empty array to store Slip Angle
IABin = NaN(max(segsizes), nsegments);  % empty array to store Inclination
Angle
PBin = NaN(max(segsizes), nsegments);   % empty array to store Tyre Pressure
NBin = NaN(max(segsizes), nsegments);   % empty array to store Wheel Speed
[rpm]
```

Place Data in Each Array

```
for seg = 1:nsegments
    %Find the indices of this sweep
    segIndice = crossings(seg):crossings(seg+1);
    %place data in the empty array
    FYBin(1:numel(segIndice), seg) = FY(segIndice);
    FZBin(1:numel(segIndice), seg) = FZ(segIndice);
```

```
    FXBin(1:numel(segIndice), seg) = FX(segIndice);
    MXBin(1:numel(segIndice), seg) = MX(segIndice);
    SABin(1:numel(segIndice), seg) = SA(segIndice);
    IABin(1:numel(segIndice), seg) = IA(segIndice);
    PBin(1:numel(segIndice), seg) = P(segIndice);
    NBin(1:numel(segIndice), seg) = N(segIndice);
end
```

Rearrange Data into Matrices

```
% note these are variables that we change to show data (Pressure, IA,
% Normal Force, etc)

fz_ID = round(mean(FZBin, 1, 'omitnan'), -2);   % take the mean of the
columns to give 1 row (has shape [1 x nsegments]) (the -2 rounds to the
nearest 100)
ia_ID = round(mean(IABin, 1, 'omitnan'));       % take the mean of the
columns to give 1 row
p_ID = round(mean(PBin, 1, 'omitnan'));
sa = round(mean(SABin, 2, 'omitnan'));          %this stores the Slip Angle
as a column vector
fz = round(mean(FZBin, 1, 'omitnan'));
fx = round(mean(FXBin, 1, 'omitnan'));
w_speed = round(mean(NBin, 2, 'omitnan'));
sa_ID = round(mean(SABin, 1, 'omitnan'));
```

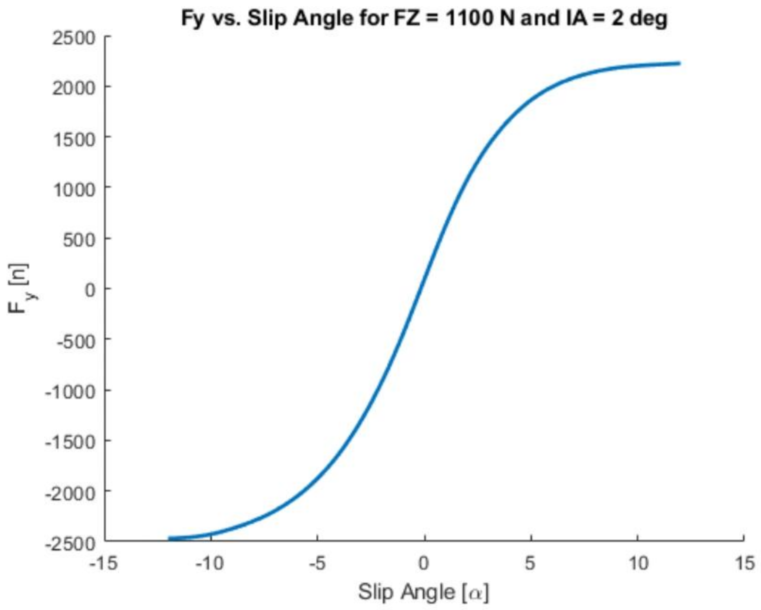
Create Conditions to Show Wanted Conditions

```
condIA0 = ia_ID == 0;       % condIA0 shows Inclination Angle equal to 0
degrees. this makes an array that is 0 (false) when this condition is not
true and is 1 (true) when it is true. This then lets fy be searched using
the elements that are 1 (true) in this array.
condIA2 = ia_ID == 2;
condIA4 = ia_ID == 4;

condP = p_ID == 97;         % in kPa

cond_FZ_200 = fz_ID == -200;    % cond_FZ_200 shows data at the normal force
of 200 N
cond_FZ_400 = fz_ID == -400;
cond_FZ_700 = fz_ID == -700;
cond_FZ_900 = fz_ID == -900;
cond_FZ_1100 = fz_ID == -1100;

cond_sa_0 = sa_ID == 0;


fy_900_IA0 = mean(FYBin(:, condIA0 & condP & cond_FZ_900), 2, 'omitnan');
%stored as a column vector
fy_1100_IA2 = mean(FYBin(:, condIA2 & condP & cond_FZ_1100), 2, 'omitnan');
fx_test = mean(FXBin(:, condIA0 & condP & cond_FZ_900), 2, 'omitnan');

fx_sa0 = mean(FXBin(:, cond_sa_0 & condP & condIA0), 2, 'omitnan');
```

2

```
%attempting to show FX and FZ relation
fz_sa0 = mean(FZBin(:, cond_sa_0 & condP & condIA0), 2, 'omitnan');

fx_900_IA0 = mean(FXBin(:, condIA0 & condP & cond_FZ_1100), 2, 'omitnan');
%sanity check to ensure FX is proper

hold on

%plot(-sa, fy_1100_IA2, 'DisplayName','IA0')
%legend()

fy_1100_IA2_smooth = csaps(-sa, fy_1100_IA2, .1);

hold on
fnplt(fy_1100_IA2_smooth)
title('Fy vs. Slip Angle for FZ = 1100 N and IA = 2 deg')
xlabel('Slip Angle [\alpha]')
ylabel('F_y [n]')
```

Warning: All data points with NaNs or Infs in their site or value will be ignored.



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3

11.4. Appendix D – Design Event Booklet

VEHICLE PERFORMANCE

2024


NU RACING
DESIGN OVERVIEW
DESIGN GOALS
5 YEAR PLAN
2023
• Top 3 in auto-x
• First through tech
• 400 kms testing
• 260 kg car
• Competitive in all static events
2024
• Finish top 5 in endurance
• First traction limited drivetrain output
• Reduction in car weight by 10%
2025
• Design cycle shift earlier
• 80 kW capable accumulator
• Limited slip rear axle
2026
• Monocoque half chassis
• Adjustable anti-roll
• < 215 kg car
2027
• Full monocoque chassis
• < 200 kg
HOW WE WIN
1. Align bottlenecks
2. Prefer simple self-documenting systems
3. Reduce part count
4. Prioritise long-term team performance
ROBOTIC SYSTEMS
JANUS ELECTRIC
AMPCONTROL
SAFEgroup Automation
DSI
ResTech
THALES
Ausgrid
BANLAW
3ME
VARLEY
THE UNIVERSITY OF NEWCASTLE AUSTRALIA
NU TEAMS

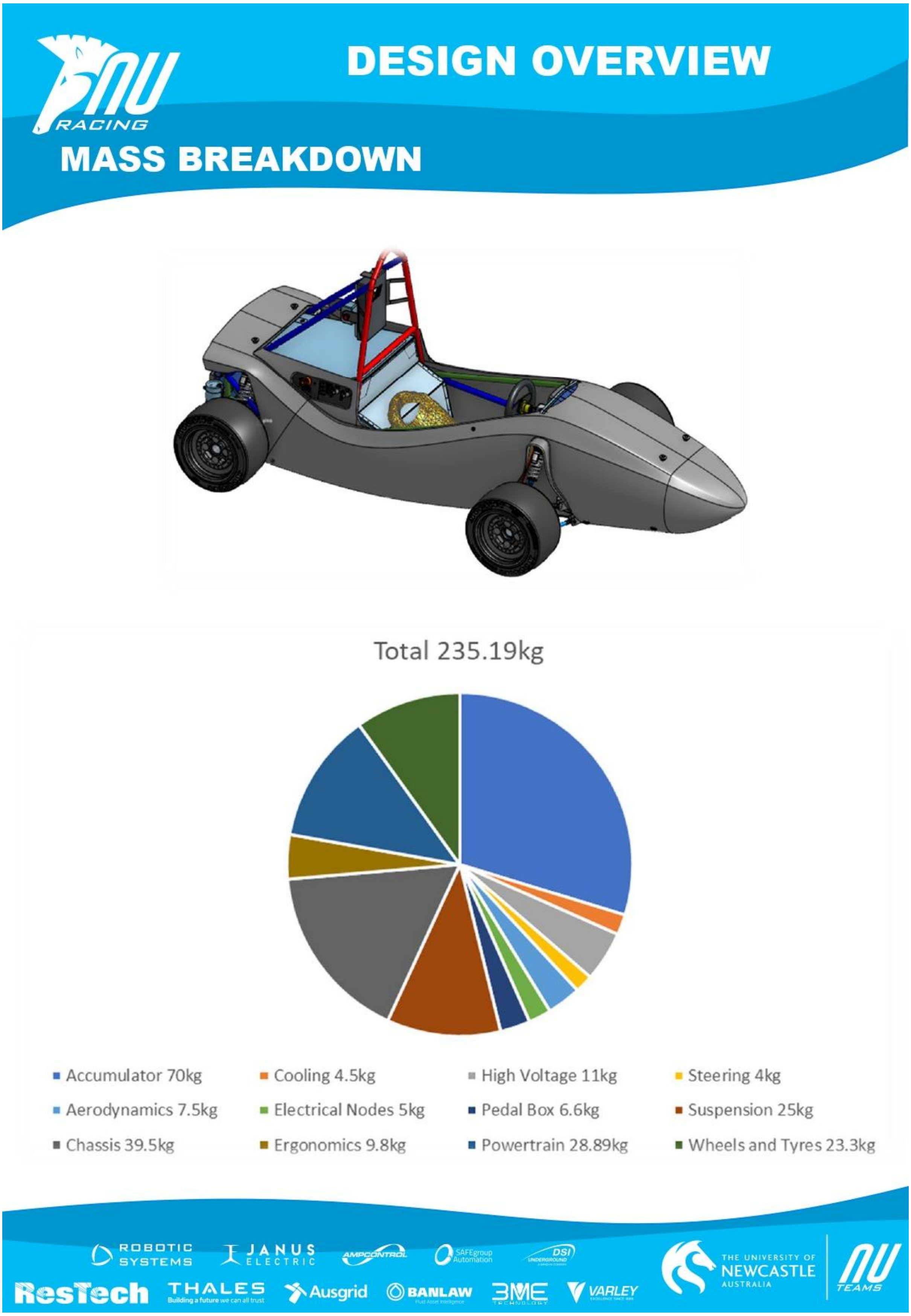
DESIGN OVERVIEW

POINTS GOAL

Event	2023 (7th)	2024 Goal	Delta	Out of
Presentation	72.55	65	-7.55	75
Cost	51.06	70	+18.94	100
Design	130.33	135	+4.67	150
Skid pad	65.77	66	+0.23	75
Acceleration	50.92	65	+14.08	100
Autocross	120.99	121	+0.01	125
Endurance	9*	260	+251	275
Efficiency	52.52	65	+12.48	100
Total	**553.14**	**847**	**+293.86**	**1000**

The total points goal of 847 points would result in first place (by 1.16 points) based on the 2023 Results.

* Projected Points from Endurance 2023 based on the average lap time would be approximately 255.


DESIGN OVERVIEW
MASS BREAKDOWN
Total 235.19kg
Accumulator 70kg
Cooling 4.5kg
High Voltage 11kg
Steering 4kg
Aerodynamics 7.5kg
Electrical Nodes 5kg
Pedal Box 6.6kg
Suspension 25kg
Chassis 39.5kg
Ergonomics 9.8kg
Powertrain 28.89kg
Wheels and Tyres 23.3kg

VEHICLE PERFORMANCE

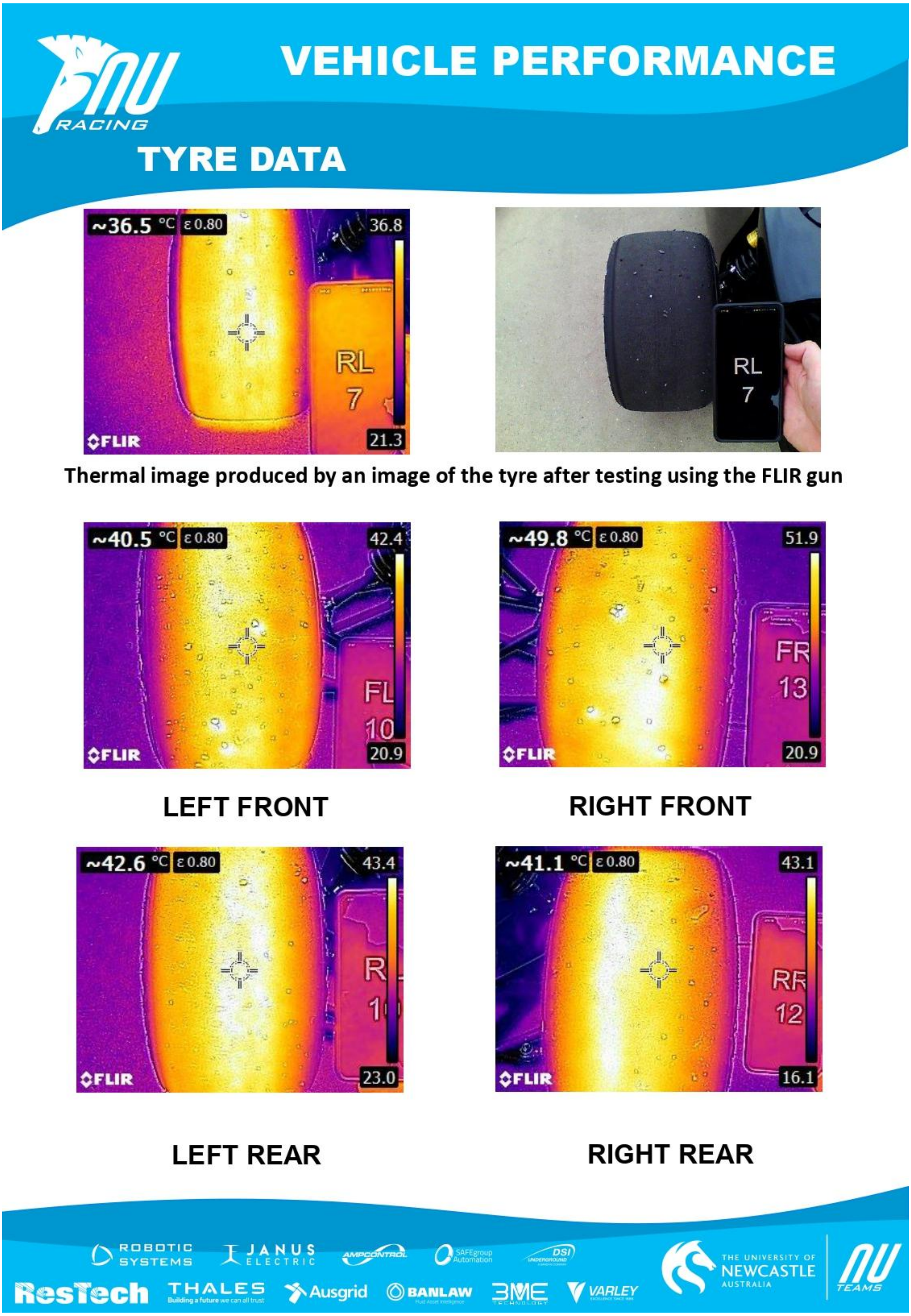
VEHICLE DYNAMICS

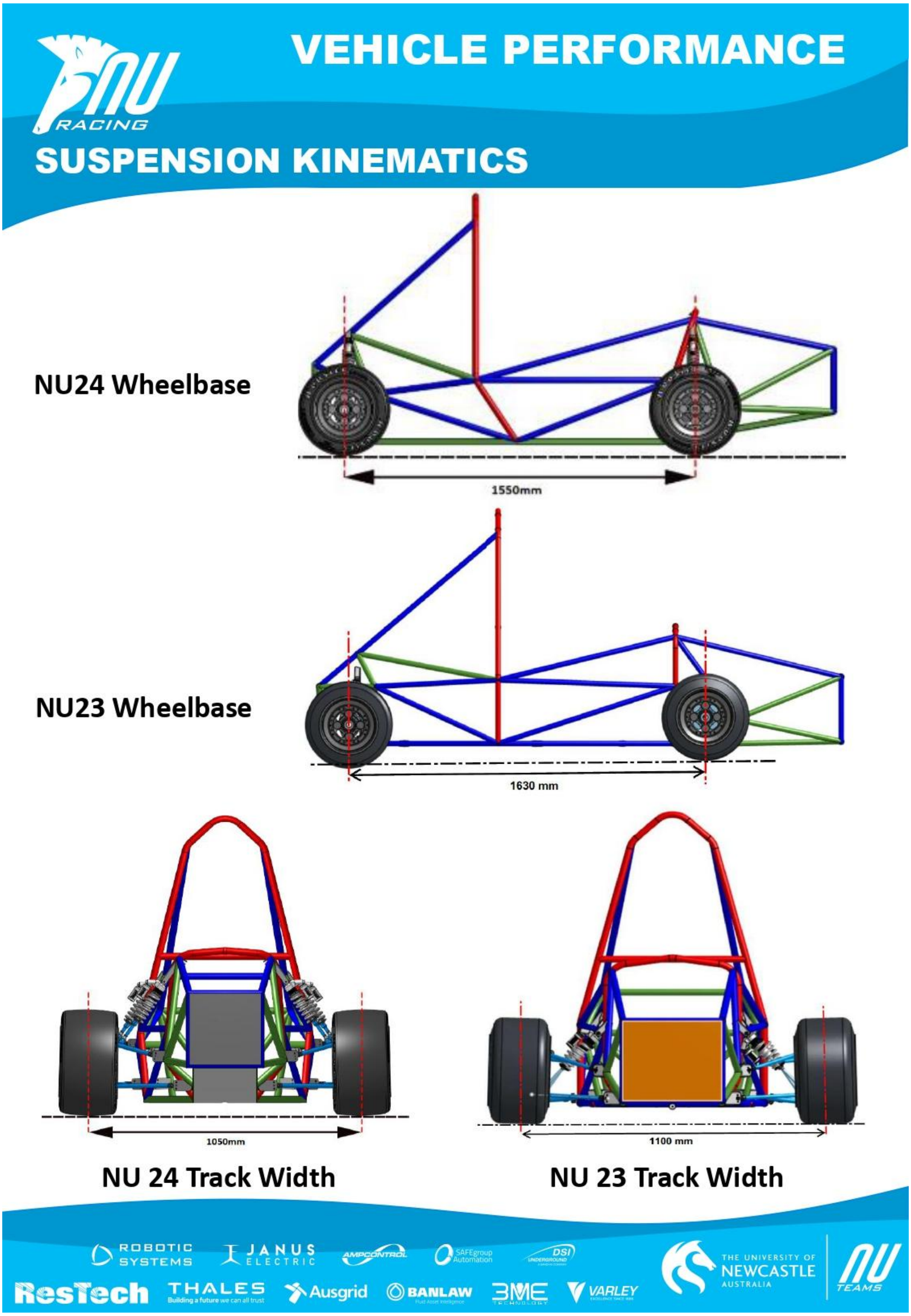
Ways in which we worked towards our goals:

- Repaired design flaws from NU23 by moving strut pickup points
- Retained effective design decisions to avoid increased manufacturing load
- Reduced vehicle size to make racing between cones easier
- Continued to utilize tyre and MoTeC data to make iterative setup changes
- Continued to utilize successful driver training methods

NU 24 Front Suspension

NU 24 Rear Suspension


VEHICLE PERFORMANCE
TYRE DATA
~36.5 °C ε 0.80
36.8
RL
7
21.3
FLIR
RL
7
Thermal image produced by an image of the tyre after testing using the FLIR gun
~40.5 °C ε 0.80
42.4
FL
10
20.9
FLIR
~49.8 °C ε 0.80
51.9
FR
13
20.9
FLIR
LEFT FRONT
RIGHT FRONT
~42.6 °C ε 0.80
43.4
23.0
FLIR
~41.1 °C ε 0.80
43.1
RR
12
16.1
FLIR
LEFT REAR
RIGHT REAR
ROBOTIC SYSTEMS
JANUS ELECTRIC
AMPCONTROL
SAFEgroup Automation
DSI
ResTech
THALES
Ausgrid
BANLAW
3ME
VARLEY
THE UNIVERSITY OF NEWCASTLE AUSTRALIA
NU TEAMS


VEHICLE PERFORMANCE
SUSPENSION KINEMATICS
NU24 Wheelbase
1550mm
NU23 Wheelbase
1630 mm
1050mm
1100 mm
NU 24 Track Width
NU 23 Track Width

VEHICLE PERFORMANCE

DATA - COLLECTION

**MoTeC BR2
Beacon Lap Timer**

**Live Telemetry using
Parani-SD1000 Bluetooth
Serial Adapters**

**Telemetry Connects to
MoTeC T2 and i2**

VEHICLE PERFORMANCE

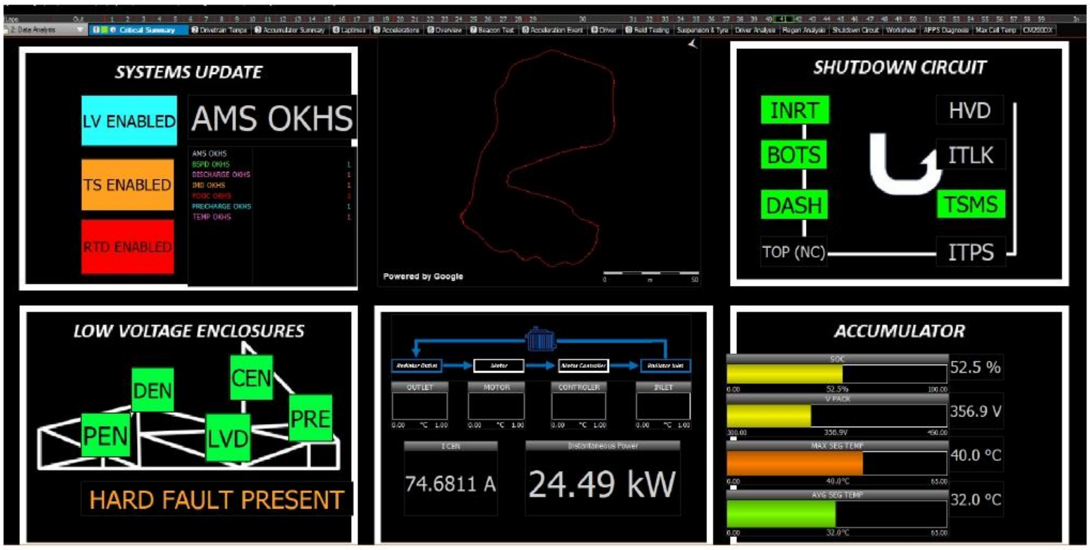
DATA - ANALYSIS

Skidpan Driver Analysis

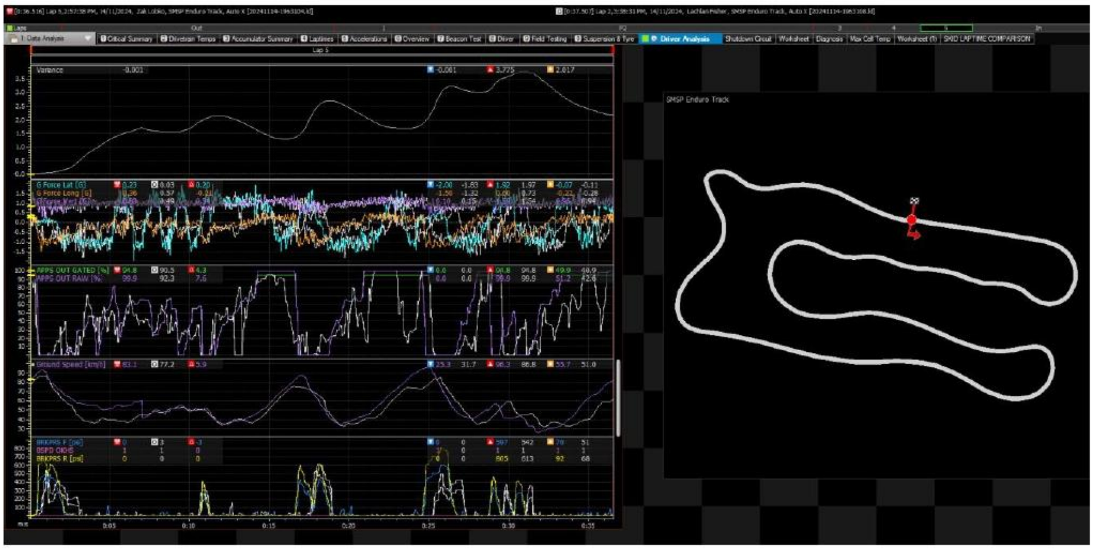
Full Endurance Run

VEHICLE PERFORMANCE

DATA - ANALYSIS



Live System Monitoring



Comparing Auto X Laps between drivers

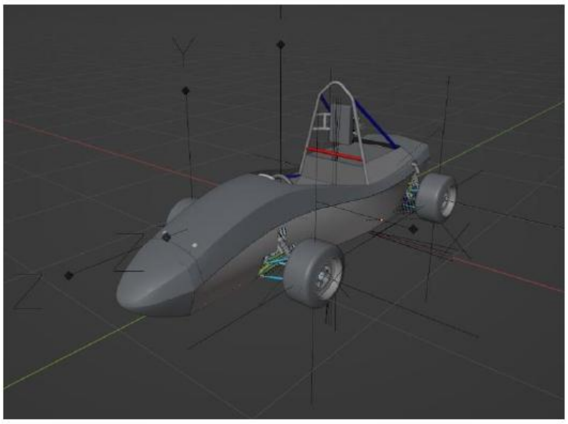
VEHICLE PERFORMANCE

DRIVER TRAINING - NU 16

Utilization of our 2016 ICE car to select and train drivers

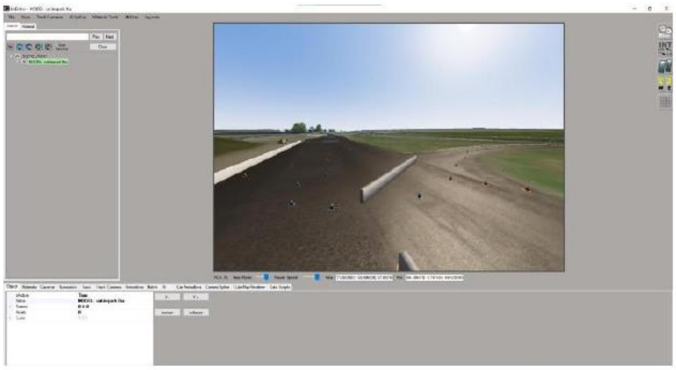
VEHICLE PERFORMANCE

DRIVER TRAINING - SIMULATOR



NU23 being prepared in blender for Assetto Corsa

Calder Park FSAE-A 2023 in KsEditor



NU23 on Calder park FSAE-A 2023 track within Assetto Corsa

ROBOTIC SYSTEMS JANUS ELECTRIC AMPCONTROL SAFEgroup Automation DSI UNDERGROUND ResTech THALES Ausgrid BANLAW 3ME TECHNOLOGY VARLEY THE UNIVERSITY OF NEWCASTLE AUSTRALIA NU TEAMS

DESIGN REPORT

NU 24

Cost Event

Lachlan Fisher

2024

1. Introduction

The Cost Event is one of three static events of the FSAE-A competition. It is made up of the Cost Report, Cost Scenario, and Cost Task. It tasks FSAE Teams with effectively costing their vehicle using universal dollars. Every system and part of the NU 24 was costed.

The Cost Report is used to calculate the cost of prototype vehicle if it was manufactured in a batch of 3000. Each material, process, fastener, and required tooling for every part and system must be completed. A manufacturing drawing for each part and assembly is required for all made parts. All bought parts require a datasheet. These both must be attached to the final Cost Report submission.

After the Cost Report is complete, the Cost Scenario tasks the team with one of three scenarios, which they can choose. The team must then provide a presentation to the Cost Judges and display their findings.

The Cost Task is where one member of the team is required to cost a part of their vehicle live to the judges using the format of the Cost Report.

The Cost Event Lead, the author, is responsible for delegating resources to each section of the Cost Report especially. They are also responsible for compiling the final report, including all the drawings and datasheets prior to submission.

The FSAE Rules, Addendum, and Cost Event Supplement govern the rules of the Cost Event and provide some guidance.

2. Cost Report

2.1. Breakdown

The Cost Report is a report that costs the materials, processes, fasteners, and required tooling to make every part for a prototype vehicle, in this case NU 24. All parts must be classed as bought or made.

The total cost of NU 24 can be seen in Figure 185.

FORMULA SAE AUSTRALASIA

Cost Report

for:

University of Newcastle

Vehicle Number E03

	Vehicle System	Materials	Processes	Fasteners	Tooling	Total
BR	Brake System	$ 1,408.83	$ 359.76	$ 3.99	$ -	$ 1,772.58
DR	Engine/Tractive Path and Drivetrain	$25,020.17	$ 2,869.17	$ 169.09	$ 9.01	$ 28,067.45
FR	Frame and Body	$ 310.50	$ 933.12	$ 30.88	$ 36.53	$ 1,311.02
AD	Aerodynamics	$ 1,119.69	$ 1,409.46	$ 586.06	$ 52.51	$ 3,167.72
EL	Electrical System	$ 3,627.44	$ 830.33	$ 15.12	$ 9.52	$ 4,482.41
MS	Miscellaneous, Fit, and Finish	$ 19.60	$ 58.54	$ 6.62	$ 4.01	$ 88.76
ST	Steering System	$ 153.41	$ 268.91	$ 11.44	$ 12.32	$ 446.09
SU	Suspension	$ 3,076.78	$ 1,228.51	$ 22.54	$ 9.33	$ 4,337.16
WT	Wheels & Tires	$ 574.00	$ 11.68	$ 6.40	$ -	$ 592.08
AV	Autonomous Systems	$ -	$ -	$ -	$ -	$ -
	Total Vehicle	##########	$ 7,969.47	$ 852.14	$ 133.24	$ 44,265.27

Figure 185. Cost Report - Cost Summary

The Cost Report splits the car up into ten different systems as follows:

- Brake System
- Engine/Tractive Path and Drivetrain
- Frame and Body
- Aerodynamics
- Electrical System
- Miscellaneous, Fit, and Finish

- Steering System
- Suspension
- Wheels and Tires
- Autonomous Systems

2.1.1. BOM

From there a BOM template provided by FSAE must be filled out to represent every assembly and part of the car. It is not decided by the team where each assembly goes in the Cost Report, instead the Cost Allocation Flowchart provided by FSAE was used. This is shown in 7.1 Appendix A – Cost Allocation Flowchart.

Each assembly can be broken down into parts or into a further sub-assembly. This is completed at the team’s discretion. It is recommended that assemblies are broken down into sub-assemblies as if they were being removed from NU 24. For example, the Powerbox has the Motor, Spool, and Driveshafts as sub-assemblies. This is shown in Figure 186 where the level dictates if what sub-assembly or part level it is. Level 1 is the Assembly, Level 2 is parts and sub-assemblies, and Level 3 is the same.

University	University of Newcastle
Competition Code	FSAE-A
Year	2024
Vehicle Entry Number	E03

Line No.	Vehicle System		Assembly No.	Level	Part No.	Revision	Assembly/ Part Number	Assembly Description	Part Description
	Brake System	BR							Area Total
20	Engine/Tractive Path and Drivetrain	DR	01	1	000	01	E03-20-DR-011000-01	Powerbox	
21	Engine/Tractive Path and Drivetrain	DR	01	2	001	01	E03-20-DR-012001-01		Motor Plate
22	Engine/Tractive Path and Drivetrain	DR	01	2	002	01	E03-20-DR-012002-01		Brake Plate
23	Engine/Tractive Path and Drivetrain	DR	01	2	003	01	E03-20-DR-012003-01		Chain Guard
24	Engine/Tractive Path and Drivetrain	DR	01	2	004	01	E03-20-DR-012004-01		Scatter Shield
25	Engine/Tractive Path and Drivetrain	DR	01	2	005	01	E03-20-DR-012005-01		Final Drive Bearing
26	Engine/Tractive Path and Drivetrain	DR	01	2	006	01	E03-20-DR-012006-01	Motor	
27	Engine/Tractive Path and Drivetrain	DR	01	3	007	01	E03-20-DR-013007-01		Emrax 228 Motor
28	Engine/Tractive Path and Drivetrain	DR	01	3	008	01	E03-20-DR-013008-01		Transmission Shaft
29	Engine/Tractive Path and Drivetrain	DR	01	3	009	01	E03-20-DR-013009-01		14T Drive Sprocket
30	Engine/Tractive Path and Drivetrain	DR	01	3	010	01	E03-20-DR-013010-01		Sprocket Spacer
31	Engine/Tractive Path and Drivetrain	DR	01	2	011	01	E03-20-DR-012011-01	Spool	
32	Engine/Tractive Path and Drivetrain	DR	01	3	012	01	E03-20-DR-013012-01		Drive Side Tripod Housing
33	Engine/Tractive Path and Drivetrain	DR	01	3	013	01	E03-20-DR-013013-01		Brake Side Tripod Housing
34	Engine/Tractive Path and Drivetrain	DR	01	3	014	01	E03-20-DR-013014-01		46T Drive Sprocket
35	Engine/Tractive Path and Drivetrain	DR	02	1	015	01	E03-20-DR-021015-01	Driveshafts	
36	Engine/Tractive Path and Drivetrain	DR	02	2	016	01	E03-20-DR-022016-01		Driveshaft

Figure 186. Powerbox BOM Breakdown

Extra care must be taken when completing the BOM as there are large point penalties for missing parts, assemblies, and fasteners.

2.1.2. Material Table

A Material Table, provided by FSAE, lists the materials that can be used to manufacture the vehicle. These are not just raw materials such as aluminium and steel but also include bought components such as bearings, tyres, brake master cylinders, and electrical connectors.

For each material there is a Size1, Size2, C1, and C2 as well as a formula that is used to calculate the unit cost for any part. C1 and C2 are constants that do not need to be updated. Size1 and Size2 are measured values from the part. This means that the Material Table must be edited to generate costs for different sized items.

For example, a Steel Ball Bearing has Size1 which is the outer diameter in mm, and Size2 as the thickness. C1 is 0.003 and C2 is 0.05. The formula is for the Ball Bearing is shown in shown in Equation 7.1

$$Cost = ([C1] * [Size1]) + [C2] \tag{7.1}$$

Therefore, for a 110 mm bearing the cost is $0.38.

Some parts instead just have a unit cost. For example, Hoosier LC0 16 × 7.5 × 10 tyres are $85/tyre.

Due to the amount of items in the Material Table (1043) and how often it is required the possibility of someone editing a unit cost or formula is quite high. Due to this every column in the Material Table besides Size1 and Size2 is locked. This is achieved by protecting the sheet and editing the unlocking certain cells [48].

Protecting the sheet also requires adding a password to the sheet. This password should only be known by the Cost Event Lead and kept in a safe place.

If there is not a material cost for a bought item and it is unreasonable to cost as manufactured, the team can fill out a Catalogue Add Item Request (CAIR) form to FSAE-A and they will consider adding a material and unit cost. For example, the team submitted a CAIR form for the High Voltage DC-DC and the team received the response in Figure 187.

Dear Timothy,
Please see the judgements on these Cost add Item Requests as follows:
Item 1:
Item Description: " DC DC (450V Input, 14V Output)"
Cost Catalogue Affected: Materials
Approval Status: Affirmed
Description: Power Converter, DC-DC, HV to LV, per kW
Supplier: Any
Category: Electronics
Unit Cost: [Needs Calc]
Unit1: kW
Size1: Output Power
[C1]: 125
Formula: =[C1]*[Size1]
Comments: For DC-DC converters used between the HV Accumulator circuit and the LV power system. Cost per kW of rated output power.
Please reach out if you have any confusion in this ruling.
FSAEA Cost Committee.

Figure 187. DC-DC CAIR Response

An exerpt of the Material Table is shown in Figure 188.

792	Printed Circuit Board	Any	Printed Circuit Boards	mm^2		26516.291	2	=0.002*[Size1]*[Size2]	$	106.07
793	Complex Integrated Circuit	Any	Printed Circuit Boards	unit					$	10.00
794	Conformal Coating	Any	Printed Circuit Boards	mm^2	unit	12813.9965	2	=0.00000127*[Size1]*[Size2]	$	0.03
795	Connector, Wire to Board, Aerospace Quality	Any	Printed Circuit Boards	pin				=1*[Size1]	$	-
796	Connector, Wire to Board, Computer Type	Any	Printed Circuit Boards	pin				=1*[Size1]	$	-
797	Connector, Wire to Board, High Power, > 2 Amps	Any	Printed Circuit Boards	pin				=2*[Size1]	$	-
798	Connector, Wire to Board, OEM Quality	Any	Printed Circuit Boards	pin				=0.5*[Size1]	$	-
799	Connector, Wire to Board, Single Wire	Any	Printed Circuit Boards	pin				=0.05*[Size1]	$	-
800	Development Board, Hobby	Any	Printed Circuit Boards	unit					$	20.00
801	Flexible Printed Circuit Board		Printed Circuit Boards	mm^2		Surface Area	Number of layers	=0.004*[Size1]*[Size2]		#VALUE!
802	Memery Chip, RAM or ROM	Any	Printed Circuit Boards	Unit		MB of storage		=0.0024*[Size1]		#VALUE!
803	Simple Integrated Circuit	Any	Printed Circuit Boards	Unit					$	2.00
804	Simple PCB component	Any	Printed Circuit Boards	unit				=0.02*[Size1]	$	-
805	Semi-complex PCB component	Any	Printed Circuit Boards	unit		19		=0.05*[Size1]	$	0.95
806	Aluminum Metal Matrix Composite (by Dimensions)	Any	Raw Material	kg				=33*[Area]*[Length]*[Density]	[Needs Calculation]	
807	Aluminum, Normal (by Dimensions)	Any	Raw Material	kg				=4.2*[Area]*[Length]*[Density]	[Needs Calculation]	
808	Aluminum, Premium (by Dimensions)	Any	Raw Material	kg				=4.2*[Area]*[Length]*[Density]	[Needs Calculation]	

Figure 188. Exerpt of the Material Table

2.1.3. Process Table

The Process Table is like the Material Table in its function. It provides a list of Processes that can be used to manufacture and assemble parts, fasteners, and materials. Each process has a unit cost and unit depending on its use. For example, Machining is a process that has a $0.04 unit cost. Its units are given in cm^3. This means that when machining it costs $0.04/$cm^3$.

The comments in the Process Table provide context and tips for each process.

The most used process is the Assembly process. It costs the physical movement of parts together. Assembly cost is per unit however it is determined on the fit type. Loose is parts that require no force, Line on Line means they are a closer fit, and some force is required to move it into place, and Interference where significant force is required [49]. Assembly is also costed on weight of the assembly or part being moved. The weights are 1 kg, 3 kg, 5 kg, 10 kg, 15 kg, 20 kg, and >20 kg. The weight of the part must be equal to less than the weight used for the Assembly process. For example, a 4.5 kg assembly requires a 5 kg Assembly process.

The Process Table also needs to be locked in the same way as the Material Table.

2.1.4. Process Mutlipier Table

The Process Mutlipier Table supplies the cost multipliers for different process and materials that are multiplied to the process cost. For example, there are material multipliers that are used when a certain material is machined. The represent the difficulty of the process (i.e. stainless steel is harder to machine than aluminium).

Fastener engagement lengths are another multiplier. They represent the length of the thread of the bolt or stud during assembly. The longer a thread is, the longer it takes to fasten and is therefore penalised.

Repeat multipliers are similar to increasing the quantity of the process. It just shows that the process needs to be repeated a certain number of times.

2.1.5. Tooling Table

The Tooling Table is used to cost the manufacture of a jig or fixture to mass produce a part. As the Cost Report is costing the manufacture of 3000 vehicles, tool would be used to create the same part together 3000 times.

The Production Volume Factor (PVF) represents the manufacture of 3000 cars and is used to divide the tooling costs by this number to gain a unit cost. Note that 3000 is used for all parts that are not a composite monocoque part, where 120 is used instead.

For example, a welding fixture would be created to weld the Chassis together. As this fixture is used to make the 3000 Chassis' the unit cost for the fixture is the tooling cost ÷ PVF (where the PVF = 3000).

2.1.6. Fastener Table

The Fastener Table provides the cost for every fastener used on the car. As for certain materials, a Size1, Size2, C1, and C2 are used to generate a unit cost for each fastener. Again like the Material Table everything must be locked except the Size1 and Size2 columns.

2.1.7. Part and Assembly Template

Part and Assembly Templates were created by Drew Bender for the 2023 Cost Report and only slightly changed for 2024 [1]. The 2024 Part Template is shown in Figure 189.

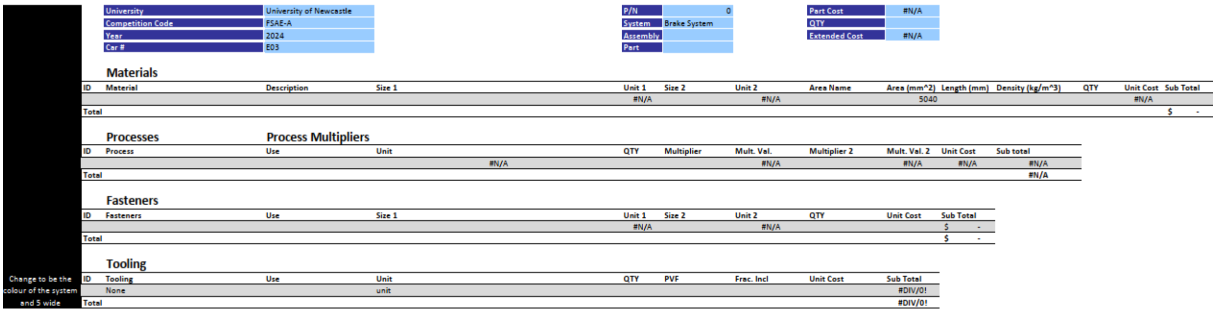


Figure 189. Part Template

The Part Template allows space for the material, process, fastener, and tooling cost to be completed.

The Material, Process, Multiplier 1 and 2, Fastener, and Tooling cells are all cells that use Data Validation to create drop down lists from the respective table (i.e. Material Table). When a drop down is selected the unit cost, multiplier value, and units are automatically updated using the XLOOKUP function.

The Part Number and System are automatically updated when the Part Name is entered from an XLOOKUP function that references the BOM.

The Assembly Template is very similar to the Part template and is shown in Figure 190.

University	University of Newcastle	A/N	0	Part Cost	N/A
Competition Code	FSAE-A	System	Brake System	QTY	N/A
Year	2024	Assembly		Extended Cost	#N/A
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	0				$ -
Total					$ -

Processes **Process Multipliers**

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val. 2	Unit Cost	Sub total
			#N/A			#N/A		#N/A	#N/A	#N/A
Total										#N/A

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Change to be the colour of the system and 5 wide

Figure 190. Assembly Template

2.1.8. Template Instructions

The Template Instructions shown in Figure 191 were completed by Drew Bender and not altered for 2024 as the templates did not change significantly [1]. These allow members of the team to understand the workflow of the Cost Report quickly and easily.

INSTRUCTIONS FOR COMPLETE TEMPLATE SHEET

TO BEGIN EDITING:
MAKE A COPY OF THE PART/ASSEMBLY/SYSTEM TEMPLATE SHEET. RIGHT CLICK THE COPIED SHEET AND SELECT PAUSE PROTECTION. TYPE PASSWORD "unlock"
RENAME COPIED SHEET YOUR SYSTEM/ASSEMBLY/COMPONENT AND ADD RELEVANT TAB COLOUR
NOTE: WHEN COMPLETELY FINISHED WITH THE SHEET, RIGHT CLICK AND RESUME PROTECTION

MATERIALS:
SELECT YOUR MATERIAL FROM THE DROP DOWN MENU
UNIT 1 AND UNIT 2 WILL AUTOMATICALLY BE INPUT INTO THE ROW, DO NOT TOUCH

RAW MATERIALS:
CHECK tblMaterials FOR UNIT COST AND DENSITY, INPUT INTO TEMPLATE
INPUT AREA, LENGTH AND QUANTITY
J9*K9*L9/10^9*N9*M9
ENTER ABOVE FORMULA INTO SUB TOTAL CELL WITH AN EQUAL SIGN IN FRONT, DRAG DOWN FOR ANY MORE RAW MATERIAL CALCULATIONS

ALL ELSE:
FOLLOW SAME INSTRUCTIONS AS FASTENERS BUT FOR tblMaterials
NOTE: SUBTOTAL WILL NOT BE AUTOMATICALLY CALCULATED LIKE IN FASTENERS, ADD A FORMULA THAT MULTIPLIES QTY BY UNIT COST

PROCESSES:
SELECT YOUR PROCESS FROM DROP DOWN MENU
UNIT AND UNIT COST WILL AUTOMATICALLY BE INPUT INTO THE ROW, DO NOT TOUCH
READ tblProcess SHEET AND DETERMINE WHAT MULTIPLIER IS NEEDED
SELECT MULTIPLIER FROM DROP DOWN MENU, MULT VAL WILL AUTOMATICALLY BE INPUT
REPEAT ABOVE STEP FOR MULTIPLIER 2 AND MULT VAL 2
ENTER QUANTITY AND SUB TOTAL WILL BE CALCULATED

FASTENERS:
SELECT FASTENER FROM DROP DOWN MENU
UNIT 1 AND UNIT 2 WILL AUTOMATICALLY BE INPUT, DO NOT TOUCH
GO TO tblFasteners SHEET, INPUT SIZE 1 (AND SIZE 2 IF NEEDED). INSTRUCTIONS IN COMMENTS COLUMN
NOTE GENERATED CALC PRICE AND INPUT INTO UNIT COST IN TEMPLATE
INPUT SIZE 1 (AND SIZE 2 IF NEEDED) IN TEMPLATE
ENTER QUANTITY AND SUB TOTAL WILL BE CALCULATED
NOTE: SOME FASTENERS ALREADY HAVE A PROVIDED UNIT COST IN tblFasteners

TOOLING:
SELECT TOOLING FROM DROP DOWN MENU
UNIT COST WILL AUTOMATICALLY BE INPUT, DO NOT TOUCH
SELECT PVF FROM DROP DOWN MENU AND INPUT FRAC INCL (GUIDE IN tblTooling)
ENTER QUANTITY AND SUB TOTAL WILL BE CALCULATED

ADD A NEW ROW:
CLICK THE ROW NUMBER BELOW THE LAST USED ROW TO SELECT THE ROW
RIGHT CLICK THE ROW NUMBER AND SELECT INSERT
SELECT YOUR MATERIAL/PROCESS/FASTENER/TOOLING FROM THE DROP DOWN MENU
THE REST OF THE ROW AND ASSOSCIATED FORMULAS WILL APPEAR

[redacted]

		Processes		Process Multipliers						
15										
16		Processes		Process Multipliers						
17	ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Unit Cost	Sub total
18		Attach Wire, Fork		unit	0.5	-	1	$ 0.25	$ 0.13
19		Potting		cm	3	Repeat 10	10	$ 0.50	$ 15.00
20									

DELETE A ROW:
CLICK THE ROW NUMBER YOU WANT TO DELETE
RIGHT CLICK ROW NUMBER AND SELECT DELETE
NOTE: IF ANY SECTION (MATERIALS/PROCESSES/FASTENERS/TOOLING) IS NOT REQUIRED, DELETE ALL THE ROWS UNDER THE HEADING. THE RESULT IS SHOWN BELOW

Tooling							
ID	Tooling	Use	QTY	PVF	Frac. Incl	Unit Cost	Sub Total

Figure 191. Template Instructions created by Drew Bender [1]

2.2. Scoring

The overall cost of the vehicle, a D multiplier, and an A multiplier are used to create the penalised score of the car from the Cost Report. This is shown in Figure 192.

a. The raw cost of the vehicle will be used as a base value in which 2 multipliers for accuracy and documentation submission quality will be applied to determine the penalised cost value of the vehicle.

$$P_{(your)} = P_{(reported)} * D * A$$

where

i. "P(your)" is your penalised vehicle cost.

ii. "P(reported)" is the vehicle cost as reported in the cost report submitted and after processing of any changes made in the Cost Addendum and the targeted component penalty process, if applicable.

iii. "D" is a multiplier used to adjust the cost based on documentation inadequacies and assessing the readiness for manufacturing of your vehicle. This multiplier represents the additional costs produced downstream due to the lack of completeness of the vehicles documentation. The multiplier is calculated as the multiple of the 4 sub-multipliers D1 through D4, as below.

$$D = D_1 * D_2 * D_3 * D_4$$

iv. "A" is a multiplier used to adjust the cost based on the accuracy of the costing calculations presented in the cost report, using a combination of subsections in the vehicles, as described in S.3.17, to determine an estimated accuracy level for the entire cost report submitted. This multiplier represents the additional costs incurred into the vehicle mass production build due to the inaccuracies present in the cost report data, nominally through process and capital planning and execution.

Figure 192. Penalised Cost Scoring [50]

The four D multipliers are datasheets, renders/images, assembly drawings, and part drawings. If any of these additional documents are not supplied with the submitted Cost Report the value of the corresponding D multiplier increases, which increases the cost of the car.

The A multiplier, as shown in Figure 192, is derived from the accuracy of a subset of systems chosen by FSAE-A. These sub-sections are not informed to the team until the Cost Briefing, which occurred on the Wednesday afternoon before competition began on Thursday. The groups of sub-sections that can be chosen are shown in Figure 193.

a. DR (Engine/Tractive Path and Drivetrain) and EL (Electrical).

b. CH (Chassis) and MS (Miscellaneous, Fit, and Finish).

c. SU (Suspension), ST (Steering), and BR (Brakes).

d. AD (Aerodynamics) and WT(Wheels and Tyres).

Where a vehicle has little to no aerodynamic devices fitted, the judges may elect to include the ST (Steering) and BR (Brakes) systems to ensure a large enough section of the cost report is reviewed to apply the "A" multiplier equally across all vehicles.

Figure 193. Accuracy System Selection [50]

The final overall score is a normalised score, depending on your overall cost, and the minimum and maximum costs of each team's cars. This is shown in Figure 194.

S.3.16.1 The cost report score will be issued as a score out of 80. The cost report score, prior to the omitted item penalisation strategy, will be issued based on the vehicles cost relative to other vehicles in the competition, using the below formula.

$$\text{Cost report score} = 80 * \frac{(\text{Pmax} - \text{Pyour})}{(\text{Pmax} - \text{Pmin})}$$

Figure 194. Overall Cost Report Scoring [50]

2.3. Contribution

The authors contributions to the Cost Report as the Cost Event Lead are as follows:

- Costing of the:
  - Brake System
  - Steering System
  - Powerbox
  - Tractive System
  - Aerodynamics
  - Wheels and Tires
- Delegation of Cost Report tasks:
  - Costing of systems
  - Creating drawings
  - Creating wiring diagrams
  - Supplying datasheets
- Organisation and finalisation of the Cost Report:
  - Formatted all sections
  - Added all drawings, wiring diagrams, and datasheets
- Review of Cost Report Systems

2.4. Costing Machined Parts

For machined parts in the Cost Report the process requires the volume of material removed. This is not something that can often be easily calculated. The method that the 2024 team used was modelling the stock (blank material before manufacture) in the same part studio as the part you were costing. Then using a Boolean operator to subtract the volume of the finalised part. Once this was complete, the volume could be easily seen using Onshape's measurement tab.

An example of this is the Drive Side Tripod Housing in the Spool Assembly. The process list is shown in Figure 195.

	Processes	Process Multipliers								
ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Machining Setup, Install and remove	Set up lathe	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining	Turn front face of Tripod Housing	cm^3	1955.2	Material - Aluminum	1	None	1	$ 0.04	$ 78.21
	Machining Setup, Change	Flip in lathe	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Machining	Face excess stock	cm^3	53.0144	Material - Aluminum	1	None	1	$ 0.04	$ 2.12
	Machining	Machine up to sprocket flange and chamfer	cm^3	24.6017	Material - Aluminum	1	None	1	$ 0.04	$ 0.98
	Machining Setup, Change	Change to boring bar	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Machining	Bore out Ø76.7 mm hole	cm^3	468.722	Material - Aluminum	1	None	1	$ 0.04	$ 18.75
	Machining Setup, Install and remove	Set up mill	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining	Mill out tripod housing	cm^3	109.593	Material - Aluminum	1	None	1	$ 0.04	$ 4.38
	Machining Setup, Change	Flip in mill	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Machining	Machine out sprocket holes and profile	cm^3	31.7219	Material - Aluminum	1	None	1	$ 0.04	$ 1.27
Total										$ 110.26

Figure 195. Costed Process List for the Drive Side Tripod Housing

To get the volumes for each process, the model shown in Figure 196 was generated. Each colour of the model represents a different process. For example, the blue volume is the second process "Turn front face of Tripod Housing" and has a volume of 1955196 mm^3. What must be noted is that the Cost Report asks for machining volumes to be in cm^3. Therefore, the total removed volume from this process is 1955.2 cm^3.

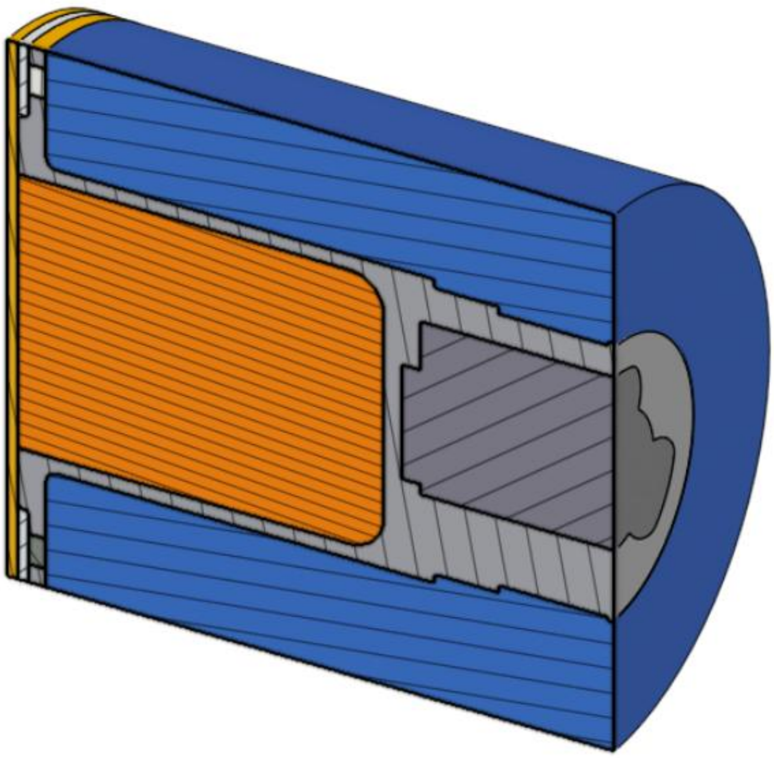


Figure 196. Section View of the Drive Side Tripod Housing and Resulting Volumes

To ensure that this modelling was not lost, and so it could be checked, the feature in the model tree used to create the Boolean volumes are grouped into a folder and suppressed.

2.5. Cost Report Export and Organisation

The Cost Report needs to be submitted as a PDF to FSAE. Due to the sheer size of the spreadsheet the team in 2023 had issues exporting the file and being able to easily add drawings and datasheets. The author was able to export the PDF with no issue and add drawings and datasheets easily.

The export process from Excel is quite simple. Simply follow:

File > Export > Create PDF / XPS Document

Once the new window opens select “Optimize for: Minimum size”. Make sure to press “Options…” and select Entire workbook under “Publish what”.

After this the document can be published and easily opened.

To add the drawings and datasheets the author suggests using Foxit PDF Editor. It is a paid service, but a free trial can be used to compile the Cost Report.

3. Cost Scenario

3.1. Introduction

The Cost Scenario is a presentation that must be address one of three options given by FSAE-A. From this the team must present their given information to the Cost Judges who then deliver a score out of 15 total competition points.

3.2. Scenario

From the three given options, the author selected the third which is shown in Figure 197. The Cost Scenario was completed by the author, Alec Chapman, and Joshua Hayward.

<u>Option 3:</u>

Teams are to assume that their prototype vehicle has been selected to go into production, however the FSAEA Management team has received a request from key stakeholders that the profitability of the production run needs to increase, with this to be achieved through a minimum 5% decrease in vehicle production costs. This reduction of costs should result in a performance change of no more than 1%, and the general styling of the vehicle should remain unaffected. Teams are to present a proposal which presents the following information:

a. Their reported cost, and what level of savings would be required to meet the 5% cost decrease target.

b. A feasibility analysis on this target, highlighting:

    i. A list of assemblies which the team believes can have reduced production costs without effects on performance;
    ii. An estimation of the cost deltas across these assemblies.
    iii. A detailed costing of at least 2 of these assemblies to give reasonable proof that the cost estimations are accurate.

c. A summary of validation testing required to validate the changes are within the <1% performance difference requirement.

d. A recommendation on whether the cost reduction activities are feasible to produce a 5% vehicle production cost reduction.

Figure 197. Cost Scenario

This option was immediately selected due to the goals and scoping of NU 24 which was to create a serviceable car. Due to this, when completing the Cost Report items such as the Quik Latch connectors for the Body Kit and the Dry Break Disconnects in the Brake Lines had to be costed as well. These were quite expensive in the Cost Report, equating to nearly 2% of the total vehicle cost.

As these were only included on NU 24 for serviceability and ease of use, they could be removed at no loss of performance. This was input into a duplicate version of the Cost Report to provide the cost analysis difference.

Alec Chapman and Joshua Hayward completed costing and calculations to prove the downsizing the Emrax 228 to the Emrax 208 would be possible in within the <1% target dictated by the scenario [32], [39].

Following this the author, Chapman, and Hayward created a presentation of the findings, with the assistance of Zak Lobko, to present at competition. This is shown in 7.2 Appendix B – Cost Scenario Presentation.

4. Cost Task

4.1. Introduction

The Cost Task takes place during the Cost Event at competition and is worth 5 competition points. A part on the car is selected at random and a member of the team is required to complete the costing in the same format as the Cost Report, including the materials, processes, process multipliers, fasteners, and tooling. This requires a strong understanding of the Cost Report, and as such the author and Alec Chapman were prepared to complete the task, depending on the system of the car. If it was electrical, Chapman would complete the task. If it were mechanical, the author would.

4.2. Task

The part selected for the Cost Task was the Steering Rack. This was costed effectively by the author.

5. Competition Results

At the Cost Event Briefing the team was advised that the three selected systems that would be used to generate the Accuracy multiplier were the Steering, Suspension, and Brakes.

Two hours before the Cost Event began, the team was sent their accuracy sheet. There were three main errors that had occurred. In the Assembly sheets there is a section that shows what parts are in the assembly, and what their costs are. The costing of some brake parts, and nearly every suspension part had different part costs in the some of the assemblies compared to the BOM and their own part sheets. This was because this number was never updated after changing the sheet. This had no effect on the cost of the car, as the part cost was correct, the BOM was correct, and the incorrect part costs in assemblies did not affect any numbers. The author was able to argue that this did not affect the total cost and was an input error. The judges slightly agreed, and stated they would still add a demerit but only one for a repeated error. The Accumulator Cells were costed with batteries that explicitly said, “not for use as an EV main battery”. The judges also gave demerits for not displaying a material or datasheet for a vehicle ECU. Alec Chapman advised them that NU 24 does not have an ECU and this was removed. The annotated Accuracy Sheet is shown in 7.3 Appendix C – Accuracy Sheet.

Following this the Cost Scenario was presented by the author and Alec Chapman. This went extremely well, and the judges were satisfied.

NU Racing scored 75.55 points in the Cost Event which placed 8th. This was by far the most ever in the history of the team, the previous best 51.06 points achieved in 2023 which also placed 8th. This was due to the higher level of detail that the Cost Report in particular, was completed in. The 2023 teams score was hampered due to total systems being completed poorly, no datasheets, limited drawings, and the three systems selected for their scoring being their worst systems. The author made sure that these issues were thoroughly ironed out to maximise point gain in the event.

NU Racing was never supplied with their Cost Score Sheet, which details what points were scored in the different parts of the Cost Event, the A multiplier, and the four D multipliers. The author emailed SAE and is awaiting a response.

6. Conclusions and Recommendations

NU Racing were able to score 75.55 points in the Cost Event in 2024. This was a great achievement, building on the foundation laid out by the 2023 team, especially Drew Bender. The increase in points were credited to the level of detail throughout the entire report, and the overwhelming amount of documentation that was supplied with the Cost Report, totalling 691 pages.

To continue the growth of the team, the role of Cost Event Lead cannot be held by a member of the Leadership Team. The workload induced during the Cost Report period was immense for both the author and Chief Mechatronic Engineer, Alec Chapman. It must be delegated to a member with a keen eye for detail. This will assist the team in becoming more balanced, and the Department Leads not being spread so thin.

Ensure that the Cost Report PDF is exported as detailed in section 2.4. This will make submission and compilation of the total report, including the drawings and datasheets, much simpler and save valuable time.

Do not change the name of each sheet to the part number or assembly number until the BOM is definitely completed. This did not happen in 2024, and as the BOM changed it would change part numbers and mass reorganisation was required at different times.

Ensure when people are being taught how to complete parts and assemblies, they are all formatting the sheets properly. This includes changing the colour of the border. This was not done by some members in 2024, and the author spent a lot of time formatting sheets prior to submission.

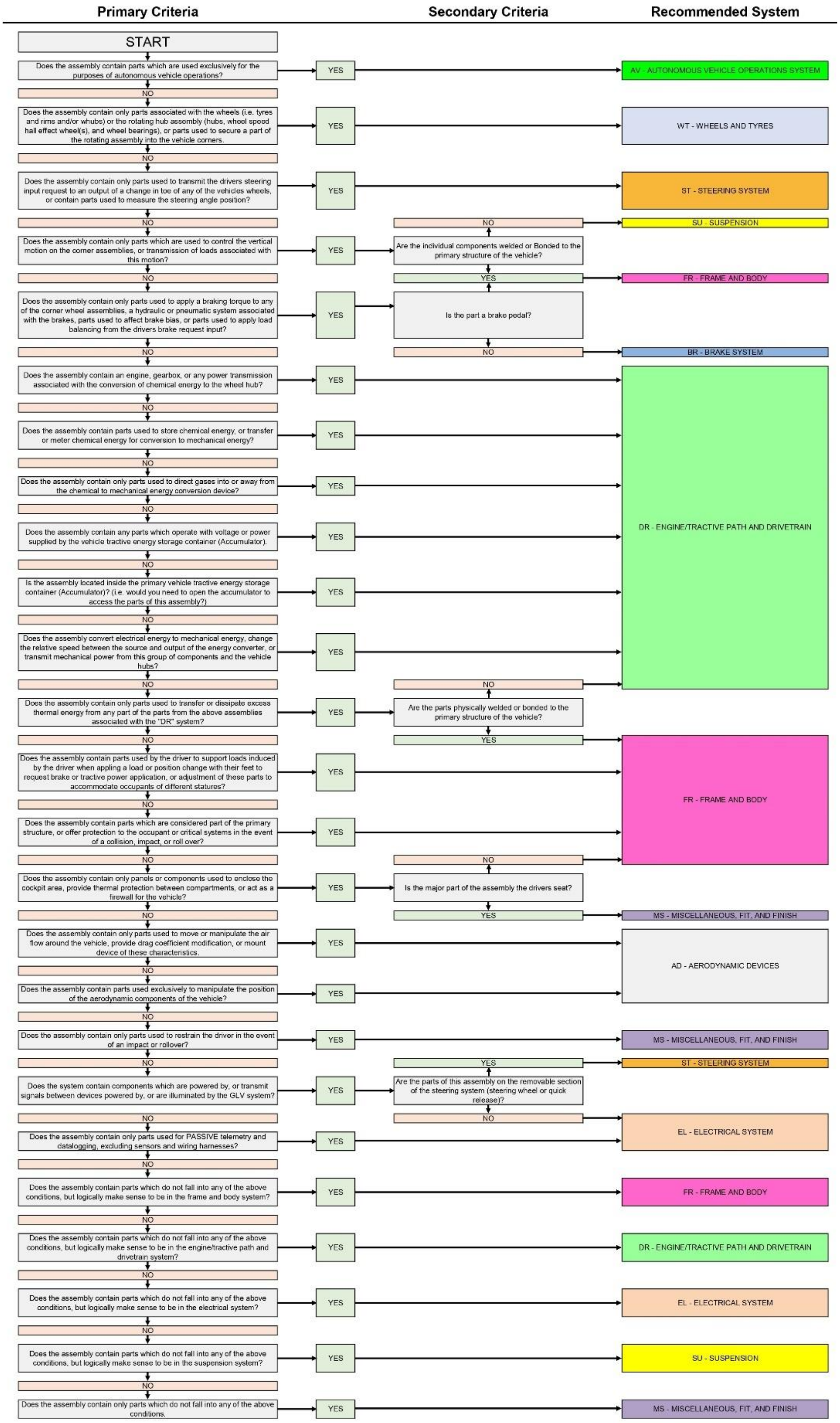
Create a team of people for the Cost Report early and build them up. The Cost Report can begin as early as June once the main manufacturing period ends. A smaller team of approximately 8-

10 people would be ideal. This would allow for enough manpower to complete the report but gives each of them long enough to learn how to complete the report and will ensure high quality.

Encourage the team to complete the bulk of the Cost Report in a room together and get them talking to each other about how they cost different things. This eliminates people doing it alone before realising they are completing it differently to everyone else. In 2024 there were large discrepancies within similar parts and assemblies when people were working on the report solo.

7. Appendix

7.1. Appendix A – Cost Allocation Flowchart



Primary Criteria
Secondary Criteria
Recommended System
START
Does the assembly contain parts which are used exclusively for the purposes of autonomous vehicle operations?
AV - AUTONOMOUS VEHICLE OPERATIONS SYSTEM
Does the assembly contain only parts associated with the wheels (i.e. tyres and rims and/or whubs) or the rotating hub assembly (hubs, wheel speed hall effect wheel(s), and wheel bearings), or parts used to secure a part of the rotating assembly into the vehicle corners.
WT - WHEELS AND TYRES
Does the assembly contain only parts used to transmit the drivers steering input request to an output of a change in toe of any of the vehicles wheels, or contain parts used to measure the steering angle position?
ST - STEERING SYSTEM
SU - SUSPENSION
Does the assembly contain only parts which are used to control the vertical motion on the corner assemblies, or transmission of loads associated with this motion?
Are the individual components welded or Bonded to the primary structure of the vehicle?
FR - FRAME AND BODY
Does the assembly contain only parts used to apply a braking torque to any of the corner wheel assemblies, a hydraulic or pneumatic system associated with the brakes, parts used to affect brake bias, or parts used to apply load balancing from the drivers brake request input?
Is the part a brake pedal?
BR - BRAKE SYSTEM
Does the assembly contain an engine, gearbox, or any power transmission associated with the conversion of chemical energy to the wheel hub?
Does the assembly contain parts used to store chemical energy, or transfer or meter chemical energy for conversion to mechanical energy?
Does the assembly contain only parts used to direct gases into or away from the chemical to mechanical energy conversion device?
Does the assembly contain any parts which operate with voltage or power supplied by the vehicle tractive energy storage container (Accumulator).
Is the assembly located inside the primary vehicle tractive energy storage container (Accumulator)? (i.e. would you need to open the accumulator to access the parts of this assembly?)
Does the assembly convert electrical energy to mechanical energy, change the relative speed between the source and output of the energy converter, or transmit mechanical power from this group of components and the vehicle hubs?
DR - ENGINE/TRACTIVE PATH AND DRIVETRAIN
Does the assembly contain only parts used to transfer or dissipate excess thermal energy from any part of the parts from the above assemblies associated with the "DR" system?
Are the parts physically welded or bonded to the primary structure of the vehicle?
Does the assembly contain parts used by the driver to support loads induced by the driver when appling a load or position change with their feet to request brake or tractive power application, or adjustment of these parts to accommodate occupants of different statures?
Does the assembly contain parts which are considered part of the primary structure, or offer protection to the occupant or critical systems in the event of a collision, impact, or roll over?
FR - FRAME AND BODY
Does the assembly contain only panels or components used to enclose the cockpit area, provide thermal protection between compartments, or act as a firewall for the vehicle?
Is the major part of the assembly the drivers seat?
MS - MISCELLANEOUS, FIT, AND FINISH
Does the assembly contain only parts used to move or manipulate the air flow around the vehicle, provide drag coefficient modification, or mount device of these characteristics.
Does the assembly contain parts used exclusively to manipulate the position of the aerodynamic components of the vehicle?
AD - AERODYNAMIC DEVICES
Does the assembly contain only parts used to restrain the driver in the event of an impact or rollover?
MS - MISCELLANEOUS, FIT, AND FINISH
ST - STEERING SYSTEM
Does the system contain components which are powered by, or transmit signals between devices powered by, or are illuminated by the GLV system?
Are the parts of this assembly on the removable section of the steering system (steering wheel or quick release)?
EL - ELECTRICAL SYSTEM
Does the assembly contain only parts used for PASSIVE telemetry and datalogging, excluding sensors and wiring harnesses?
Does the assembly contain parts which do not fall into any of the above conditions, but logically make sense to be in the frame and body system?
FR - FRAME AND BODY
Does the assembly contain parts which do not fall into any of the above conditions, but logically make sense to be in the engine/tractive path and drivetrain system?
DR - ENGINE/TRACTIVE PATH AND DRIVETRAIN
Does the assembly contain parts which do not fall into any of the above conditions, but logically make sense to be in the electrical system?
EL - ELECTRICAL SYSTEM
Does the assembly contain parts which do not fall into any of the above conditions, but logically make sense to be in the suspension system?
SU - SUSPENSION
Does the assembly contain only parts which do not fall into any of the above conditions.
MS - MISCELLANEOUS, FIT, AND FINISH
YES
NO

7.2. Appendix B – Cost Scenario Presentation


RACING
Cost Scenario
THE UNIVERSITY OF NEWCASTLE
E03
SANDVIK
ResTech
Ausgrid
RPC
JANUS ELECTRIC
ROBOTIC SYSTEMS
Lachlan Fisher
Alec Chapman
Joshua Hayward

Cost Scenario

Option 3:

Teams are to assume that their prototype vehicle has been selected to go into production, however the FSAEA Management team has received a request from key stakeholders that the profitability of the production run needs to increase, with this to be achieved through a minimum 5% decrease in vehicle production costs. This reduction of costs should result in a performance change of no more than 1%, and the general styling of the vehicle should remain unaffected. Teams are to present a proposal which presents the following information:

a. Their reported cost, and what level of savings would be required to meet the 5% cost decrease target.

b. A feasibility analysis on this target, highlighting:

   i. A list of assemblies which the team believes can have reduced production costs without effects on performance;
   ii. An estimation of the cost deltas across these assemblies.
   iii. A detailed costing of at least 2 of these assemblies to give reasonable proof that the cost estimations are accurate.

c. A summary of validation testing required to validate the changes are within the <1% performance difference requirement.

d. A recommendation on whether the cost reduction activities are feasible to produce a 5% vehicle production cost reduction.

Total Cost

FORMULA SAE AUSTRALASIA

Cost Report

for:

University of Newcastle

Vehicle Number E03

	Vehicle System	Materials	Processes	Fasteners	Tooling	Total
BR	Brake System	$ 1,408.83	$ 360.33	$ 4.37	$ -	$ 1,773.54
DR	Engine/Tractive Path and Drivetrain	$ 25,025.83	$ 2,875.35	$ 169.40	$ 9.01	$ 28,025.73
FR	Frame and Body	$ 310.50	$ 933.12	$ 30.88	$ 36.53	$ 1,311.02
AD	Aerodynamics	$ 1,119.69	$ 1,416.90	$ 586.58	$ 52.51	$ 3,175.67
EL	Electrical System	$ 3,587.38	$ 868.53	$ 15.20	$ 9.52	$ 4,545.96
MS	Miscellaneous, Fit, and Finish	$ 19.60	$ 58.54	$ 6.62	$ 4.01	$ 88.76
ST	Steering System	$ 153.41	$ 268.91	$ 11.44	$ 12.32	$ 446.09
SU	Suspension	$ 3,076.78	$ 1,228.51	$ 22.54	$ 9.33	$ 4,337.16
WT	Wheels & Tires	$ 574.00	$ 11.68	$ 6.40	$ -	$ 592.08
AV	Autonomous Systems	$ -	$ -	$ -	$ -	$ -
	Total Vehicle	$35,276.01	$ 8,021.86	$ 853.43	$ 133.24	$ 44,296.02

5% Cost - $2,214.801

Serviceability

Dry Break Disconnects

Quick Release Latch

Serviceability

University	University of Newcastle	P/N	E03-20-BR-012001-01	Part Cost	$ 497.95
Competition Code	FSAE-A	System	Brake System	QTY	1
Year	2024	Assembly	Brake Lines	Extended Cost	$ 497.95
Car #	E03	Part	Rear Brake Line		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Fitting/H.P./Elbow/45 deg./Steel/	45 deg fittings for firewall (AN3)	4.78	mm		0					2	$ 11.60	$ 23.20
	Fitting/H.P./MAluminume Pipe//Steel/	Hose Ends (AN3)	4.78	mm		0					8	$ 8.00	$ 64.00
	Fitting/H.P./Straight//Steel/	Straight fittings to Quick Disc fittings (4x) and through the firewall (1x) (AN3)	4.78	mm		0					5	$ 5.96	$ 29.82
	Fitting/H.P./Elbow/90 deg./Steel/	90 deg fittings to Master Cylinder and Rear Brake Caliper (AN3)	4.78	mm		0					2	$ 12.37	$ 24.74
	Adapter/L.P./Bulkhead Male Connector//Steel/	Bulkhead connector to rear brake caliper (AN3 to 3/8")	4.78	mm	9.53	mm					1	$ 6.52	$ 6.52
	Hose, High Pressure, Stainless Steel Braided Outer (per m)	Length for all 4 lengths of Brake Lines (Master Cylinder to 1st Disconnect, 1st Disconnect to Firewall, Firewall to 2nd Disconnect, 2nd Disconnect to Rear Caliper)	6.35	mm		0					2.27	$ 12.97	$ 29.45
	Break Coupling, Dry, Male, Goodridge	Quick Disconnects		unit		0					2	$ 72.50	$ 145.00
	Break Coupling, Dry, Female, Goodridge	Quick Disconnects		unit		0					2	$ 64.00	$ 128.00
	Adapter/L.P./Bulkhead Tee//Steel/	Tee Fitting between Master Cylinder and Brake line (houses Pressure Sensor) (AN3 with 3/8" Tee)	9.53	mm	4.78	mm					1	$ 13.59	$ 13.59
Total													$ 464.33

Dry Break Disconnect Costs - **$273 Total**

Serviceability

University	University of Newcastle	A/N	E03-20-AD-011000-01	Part Cost	N/A
Competition Code	FSAE-A	System	Aerodynamics	QTY	N/A
Year	2024	Assembly	Body Kit	Extended Cost	$ 3,167.72
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-AD-012001-01	Body Kit	$ 2,524.54	1	$ 2,524.54
Total					$ 2,524.54

Processes / **Process Multipliers**

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val. 2	Unit Cost	Sub total
	Assemble, 5 kg, Loose	Assemble Nosecone to chassis	unit	1	None	1	None	1	$ 0.31	$ 0.31
	Assemble, 1 kg, Loose	Assemble washer to bolt	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Assemble, 1 kg, Loose	Nosecone bolt through Nosecone and Chassis	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Assemble, 1 kg, Loose	Washer on other side of bolt	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Hand - Start Only	Start nut	unit	1	Repeat 4	4	None	1	$ 0.12	$ 0.48
	Ratchet <= 25.4 mm	Tighten Nosecone to Chassis	unit	1	Repeat 4	4	None	1	$ 0.75	$ 3.00
	Reaction Tool <= 25.4 mm	Tighten Nosecone to Chassis	unit	1	Repeat 4	4	None	1	$ 0.25	$ 1.00
	Assemble, 1 kg, Loose	Assemble in pin into the body kit tabs on chassis	unit	12	None	1	None	1	$ 0.06	$ 0.72
	Assemble, 1 kg, Loose	Assemble bottom washers	unit	12	None	1	None	1	$ 0.06	$ 0.72
	Assemble, 1 kg, Loose	Assemble top washers	unit	12	None	1	None	1	$ 0.06	$ 0.72
	Hand - Start Only	Hand start bottom nuts	unit	12	None	1	Fastener Enga	1.25	$ 0.12	$ 1.80
	Hand - Start Only	Hand start top nuts	unit	12	None	1	Fastener Enga	1.25	$ 0.12	$ 1.80
	Wrench <= 25.4 mm	Tighten top nuts	unit	12	None	1	None	1	$ 1.50	$ 18.00
	Reaction Tool <= 25.4 mm	Tighten bottom nuts	unit	12	None	1	None	1	$ 0.25	$ 3.00
	Assemble, 1 kg, Loose	Assemble Quick Latch Latch to Body Kit	unit	12	None	1	None	1	$ 0.06	$ 0.72
	Hand - Start Only	Start Quick Latch Lock Nut	unit	12	None	1	None	1	$ 0.12	$ 1.44
	Ratchet > 25.4 mm	Tighten Lock Nut	unit	12	None	1	None	1	$ 1.50	$ 18.00
	Assemble, 20 kg, Line-on-Lin	Place body kit on chassis	unit	1	None	1	Assemble - Le	1.25	$ 2.50	$ 3.13
	Assemble, 1 kg, Line-on-Line	Pop Quick Latches onto body kit	unit	12	None	1	None	1	$ 0.13	$ 1.56
Total										$ 57.12

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Pin, Quick Release	Body Kit Quick Latches	25.4	mm	54	mm	12	$ 48.84	$ 586.06
Total									$ 586.06

Quick Release Pins - **$643.18**

Serviceability

University	University of Newcastle	A/N	E03-20-AD-011000-01
Competition Code	FSAE-A	System	Aerodynamics
Year	2024	Assembly	Body Kit
Car #	E03	Part	N/A

Part Cost	N/A
QTY	N/A
Extended Cost	$ 2,582.99

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-AD-012001-01	Body Kit	$ 2,524.54	1	$ 2,524.54
Total					$ 2,524.54

Processes **Process Multipliers**

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val. 2	Unit Cost	Sub total
	Assemble, 5 kg, Loose	Assemble Nosecone to chassis	unit	1	None	1	None	1	$ 0.31	$ 0.31
	Assemble, 1 kg, Loose	Assemble washer to bolt	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Assemble, 1 kg, Loose	Nosecone bolt through Nosecone and Chassis	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Assemble, 1 kg, Loose	Washer on other side of bolt	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Hand - Start Only	Start nut	unit	1	Repeat 4	4	None	1	$ 0.12	$ 0.48
	Ratchet <= 25.4 mm	Tighten Nosecone to Chassis	unit	1	Repeat 4	4	None	1	$ 0.75	$ 3.00
	Reaction Tool <= 25.4 mm	Tighten Nosecone to Chassis	unit	1	Repeat 4	4	None	1	$ 0.25	$ 1.00
	Assemble, 1 kg, Loose	Assemble in pin into the body kit tabs on chassis	unit	12	None	1	None	1	$ 0.06	$ 0.72
	Assemble, 1 kg, Loose	Assemble bottom washers	unit	12	None	1	None	1	$ 0.06	$ 0.72
	Assemble, 1 kg, Loose	Assemble top washers	unit	12	None	1	None	1	$ 0.06	$ 0.72
	Hand - Start Only	Hand start bottom nuts	unit	12	None	1	Fastener Enga	1.25	$ 0.12	$ 1.80
	Hand - Start Only	Hand start top nuts	unit	12	None	1	Fastener Enga	1.25	$ 0.12	$ 1.80
	Wrench <= 25.4 mm	Tighten top nuts	unit	12	None	1	None	1	$ 1.50	$ 18.00
	Reaction Tool <= 25.4 mm	Tighten bottom nuts	unit	12	None	1	None	1	$ 0.25	$ 3.00
	Assemble, 1 kg, Loose	Assemble Quick Latch Latch to Body Kit	unit	12	None	1	None	1	$ 0.06	$ 0.72
	Hand - Start Only	Start Quick Latch Lock Nut	unit	12	None	1	None	1	$ 0.12	$ 1.44
	Ratchet > 25.4 mm	Tighten Lock Nut	unit	12	None	1	None	1	$ 1.50	$ 18.00
	Assemble, 20 kg, Line-on-Lin	Place body kit on chassis	unit	1	None	1	Assemble - Le	1.25	$ 2.50	$ 3.13
	Assemble, 1 kg, Line-on-Line	Pop Quick Latches onto body kit	unit	12	None	1	None	1	$ 0.13	$ 1.56
Total										$ 57.12

Fasteners

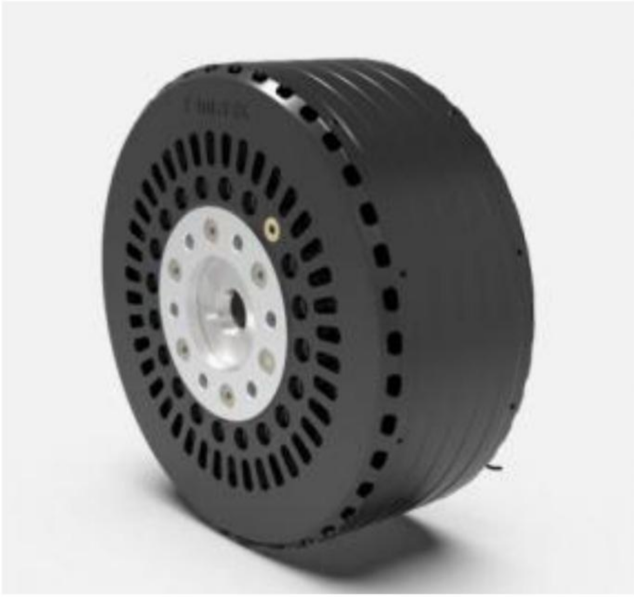
ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 8.8 (SAE 5)	Bolt Body Kit to Tabs	6	mm	30	mm	12	0.07	$ 0.78
	Nut, Grade 8.8 (SAE 5)	Bolt Body Kit to Tabs	6	mm		0	12	$ 0.03	$ 0.36
	Washer, Grade 8.8 (SAE 5)	Bolt Body Kit to Tabs	6	mm		0	24	$ 0.01	$ 0.20
Total									$ 1.34

Replacement Bolts - **$58.46**

Cost Savings and Performance

Dry Brake Disconnects	Quick Release Latch	Cost ($)
$273	$643.18 – $58.46 = $584.72	$857.72

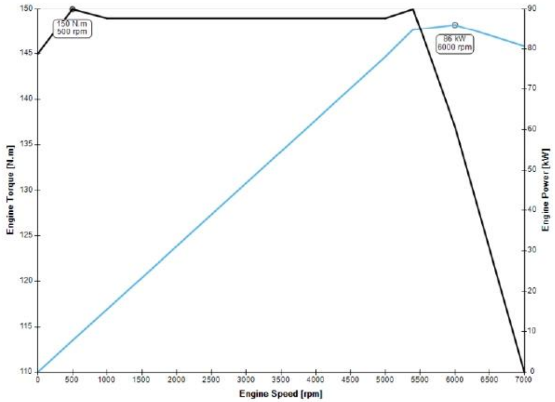
EMRAX 228 VS EMRAX 208 AC ELECTRIC MOTORS



Motor Specs and Power Curves

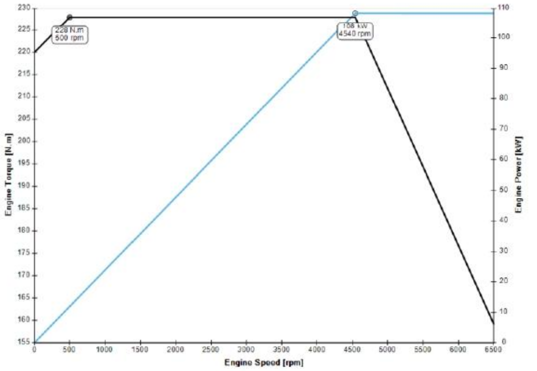
EMRAX 208	
DIAMETER | LENGTH	208 mm | 85 mm
WEIGHT	9,4-10,3 kg
COOLING	air / water / combined
PEAK | CONTINUOUS POWER	86 kW | 56 kW*
PEAK | CONTINUOUS TORQUE	150 Nm | 90 Nm*
MAXIMUM SPEED	7000 RPM
OPERATING VOLTAGE	50 - 580 V
EFFICIENY	up to 96%*
POSITION SENSOR	resolver / encoder

Engine Torque and Power vs Engine Speed

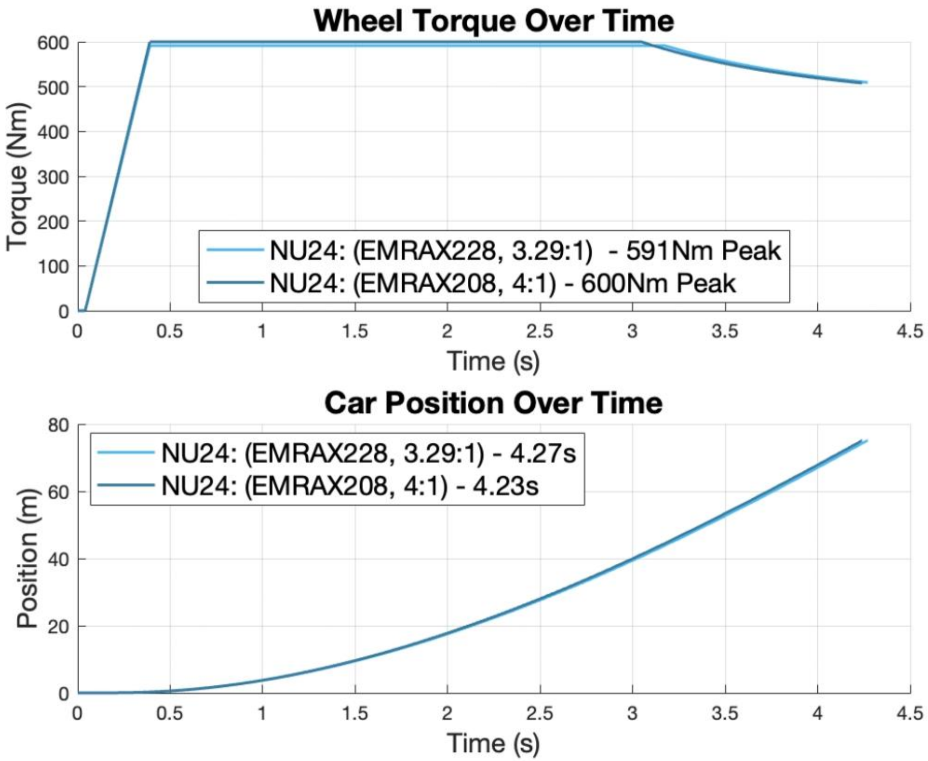


EMRAX 228	
DIAMETER | LENGTH	228 mm | 86 mm
WEIGHT	12,9-13,5 kg
COOLING	air / water / combined
PEAK | CONTINUOUS POWER	124 kW | 75 kW*
PEAK | CONTINUOUS TORQUE	230 Nm | 130 Nm*
MAXIMUM SPEED	6500 RPM
OPERATING VOLTAGE	50 - 710 V
EFFICIENY	up to 96%*
POSITION SENSOR	resolver / encoder

Engine Torque and Power vs Engine Speed



Speed vs Distance



Cost Savings

University	University of Newcastle	P/N	E03-20-DR-013007-01	Part Cost	$ 7,503.84
Competition Code	FSAE-A	System	Engine/Tractive Path and Drivetrain	QTY	1
Year	2024	Assembly	Motor	Extended Cost	$ 7,503.84
Car #	E03	Part	Emrax 228 Motor		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Motor, Tractive AC	Emrax 228 Motor	75	kW		0					1	$ 7,500.00	$ 7,500.00
	Connector, Single Wire	Soldered connection in Motor	1	Unit		0					8	$ 0.05	$ 0.40
Total													$ 7,500.40

Processes / Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val. 2	Unit Cost	Sub total
	Attach Wire, Solder	Solder motor connections	wire	1	Repeat 8	8	None	1	$ 0.43	$ 3.44
Total										$ 3.44

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

75 kW (continuous) * $100 / kW = $7500 for 228 EMRAX

Cost Savings

University	University of Newcastle	P/N	E03-20-DR-013007-01	Part Cost	$ 5,603.84
Competition Code	FSAE-A	System	Engine/Tractive Path and Drivetrain	QTY	1
Year	2024	Assembly	Motor	Extended Cost	$ 5,603.84
Car #	E03	Part	Emrax 228 Motor		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Motor, Tractive AC	Emrax 228 Motor	56	kW		0					1	$ 5,600.00	$ 5,600.00
	Connector, Single Wire	Soldered connection in Motor	1	Unit		0					8	$ 0.05	$ 0.40
Total													$ 5,600.40

Processes / Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val. 2	Unit Cost	Sub total
	Attach Wire, Solder	Solder motor connections	wire	1	Repeat 8	8	None	1	$ 0.43	$ 3.44
Total										$ 3.44

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

56 kW (continuous) * $100 / kW = $5600 for 208 EMRAX

Cost Savings and Performance

Motors	Cost ($)	Performance (Seconds)
EMRAX 228	$7500	4.27
EMRAX 208	$5600	4.23
DELTA	$1900	-0.04 (1% INCREASE)

Changes to Powerbox for EMRAX 208

University	University of Newcastle	P/N	E03-20-DR-013014-01	Part Cost	$ 6.99
Competition Code	FSAE-A	System	Engine/Tractive Path and Drivetrain	QTY	1
Year	2024	Assembly	Spool	Extended Cost	$ 6.99
Car #	E03	Part	46T Drive Sprocket		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Aluminum, Premium (by Dimensions)		0.566952702	kg		0	Ø195 round bar	29864.76516	7	2712	1	$ 4.20	$ 2.38
Total													$ 2.38

Processes / **Process Multipliers**

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val. 2	Unit Cost	Sub total
	Machining Setup, Install and remove	Set up mill	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining	Mill teeth, mount holes, weight saving, and centre bore	cm^3	33.26161	Material - Aluminum	1	None	1	$ 0.04	$ 1.33
	Machining Setup, Change	Flip sprocket in mill	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Machining	Mill opposite side teeth, mount holes, weight saving, centre bore	cm^3	33.26161	Material - Aluminum	1	None	1	$ 0.04	$ 1.33
Total										$ 4.61

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

Original 46T Sprocket - $6.99

University	University of Newcastle	P/N	E03-20-DR-013014-01	Part Cost	$ 7.39
Competition Code	FSAE-A	System	Engine/Tractive Path and Drivetrain	QTY	1
Year	2024	Assembly	Spool	Extended Cost	$ 7.39
Car #	E03	Part	52T Drive Sprocket		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Aluminum, Premium (by Dimensions)		0.596399949	kg		0	Ø200 round bar	31415.92654	7	2712	1	$ 4.20	$ 2.50
Total													$ 2.50

Processes / **Process Multipliers**

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val. 2	Unit Cost	Sub total
	Machining Setup, Install and remove	Set up mill	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining	Mill teeth, mount holes, weight saving, and centre bore	cm^3	36.64515	Material - Aluminum	1	None	1	$ 0.04	$ 1.47
	Machining Setup, Change	Flip sprocket in mill	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Machining	Mill opposite side teeth, mount holes, weight saving, centre bore	cm^3	36.64515	Material - Aluminum	1	None	1	$ 0.04	$ 1.47
Total										$ 4.88

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

52T Sprocket - $7.39

Cost Savings

Item (-)	Cost ($)
Emrax 208 (- Sprocket Change)	$1900 - $0.40 = $1899.60
Dry Break Disconnects	$273
Quick Release Latch	$584.72
TOTAL	$2,757.32

Cost Savings

5% of Initial ($)	Savings ($)	Delta
$2,214.801	$2,757.32	$542.519

We recommend that it is feasible to reduces costs, however this reduces the serviceability of the car. If possible, only the change from the Emrax 228 to the Emrax 208 should be implemented. The removal of the Quick Release Latch and the Dry Break Disconnects stray from the design philosophy of the car, making it less user friendly.

7.3. Appendix C – Accuracy Sheet

FSAE-A COST EVENT

Score Sheet

FORMULA SAE AUSTRALASIA

Entry Year	2024
Car #	E03
University	University of Newcastle
Cost Judge	Margaret ; Anastasia

EMRAX 228

DIAMETER | LENGTH	228 mm | 86 mm
WEIGHT	12,9-13,5 kg
COOLING	air / water / combined
PEAK | CONTINUOUS POWER	124 kW | 75 kW*
PEAK | CONTINUOUS TORQUE	230 Nm | 130 Nm*
MAXIMUM SPEED	6500 RPM
OPERATING VOLTAGE	50 - 830 V
EFFICIENY	up to 96%*
POSITION SENSOR	resolver / encoder

*Subject to motor configuration, drive cycle, thermal conditions, and controller capability.

Part Number	Error Description	Demerit	
	Battery used is listed as "not for use as an EV main battery"		
	Incorrect accumulator cell cost (likely due to incorrect battery) (-$127.01)	0.0025	
	Incorrect Tractive Motor cost (+1300) (continuous power appears to have	0.0025	Cost per kW continuous power. Use peak power * 0.5 if this figure is not available. The calc is right but someone clearly left the peak power in there
	Tractive controller listed as AC in PDF but DC for datasheet and for calcu	0.0025	Wrong listing but is still costed correctly
	Missing vehicle ECU material	0.0025	We don't have a ECU
	Missing vehicle ECU datasheet	0.0025	We don't have a ECU
BR 022001-01	Detail has 2 x $197.50 = $395 but BOM has 2 x $117.50 = 235	$160	Correct Costing in the BOM as we use the Tilton 78's.
BR 022002-01	Detail has 1 x $30 but BOM has 4 x $30 = $120	- $90?	
BR 022003-01	Master Cylinder Clevis detail Asm sheet $48.30 but $49.50 on BOM	-$1.20?	The ASM isn't counted in total cost so this doesn't matter
BR 032001-01	Dual Chamber Reservoir $13.03 on Asm page but $20.59 on BOM & Part detail pages		Correct in BOM and Part
BR 041000-01	Doubled brake pad cost of $1.11 EA x 6 = $6.66 to $13.66 instead, but BOM & part detail page have $2.28 EA		Comes out as the same
BR 051000-01	Breakdown & BOM Costs are different		ASM Costs wrong but don't matter
	Suspension has 14 small variances where Asm is not equal to individua part costings		Costed right in all of the parts, the ASM weren't updated. This is shown as they are right in the Bom
SU 011001-01	As Above	-$1.44	ALSO ALL OF THESE PART NUMBERS ARE WRONG - I CAN INFER WHAT YOU MEAN BUT THIS IS BAD
SU 011002-01	As Above	-$4.12	
SU 011003-01	As Above	-$1.44	
SU 011004-01	As Above	-$4.12	
SU 011005-01	As Above	$0.06	
SU 011010-01	As Above	-$1.64	

PAGE 1 of 2

FSAE-A COST EVENT

Score Sheet

FORMULA SAE AUSTRALASIA

Entry Year	2024
Car #	E03
University	University of Newcastle
Cost Judge	Margaret ; Anastasia

Part Number	Error Description	Demerit	
SU 011015-01	As Above	-$0.52	
SU 011019-01	As Above	-$2.61	
SU 022001-01	As Above	-$1.33	
SU 022002-01	As Above	-$1.00	
SU 022003-01	As Above	-$1.33	
SU 022004-01	As Above	-$1.00	
SU 022005-01	As Above	$0.06	
SU 022015-01	As Above	-$0.52	
SU 012008-01	Whel Bearing Front 4 x $113.84 = $455.38 OK in BOM but not Asm detail which is 8 x $113.84 which is a $455.38 difference	-$455.38?	ASM Detail is wrong, they are costed right in the Bom and in the Part Detail - only place where cost is counted
SU 022008-01	Whel Bearing Rear 4 x $113.84 = $455.38 OK in BOM but not Asm detail which is 8 x $113.84 which is a $455.38 difference	-$455.38?	ASM Detail is wrong, they are costed right in the Bom and in the Part Detail - only place where cost is counted
ST 0320003-01	Steering - Asm Qty 1 but BOM Qty 4 for Misalignment Spacer	-$5.19?	Doesn't matter - Part and BOM Costs are correct - therefore the total cost is correct
ST 0320004-01	Asm Qty 1 but BOM Qty 4 for outboard tie rod spacer	-$5.31?	Doesn't matter - Part and BOM Costs are correct - therefore the total cost is correct

Technical Inspection

DESIGN REPORT

NU 24

Lachlan Fisher

2024

1. Introduction

Technical Inspection (TI) occurs in the two days before Dynamic Events at the FSAE-A competition. The TI's are as follows:

- Accumulator Inspection
- EV Static
- Mechanical Inspection
- Driver Egress
- EV Functional
- Weight
- Tilt Table
- Rain Test
- Brake Test

Both Department Leads were responsible for each inspection and its preparation. The author was responsible for Mechanical Inspection, Driver Egress, Tilt Test, and the Brake Test.

During these inspections NU 24 was inspected for compliance and safety prior to competing in the Dynamic Events.

2. Preparation

Every inspection must be passed before any vehicle can compete in Dynamic Events. Due to this great importance must be placed on passing these inspections. To do this the team must be thoroughly prepared and have documents, drawings, and any proof of compliance available. To do this Mock Inspections were completed throughout the back end of 2024 with the intention of showing any vulnerabilities in preparation, or parts of the car that are non-compliant.

To prove successful in any inspection the Department Leads had to select team members who had a strong understanding of certain systems and good communication skills to be utilised in the inspections. Each TI had a team that had choreographed their inspection countless times.

2.1. Mock Inspections

Mock Inspections are inspections that are held by the team, with someone taking over the role as a scrutineer. This was vital to the success of every inspection. It gave the TI teams the chance to get familiar with the process of inspection, be able to convey their understanding to prove compliance, and quickly learn what was not compliant, or what needed more proof to illustrate compliance.

Utilising a team member who has limited knowledge of an aspect of the car as the lead scrutineer proved incredibly useful, as they often had a fresh perspective, and it forced each team to provide clear documentation and proof for each rule. Dr Dylan Cuskelly was used extensively in this role, which was invaluable to the team.

To effectively practise for TI, the same team members must be used every time. The importance of TI teams having their respective inspections rehearsed before competition cannot be understated. Knowing what questions are coming and what proof is required is vital to success.

Increasing the flow of TI's is important as they are all only one hour long. If you go over time you don't pass the TI and must continue it later when the scrutineers are free. This needs to be avoided such that focus can be placed on the Static Events.

For every rule in each TI documentation needs to be prepared as proof of compliance. This bullet-proofs the team throughout TI.

2.2. Documentation

For Mechanical Inspection documentation was heavily required for many bought parts. Having the datasheets and any corresponding documentation show to the scrutineers that you are thoroughly prepared, and they become more inclined to trust. It also gives the ability to easily prove anything. Examples of documentation used during Mechanical Inspection were for the Roll Bar Padding (prove that is was SFI 45.1 rated), Impact Attenuator certification of purchase and conformation, and the catch can datasheet (to prove its capacity).

The other main kind of documentation that is required is excerpts from the FSAE Rules. TI rules often make habit of not including the full rule that it's derived from. Without having the excerpt of a given rule, parts of the car can easily be deemed non-compliant. An example of this is Mechanical Inspection Rule MI.9.12. This states that the Front Bulkhead must be fully supported back to the Front Hoop, with the top member connecting within 4" above and 2" below the Upper Side Impact Support (SIS) tube. The upper Front Bulkhead Support (FBHS) on NU 24 is greater than 4" above the Upper SIS tube, as shown in Figure 198 and upon inspection rule F.6.2.3.b is found. This is shown in Figure 199.

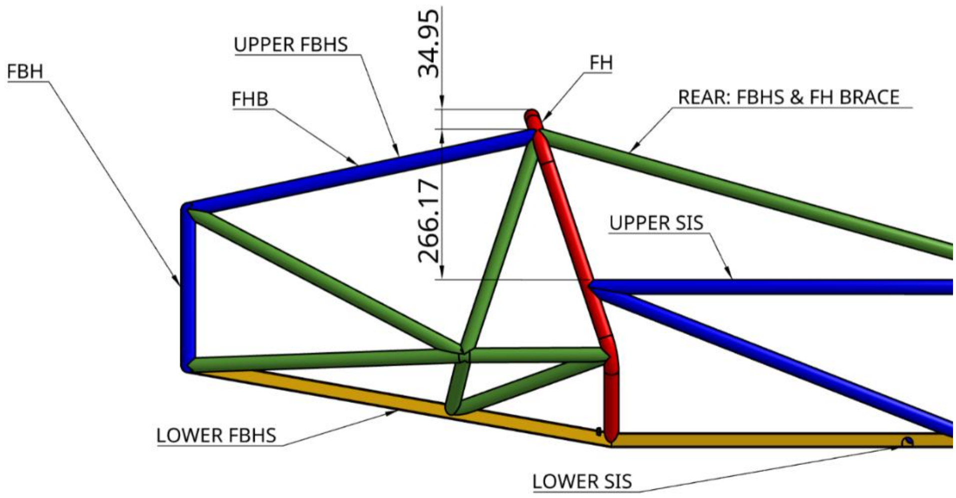


Figure 198. FBHS and SIS Drawing for MI.9.12

F.6.2.3 The Front Bulkhead must be supported back to the Front Hoop by a minimum of three Frame Members on each side of the vehicle; an upper member; lower member and diagonal brace to provide Triangulation.

a. The upper support member must be attached 50 mm or less from the top surface of the Front Bulkhead, and attach to the Front Hoop inside a zone extending 100 mm above and 50 mm below the Upper Side Impact member.

b. If the upper support member is further than 100 mm above the Upper Side Impact member, then properly Triangulated bracing is required to transfer load to the Main Hoop by one of:

- the Upper Side Impact member
- an additional member transmitting load from the junction of the Upper Support Member with the Front Hoop

Figure 199. FBHS Rule F.6.2.3.b

The rule clearly states this is ok if there is another member that braces the Front Hoop back to the Upper SIS tube, which is shown in Figure 198 as the Rear FBHS member.

During Mechanical Inspection the TI team knew as MI.9.12 was being asked the excerpt showing rule F.6.2.3.b needed to be shown.

2.3. Drawings

Drawings are required for nearly every TI rule regarding the Chassis due to the number of rules that surround it, specifically rules that require measurements of angles and distance from different tubes. The Chassis drawings were all completed by John Jones [18].

The Chassis drawings especially are vital to success at TI. This is because there is no other easy method to check the distances or angles. Showing the scrutineers these drawings makes their lives easier as well as ours.

2.4. Samples

Having samples of parts where it is possible in beyond helpful during scrutineering. This becomes especially important when parts are in hard to see or reach locations. Alec Chapman made great use of this for items inside the Accumulator during its inspection [32].

For Mechanical Inspection, sample tube sizes, harness eye bolts and their welded inserts were the only samples required. A spare Impact Attenuator was also brought in case,

2.5. Images

Images such as the size of the Impact Attenuator, weight of the GoPro, and of the telemetry were all used to give the scrutineers context. The same as samples, having photos of things that are not easily shown are vital to keeping inspection moving smoothly and completing on time.

2.6. Tech Inspection Task List

Failing during Mock Inspections is a large reason why they are completed. This allows for non-compliances to be found and documented. When non-compliances were found the Department Leads added them to a spreadsheet made by the author. The TI Task List allowed for the issues to be recorded, and a task assigned to a team member to make it compliant. An example of the task list is shown in Figure 200.

Tech Inspection Job List - Mech Tech

Date Revised: 24/11/24

Rule	Section	Task	Assignee	Deliverable	Complete?
MI.10.9	Steering, Suspension & Brakes	Show where Glenlochs are used in high temp areas	Fisher	Images of Glenlochs	No
MI.11.1	Driver Accomodation	Images of Lap belt mounting - check angle	Fisher		No
MI.11.4	Driver Accomodation	Check the rules again / wait for the new rules to come out. Should just get the firewall thing to be cut from FR-4	Kris / Fisher	Material selection for the Firewall protection - FR4 is cut, but the rules no longer require it. We are waiting to hear back on a rules enquiry	No
MI..2.2	Pre-Registration	Full List of Egress Times by Drivers	Fisher	List	No
MI.5.7	Driver's Equipment	Buy new gloves	Fisher	New gloves - need to meet FIA8856 - IN ASANA - Purchased	No
MI.9.2	Chassis & Structural	Drill 4.5 mm holes in the Chassis	Fisher	Holes in Chassis	No
MI.10.8	Steering, Suspension & Brakes	Datasheet for Glen=lochs	Fisher	Datasheets	No
MI.11.10	Driver Accomodation	Show 100 degrees vision both sides	Fisher	Images?	No
MI.11.2	Driver Accomodation	Image of reclined or upright driver	Johnny	drawing of percy	No

Figure 200. Tech Inspection Task List

2.7. Tech Bible and Scrutineer Documents

For every TI there was a document person, whose job it was to hand the team members speaking to the scrutineer's associated documentation, drawings, or samples to prove compliance.

For this purpose, a Tech Bible was created. The Bible was an edited version of the TI checklist that had a screenshot of what documentation, drawing, or sample was required. This ensured that the TI would continue smoothly, and the correct documents would be handed when they were required. There was one created for each TI. The Mechanical Tech Bible is in 6.1 Appendix A – Mechanical Tech Bible.

The required documents for each inspection were placed in one folder. This folder and all the required documentation and samples were kept in the TI box and kept together throughout Mock Inspections and competition.

3. Technical Inspection at Competition

At competition each Technical Inspection was held at the Scrutineering Bays at Calder Park, except for Accumulator Inspection and the Brake Test.

Both the Tilt Test and the Brake Test are spoken about in the 10.7 Brake Test Issues and 12.1 Static Events and Technical Inspection (Thursday – Friday) sections respectively.

3.1. Mechanical Inspection

Each Technical Inspection has minimum two inspectors. The inspectors will go through the corresponding inspection checklist and the team then demonstrates compliance. This occurred in every TI except for Mechanical Inspection. During this inspection there were six scrutineers who would ask anyone in the team questions about the car. The inspection was not run in order instead questions were asked almost randomly. Due to this the TI Team was quite scattered and the document person was working overtime to try and provide everyone documentation they required as they could not follow along using the Tech Bible.

Another huge disruption was the use of two steering wheels during Mechanical Inspection. A new Steering Wheel, designed by Brady McNeil, was utilised by only one driver from six, as it allowed them more clearance around their knees. The scrutineers were okay with using two wheels, however as the tallest driver needs to egress for the Driver Egress Inspection, which was the driver using the new wheel, they required another driver to egress. The author asked another driver to egress, however they were feeling unwell. The other three drivers were not confident performing an egress, therefore the author had to stop completing TI and get into driver gear. The additional egress was completed first time with no issues.

The Mechanical Inspection was passed first time due to the preparation of the TI prior to the event. With the incredibly stressful environment, without Mock Inspections and thorough preparation the TI would not have been passed.

4. Potential Non-Compliance

Throughout Mechanical Inspection the following issues were found that could have caused NU 24 to be non-compliant:

- Harness Eyebolts not protruding with 2 extra threads
- The Pedal Box deforming when the Brake System was tested to '2000 N'
- The Steering Rack Cover not covering the entire Steering Rack
- The tallest driver head being within 50 mm of the Main Hoop Padding

One scrutineer believed that the Harness Eyebolts not sticking out two threads made them non-compliant. The rule the scrutineer was referencing was critical fastener rule T.8.2.4. which states that two full threads must project from any lock nut [7]. The eyebolts are not threaded into a locknut and are not considered critical fasteners. Instead, they are tested under rule F.7.9.1 where they must be able to withstand 15 kN before failure. The eyebolts are still safety wired to ensure they are positively locked. The author knew this was compliant and was ready to present this information to the scrutineer, but he forgot and signed off on it.

To test the Pedal Box and Brake System a scrutineer entered the vehicle and pressed the Brake Pedal as hard as they could. The plate deformed but the scrutineers did not seem to notice or mind (there were four of them watching). The extreme pressure meant that the Pedal Had hit the Brake Reservoir Holder and broken it. Again, this was not notice and was signed off. In 2025 the Pedal Box needs to be stiffer and not allow deflection, and the position of the Brake Reservoir altered, or the type of reservoir changed to a smaller one.

The Steering Rack Cover did not cover the entire Steering Rack inside the cockpit shown in Figure 201. This was known prior to competition and the author was prepared to 3D print extensions to slot onto the side of the cover. Again, this was not noticed and passed. The Steering Rack Cover should be extended in 2025.

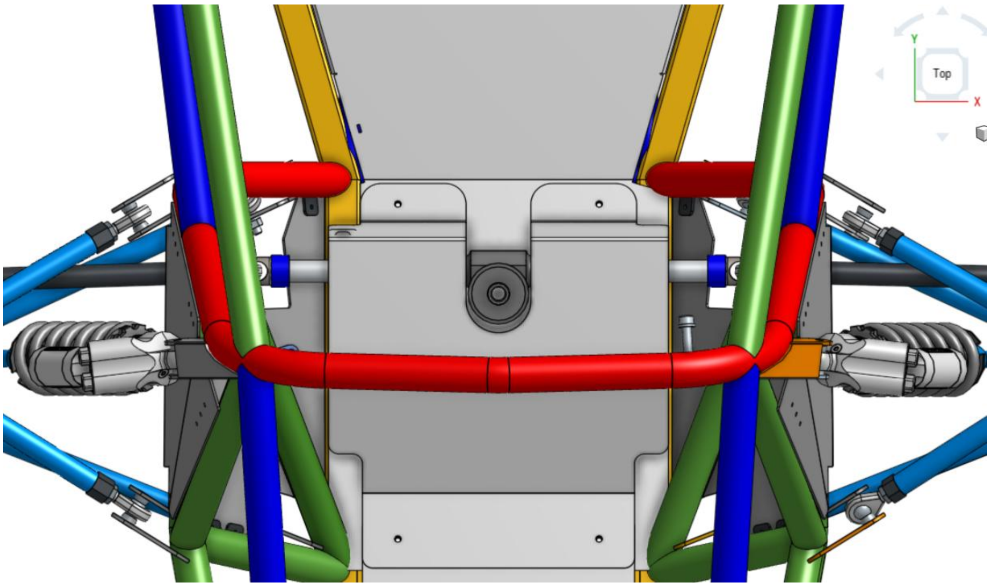


Figure 201. Steering Rack Cover Not Covering the Entire Steering Rack

When assessing the tallest driver in NU 24 a scrutineer thought that the Tech Inspection rule MI.11.7., which is shown in Figure 202, meant that the driver's helmet could not be within 50 mm of the Roll Bar Padding, as our driver was approximately 40 mm from it.

MI.11.7	Head restraint / head rest	Meets SFI or FIA listed materials. Min 38mm thick, min 15cm wide, min height 28cm. Max 25mm from helmet, Helmet contact point 50mm minimum from any edge. Adjustable or changeable for different drivers.

Figure 202. Tech Inspection Rule MI.11.7

This rule references FSAE Rule T.2.8.5 which states that "the contact point of the back of the driver's helmet on the Head Restraint is no less than 50 mm from any edge of the Head Restraint.". This clearly states that the Tech Inspection rule is asking that the contact patch of the helmet is greater than 50 mm from the edge of the Head Restraint Padding. The author stated the scrutineer had not interpreted the rule correctly, stated it was referring to the distance form the edge of the Head Restraint Padding, and offered to find rule T.2.8.5. However, this was not required, and they accepted this explanation.

5. Conclusion and Recommendations

The success of TI at competitions was the culmination of the hard work put in by both Department Leads. Every inspection was passed quite comfortably, except for the Brake Test, and was a great accomplishment.

For 2025 it is advised that they continue to use the Tech Inspection Task Lists, creating Tech Bibles, and doing as many Mock Inspections as possible. These all worked to great extents in 2024 and there is no reason that it cannot be used again for 2025.

Utilise using academics from the University and NU Racing Alumni to complete Mock Inspections. There was one Mock Inspection with NU Racing Alumni and the author gained some invaluable lessons from everyone involved. They also have full context of the competition with no context of the current car, so they will provide valuable feedback with fresh perspective.

The Department Leads should still run TI's however they should not be involved in the grunt work preparing documentation and drawings. They should instead just fill out the TI Task List and delegate most jobs. This is difficult to give critical jobs away, however the Department Leads are required in many other areas in the lead up to completion and should take care not to overextend themselves (even though this cannot be avoided sometimes).

6. Appendix

6.1. Appendix A – Mechanical Tech Bible

2024 Formula SAE-A Technical Inspection Sheet
MECHANICAL INSPECTION (ALL CLASSES)

Initial Presentation Scrutineer Name:		**Initial Presentation Lane Number:**	
1st Reinspection Scrutineer Name:		**1st Reinspection Lane Number:**	
2nd Reinspection Scrutineer Name:		**2nd Reinspection Lane Number:**	
3rd Reinspection Scrutineer Name:		**3rd Reinspection Lane Number:**	

PERSONNEL Teams are required to have an Electrical Safety Officer.			**Initial ins.**	**Inspection #** **1st reins.**	**2nd reins.**	**3rd reins.**
MI.1.1	Only team members involved in technical inspection can be in the technical inspection bay	Ask for non-essential people to leave the area				

INERT VEHICLE (EV & AV CLASSES ONLY) The Vehicle must be in a condition which prevents unexpected energization of the HV electrical systems or movement of the tractive system For ICE Class vehicles, mark as "N/A"			**Initial ins.**	**Inspection #** **1st reins.**	**2nd reins.**	**3rd reins.**
MI.1.2	Disable the HV Systems - High Voltage Disconnect (HVD)	Check the HVD is removed				
MI.1.3	Disable the HV Systems - Tractive System Master Switch (TSMS) Lock	Check the TSMS Lock is fitted and effective				
MI.1.4	(AV and Dual Purpose only) Disable the ASMS - Autonomous System Master Switch (ASMS) Lock	Check the ASMS Lock is fitted and effective				
DO NOT PROCEED WITH TECHNICAL INSPECTION IF HVD IS INSTALLED OR THE TSMS LOCK IS MISSING						

INSTRUCTIONS FOR SCRUTINEERS

This section applies to all vehicle classes.
If an item is acceptable, initial the "Passed" column.
If an item is unacceptable, initial the "Reinspect" column and inform the team members they have not meet the requirements for that item.
Teams are allowed to take their vehicle away from technical inspection and address any issues before representing for reinspection.
Scrutineers may continue with the inspection when unacceptable items are found, provided it is safe to do so.
Teams are required to pass all items before the vehicle can proceed to the Brake Test or compete in Dynamic Events.

Scrutineers reserve the right to refuse to proceed with Technical Inspection if a sufficiently serious issue which might jeopardize the safety of the technical inspection team, event personal or any other persons is found at any time.

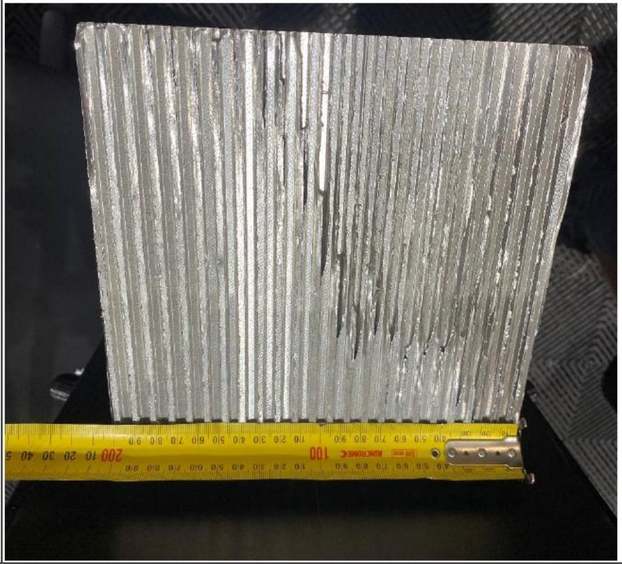
HVD OUT – TSMS LOCK IN

PEDAL BOX FURTHEST AWAY POSITIOM

ZAK IN FULL KIT

TOOLS: 5 mm ALLEN KEY – 10 mm SPANNER – DRILL + BATTERY + 4.5 mm BIT, STEEL RULE + MEASURING TAPE + DIGITAL LEVEL OR PHONE
PERCY + COCKPIT AND FOOT TEMPLATE

MECHANICAL INSPECTION

PRE-REGISTRATION				Reinspect	Passed
MI.2.1	Team completed inspection records	Teams must have self-completed the Technical Inspection Checklist and present a hardcopy	Ask for hardcopy of TI inspection sheet		
MI.2.2		Teams must provide evidence of egress times achieved by all drivers.	Ask for hardcopy record of egress times		
MI.2.3	Impact Attenuator	Teams must present a sample of their tested Impact Attenuator, or detailed photographs. (Including Standard IA if required due to Bulkhead configuration.) 	Ask to see the sample impact attenuator or photos.		

TECHNICAL INSPECTION STICKER AND COMPETITION SPONSOR STICKERS				Reinspect	Passed
MI.3.1	Technical Inspection Vehicle Panel	The Technical Inspection Sticker must be installed on the top surface of the nose of the vehicle on the vehicle centerline. The Technical Inspection Sticker must be used as provided and not modified. The Technical Inspection Sticker must be clearly visible.	Visual Check		

MECHANICAL INSPECTION					
MI.3.2	Competition Sponsor Stickers	The Competition Sponsor Sticker must be installed on the top surface of the nose of the vehicle on the vehicle centerline. The Competition Sponsor Sticker must be used as provided and not modified. The Competition Sponsor Sticker must be clearly visible.	Visual Check		

MECHANICAL INSPECTION					
WHEELS & TYRES Teams are required to bring a sample of each dry and rain tyre for use. Teams are allowed ONE SET of each type of tyre. Teams may have different tire sizes front and rear, but left and right tires must be identical. Teams may replace damaged tires but need to re-present to TI and demonstrate they are identical to the make size and compound listed below.				**Reinspect**	**Passed**
MI.4.1	Dry Tyres	Inspector to record tyre make, size and compound. Make: **Hoosier** Size: **16 x 7.5 x 10** Compound: **LC0** Apply tamper proof sticker to tire and wheel rim	Visual Check		
MI.4.2	Rain Tyres	Inspector to record tyre make, size and compound. Minimum tread depth of 2.4mm. Make: **Hoosier** Size: **18 x 6 x 10** Compound: **W3** Apply tamper proof sticker to tire and wheel rim	Visual Check		
MI.4.3	Wheels	Four wheels not in a line. 203.2 mm (8 inch) minimum diameter. A single wheel nut must have positive retainer. Check correct wheel nuts, tapered nuts, washers and spacers.	Visual Check		

MECHANICAL INSPECTION

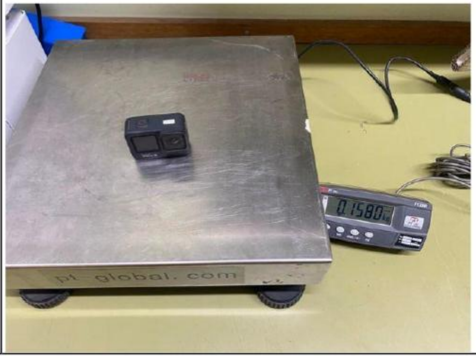
DRIVER'S EQUIPMENT					
Driver's equipment must be in good usable condition and conforming to the standards listed below				Reinspect	Passed
MI.5.1	Helmets	Must comply with Motorsport Australia, Technical Appendix, Schedule D, 2.1 Helmet standards A and B as listed	Visual Check		
MI.5.2	Frontal Head Restraint	Not compulsory - FIA 8858-2010, 8858-2002	Visual Check		
MI.5.3	Suits	Single piece - FIA 8856-2018, FIA 8856-2000, FIA 1986, SFi 3.2A/5 or superior SFi standard.	Visual Check		
MI.5.4	Underwear	Not compulsory - recommended. FIA 8856-2000, 8856-2018	Visual Check		
MI.5.5	Balaclava - hair cover	FIA 8856-2000, FIA 8856-2018	Visual Check		
MI.5.6	Socks	FIA 8856-2000, FIA 8856-2018	Visual Check		
MI.5.7	Shoes	FIA 8856-2000, FIA 8856-2018, SFi 3.3 or shoes with leather uppers.	Visual Check		
MI.5.8	Gloves	FIA 8856-2000, FIA 8856-2018 or leather.	Visual Check		
MI.5.9	Arm Restraints	SFi 3.3	Visual Check		

DRIVER'S COMMUNICATION				Reinspect	Passed
MI.6.1	Interconnected to vehicle	If part of driver's equipment, then it must not be attached to driver's helmet unless fitted by helmet OEM.	Visual Check		
MI.6.2	Telemetry	If fitted, may only be used to monitor vehicle state. 	Visual Check		

MECHANICAL INSPECTION

EXTERIOR GENERAL - VEHICLE ID & EQUIPMENT				Reinspect	Passed
MI.7.1	Fire extinguishers	Two hand-held, 0.9kg (2lb) minimum, dry powder, dry chemical, Must see both. One extinguisher mounted on Push Bar. Portable fire extinguishers must not be mounted to the vehicle. Dedicated On-board extinguishing systems encouraged	Visual Check		
MI.7.2	Push bar	With car, detachable, push and pull for 2 people standing behind car.	Visual Check		
MI.7.3	Jacking Point	Must have an exposed tube 30cm long, 2.5-2.9cm OD. Painted Orange. Rear wheels must come off the ground using Quick-jack (200mm lift).	Visual Check		
MI.7.4	Body and Styling	Open wheeled, open cockpit, formula styled body. Vertical keep out zones 75mm in front & behind tyres, no aero exceptions, tyres unobstructed from sides.	Visual Check		
MI.7.5	Car Numbers	Numbers must appear on front (upper surface of the nose, on centerline) and both sides. Not obscured. Min height 150mm with 25mm spacing from edges. Helvetica Bold. In Dayglo Yellow. Black background - Round, Oval, Square or Rectangle.	Visual Check		
MI.7.6	School Name and Other Decals	School name or initials, min height 50mm on both sides in Roman letters.	Visual Check		

EXTERIOR GENERAL - BODYWORK & AERODYNAMICS				Reinspect	Passed
MI.8.1	Wings	Securely mounted, should not wiggle when gently touched, especially side to side. If in question inform chief. Affix inspection sticker/s to front and /or rear wings/ aerodynamic devices.	Visual Check		
MI.8.2	Wing Edges	Horizontal leading edges min 5mm radius, vertical forward facing edges min 3mm radius. Radius must be part of structure or permanantly attached.	Physical check with radius gauge		
MI.8.3	Bodywork	Minimum 38mm radius on nose, No large openings in bodywork entering into driver compartment in front of or alongside driver. 75mm clearance Front and Back of tyres viewed from above.	Physical check with radius gauge		
MI.8.4	Wheel base	Minimum 1525mm (60 inch)	Physical check with tape measure		
MI.8.5	Aerodynamics	All Aero devices, wings, undertrays, splitters, max 70cm forward of front tyres, max 250mm rearward of rear tyres. Front wings no wider than outside of front tyres. Rear wings no wider than inside of rear tyres. Under trays no wider than line between front and rear tyres. No power ground effects.	Physical Check with Gauges		
MI.8.6	Aero Vertical Height	Rear wing max 1200mm above ground (inc end plates). Front wing max 250mm above ground. No bodywork or aero higher than 500mm between axles(except centre 800mm of car, ie, cockpit panels)	Physical Check with Gauges		
MI.8.7	Cameras	If >0.25kg, must be secured by two points. No cameras mounted on helmets.	Visual Check		

MECHANICAL INSPECTION						
						

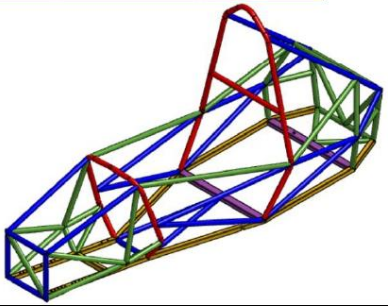
MECHANICAL INSPECTION

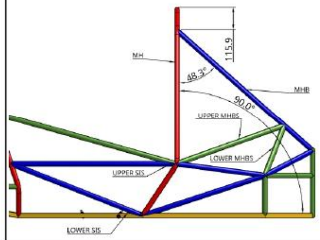
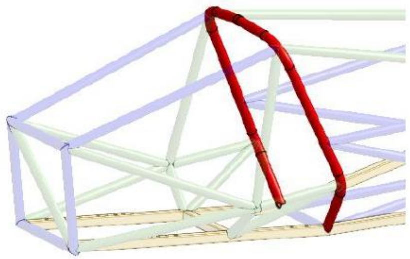
EXTERIOR GENERAL - CHASSIS & STRUCTURAL				Reinspect	Passed
MI.9.1	Alternative frame	If alternative tube size/material, approved Structural Equivalency Sheet (SES) required. If using Alternative Frame Rules, no titanium or magnesium in primary structure.	Visual / Physical Check		
MI.9.2	Inspection holes	Inspector may use ultrasound to measure wall thickness and/or ask 4.5mm hole be drilled.	Visual / Physical Check		
MI.9.3	Main hoop	MUST BE STEEL. 1.00" OD x 0.095" wall or 25mm OD x 2.5mm wall. Must be 1 piece & extend to lowest frame member. 380mm apart (inside dim.) where attaches to bottom tubes of the Major Structure. Above Major Structure, must be within 10°of vertical. No part angled rearwards more than 10°from vertical. Smooth bends with no wrinkles. Attachment to Monocoque/Composite must be mechanically affixed.	Visual / Physical Check		

Prepare tube samples and

chassis images

Catergory	Size (mm)	Size (inches)
Size A	25.4 * 2.41	1" * 0.095"
Size B	25.4 * 1.65	1" * 0.065"
Size B	25.4 * 25.4 * 1.24	1" * 1" * 0.049"
Size C	25.4 * 1.24	1" * 0.049"
Size X	25.4 * 44.5 * 16.65	1" * 1.75" * 0.065"
HV System		



MECHANICAL INSPECTION					
MI.9.4	Main hoop bracing	MUST BE STEEL. One brace each side, 1.00" x 0.065" or 25mm x 1.6mm minimum, attached within 16cm of top. Minimum 30 deg. included angle with hoop. If main hoop is not vertical, bracing must not be on same side of vertical as main hoop. No bends. No rod-ends. Proper construction for removable braces (capping etc.) on BOTH ENDS. Must take load back to bottom of main hoop and node of upper side-impact tube thru proper triangulated structure. If any item which is outside the envelope of the Primary structure is attached to the Main Hoop braces not at a node, additional bracing must be added to prevent bending loads in the braces in any rollover attitude. (eg.. suspension mounts, radiators or wings). 	Visual / Physical Check		
MI.9.5	Bolted joints	Edge of any bolt hole located > 1.5 x hole diameter from nearest edge of the material (Primary structure joints only)	Visual / Physical Check		
MI.9.6	Shoulder harness mounting bar	1.00" OD x 0.095" wall or 25mm OD x 2.5mm wall steel or equiv. Gussets or braces if not straight to main hoop	Visual / Physical Check		
MI.9.7	Front hoop	Must be closed section metal tube. 1.00" OD x 0.095" wall or 25mm OD x 2.5mm wall steel, or equiv. Can be multi-piece. Must extend down to lowest frame member. Maximum 20 deg. to vertical. No lower than top of steering wheel. Maximum 250mm horizontal distance to steering wheel. 	Visual / Physical Check		

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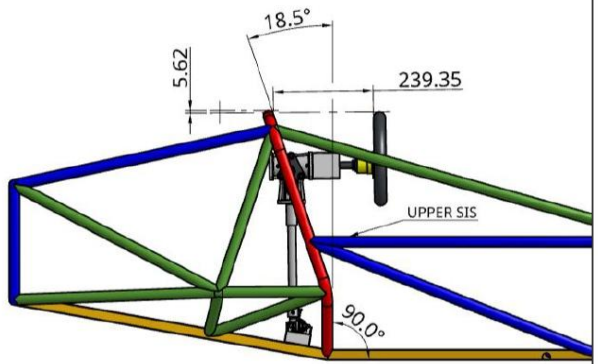
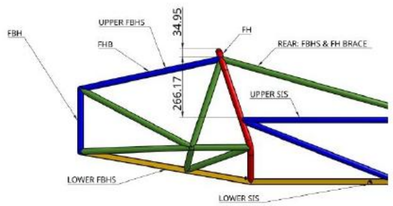
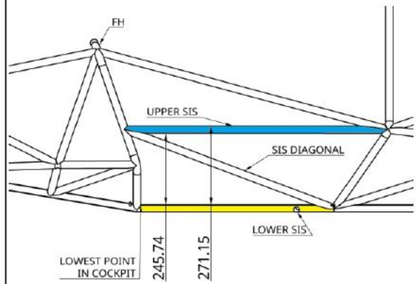
<tr><th colspan="6">MECHANICAL INSPECTION</th></tr>
<tr><td></td><td></td><td>
</td><td></td><td></td><td></td></tr>
<tr><td>MI.9.8</td><td>Front hoop bracing</td><td>Two forward facing braces, 1.00" OD x 0.065" or 25mm OD x 1.6mm steel or equivalent, attached within 5cm of top. Extra rearward bracing required if Front Hoop leans backwards more than 10 degrees.

</td><td>Visual / Physical Check</td><td></td><td></td></tr>
</table>

MECHANICAL INSPECTION

EXTERIOR GENERAL - CHASSIS & STRUCTURAL CONTINUED...				Reinspect	Passed
MI.9.9	Other side tubes	Design prevents driver's neck hitting bracing or other side tubes.	Visual Check		
MI.9.10	Side impact protection	Comprised of 3 or more tube members on each side. Must connect to main and front hoops. Lower tube to bottom of both hoops. Lower tube can be lower frame member. Upper tube must be in a zone parallel to ground between 240mm and 320mm above the lowest point of the top surface of the Lower side impact member. At least one diagonal per side must connect the upper and lower members between the main and front hoops. All tubes to be 1.0" OD x 0.065" wall or 25mm OD x 1.6m wall steel or equivalent. If Upper Side Impact tube is multi piece or bent, must have triangulating supporting tube from the furthest part of deviation from the straight line, back to a node on the chassis and the bent tube and support must be minimum 35mm x 1.2mm;  	Visual / Physical Check with gauge.		
MI.9.11	Front bulkhead	1.0" OD x 0.065" wall, or 25mm x 1.6mm wall, steel tube or equiv. No non-crushable objects forward of bulkhead.	Visual Check		
MI.9.12	Front bulkhead support	Support back to front roll hoop; minimum 3 tubes per side, all 1.00" OD x 0.049" wall steel tube or equivalent 1 bottom; 1 top within 50mm of top of bulkhead, and connecting within 4" above and 2" below upper side impact support (SIS) tube; 1 or more node-to-node diagonal to completely triangulate connections to upper and lower side impact support (SIS) tubes. (25mm x 1.5mm and 26mm x 1.2mm metric tubes OK) F.6.2.3 The Front Bulkhead must be supported back to the Front Hoop by a minimum of three Frame Members on each side of the vehicle; an upper member; lower member and diagonal brace to provide Triangulation. a. The upper support member must be attached 50 mm or less from the top surface of the Front Bulkhead, and attach to the Front Hoop inside a zone extending 100 mm above and 50 mm below the Upper Side Impact member. b. If the upper support member is further than 100 mm above the Upper Side Impact member, then properly Triangulated bracing is required to transfer load to the Main Hoop by one of: • the Upper Side Impact member • an additional member transmitting load from the junction of the Upper Support Member with the Front Hoop	Visual / Physical Check		

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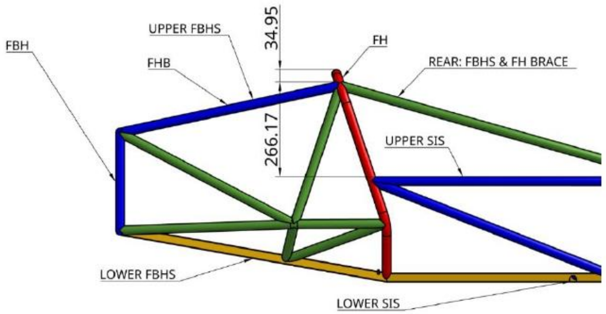
MECHANICAL INSPECTION

Moment of Inertia for RHS				
b	25.4	mm	Outer dimension	
d	25.4	mm	Outer dimension	
Wall Thickness	1.24	mm		
h	22.91	mm	Inner dimension	$\frac{bd^3 - hk^3}{12}$
k	22.91	mm	Inner dimension	
Area Moment of Inertia	11725.54	mm^4		
Cross Sectional Area	120.26	mm^2		



MECHANICAL INSPECTION					
		F.3.4 Steel Tubing and Material F.3.4.1 Minimum Requirements for Steel Tubing A tube must meet all four minimum requirements for each Size specified:			
MI.9.13	Impact Attenuator	Impact Attenuator forward of bulkhead, 200mm long x 200mm wide x 100mm high. No wing supports through the IA. Bonded, or bolted to Plate with eight 8mm bolts plus additional support.	Visual / Physical Check		

	Tube	Minimum Area Moment of Inertia	Minimum Cross Sectional Area	Minimum Outside Diameter or Square Width	Minimum Wall Thickness
a.	Size A	11320 mm^4	173 mm^2	25.0 mm	2.0 mm
b.	Size B	8509 mm^4	114 mm^2	25.0 mm	1.2 mm
c.	Size C	6695 mm^4	91 mm^2	25.0 mm	1.2 mm
d.	Size D	18015 mm^4	126 mm^2	35.0 mm	1.2 mm

MECHANICAL INSPECTION

Page 1 of 1

PLASCORE®

Certificate of Conformance

Plascore, Inc.
615 N Fairview
Zeeland, MI 49464
USA

Phone: 616-772-1220
Fax: 616-772-1289

Plascore Part #
B101428

Customer Part #

Plascore Drawing # and Revision	Customer Drawing # and Revision
B101428 Rev AL1378	**N/A**

Item Description	Total Quantity
IMPACT_ATTENUATOR A57316P5052 8.00"TX7.90"LX3.95"W PRECRUSHED	**2.00**

Core Description	Size
	8" X 7.9" X 3.95"

Customer
University of Newcastle
EC Building, 130 University Drive
NU Racing
Callaghan, NSWAustralia

Cage Code	Print Date
N/A	**6/21/2024**

HTS Code	ECCN Code
7610900050	**EAR99**

SO # **233640** - PO # **VERBAL** - WO # **199688**

Line #	Pkg #	Batch #	Quantity	Mfg Date
1	A47790	167218-10	2.00	6/21/24

Certification Statement

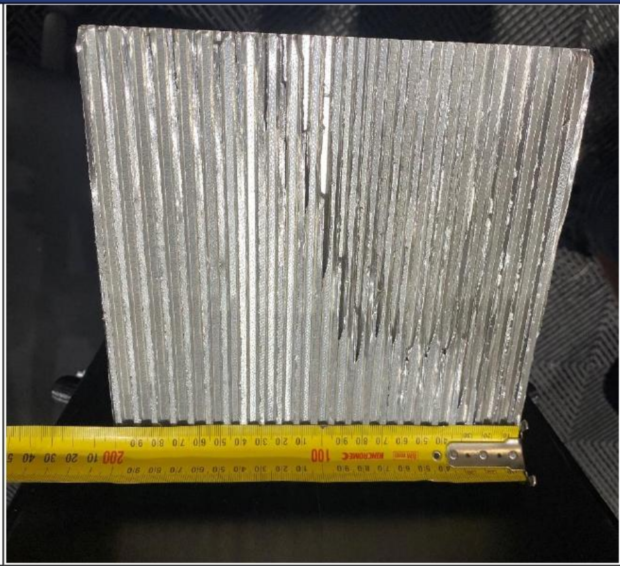
Plascore Product is certified to

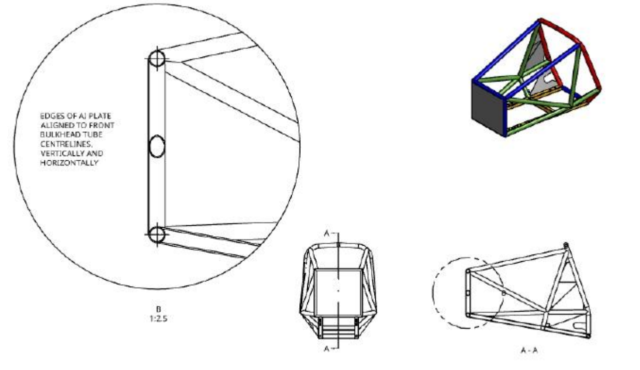
We hereby certify the above parts/materials meet the requirements of the approved drawings/models and or specifications as stipulated in the Purchase Order.

Plascore Quality Control Representative

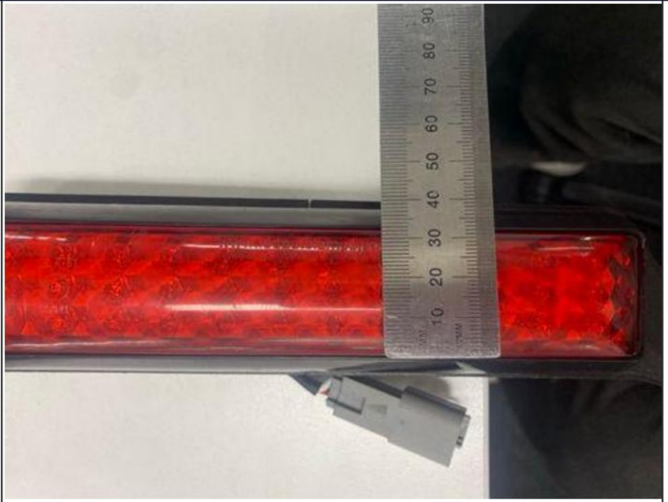
Country of Origin : USA

MECHANICAL INSPECTION

					
MI.9.14	Impact Attenuator Mounting. Anti intrusion plate	All vehicles must have 1.5mm steel, 4mm Al, or approved equivalent IA anti-intrusion plate. Plate must be capable of taking transverse and vertical loads (welded or minimum eight 8mm bolts). Same size as outside dimensions of Front Bulkhead if bolted or to tube c/l if welded. If the outside profile of the Front Bulkhead is greater than 400 mm x 350 mm; or a Standard Impact Attenuator is used, requires diagonal brace unless test results provided to show Al plate deflection was less than 25 mm. The Standard IA must be attached only by bonding	Visual / Physical Check Team to present test results if required.		

MECHANICAL INSPECTION					
					
MI.9.15	Monocoque / Composite	Must see laminate test specimens (2 or more) for both side impact support (SIS) and primary structure constructions. Steel backing plates (>2mm thick) used at attachment points.	Visual / Physical Check		
MI.9.16	Thermal Protection	Protection when entering or exiting vehicle, exhaust, coolant hoses or through seat or floor.	Visual Check		

MECHANICAL INSPECTION					
VEHICLE CONTROLS - STEERING, SUSPENSION & BRAKES				Reinspect	Passed
MI.10.1	Ground clearance	Sufficient clearance so that no part of the car other than the tyres will contact the track surface.	Visual / Physical Check		
MI.10.2	Suspension	Fully operational with dampers front and rear; 50mm minimum wheel travel with driver in vehicle 	Visual / Physical Check		
MI.10.3	Suspension pickup points	Inspected thoroughly for integrity.	Visual / Physical Check		
MI.10.4	Brakes	Dual hydraulic system & reservoirs, operating all 4 wheels, (one brake on limited slip OK). System protected by structure/shields from d/train failure & minor collisions. No plastic brake lines or brake-by-wire. No parts below chassis/tub in side view. Brake pedal (and seat) capable of 2000N (450 lbs-f) with no failures (tested only by organizers.)	Visual / Physical Check		
MI.10.5	Brake Light	One (!) RED brake light, clearly visible from the rear; on vehicles centreline; height between wheel centreline & driver's shoulders. Round, triangle, or rectangular on black background. 15cm² minimum illuminated area.	Inspect		

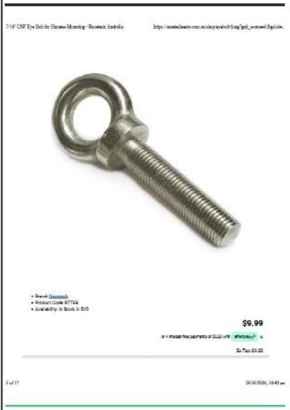
MECHANICAL INSPECTION					
					

MECHANICAL INSPECTION					
					
MI.10.6	Steering wheel	Continuous perimeter, near round (no concave sections) with driver operable quick disconnect. 25cm max from Front Hoop.	Visual / Physical Check		
MI.10.7	Steering	All steerable wheels must have positive stops to prevent linkage lock-up or tyres contacting any part of the car. 7 degrees maximum free play at the steering wheel. NO STEER-BY-WIRE on front wheels. (AVs may have an actuator on the steering, but the steering wheel must be directly mechanically attached to the wheels.) Rear steer limited to 6°total, with mechanical stops. No bonded joints in column. **Digital Level OR Phone w/** **measure app**	Visual / Physical Check		
MI.10.8	Fasteners	Intake manifold, fuel rail, steering, braking, impact attenuator (IA), EV accumulator (battery), harness & suspension system use SAE Grade 5, Metric Grade 8.8 or higher (AN/MS) with visible positive locking mechanisms, no Loctite or lock washers. Minimum of 2 exposed threads. Rod ends in single shear are captured by a washer larger than the ball diameter. Adjustable rod ends have jam nuts to prevent loosening. No button head cap, pan head or round head screws in critical locations, e.g., cage structure or harness mount. Nylon locknuts not for use above 80°C, i.e., near exhaust.	Visual / Physical Check		

MECHANICAL INSPECTION					
		Bolt Samples – M4 – M10 **BOLTS + NYLOCS +** **GLENLOCHS**			

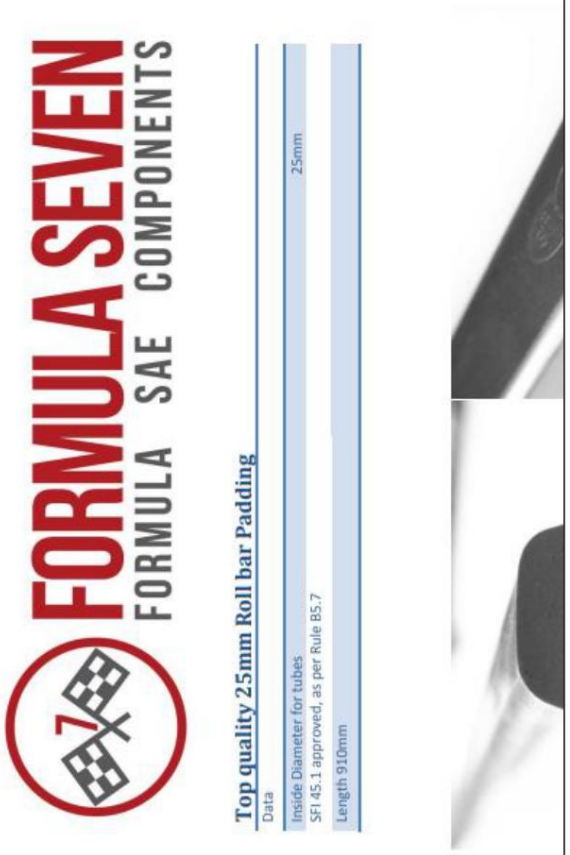
INTERIOR - DRIVER ACCOMMODATION				Reinspect	Passed
MI.11.1	Lap belt mounting	Must pass over pelvic area at between 45-65 deg. to horizontal for upright driver, 60-80 deg. for reclined. Pivoting mounting with eye bolt or shoulder bolt attached securely to Primary Structure.	Visual / Physical Check		
MI.11.2	Driver restraint harness	SFI 16.1, SFI 16.5 or FIA specs 8853/98 or 8853/2016 5, 6 or 7 point and be labelled. 50mm wide shoulder belts OK with FHR. 50mm lap belts OK for FIA & SFI 16.5, All lap belts must have Quick Adjusters. Reclined drivers must have 6 or 7 point, and Quick Adjuster sub-belts or 2 sets of sub belts. Sub belts cannot touch frame tubes or holes in seat. SFi Belts expire 2yr from manufacture date/month; FIA 8853/98 5 years after expiry year marked on label. **IMAGE OF PERCY /** **DRAWING**	Visual / Physical Check		
MI.11.3	Harness mounts	No belts can pass through a firewall. (Belts must mount on driver side of firewalls.) All belts attached securely to primary structure - 1.00" OD x 0.065" steel tube minimum. Any tabs to be 1.0" x 0.063" thick minimum. Double shear preferred. Bolt-on tabs use minimum of two 1/4" diameter Gr 5 bolts.	Visual / Physical Check		

MECHANICAL INSPECTION

INTERIOR - DRIVER ACCOMMODATION CONTINUED…				Reinspect	Passed
MI.11.4	Firewall	Fire resistant material; must separate driver (line-of-sight up to mid-height of driver's helmet) from fuel, cooling & oil systems. Wire/cable pass-throughs OK with grommets. Multiple panels OK w/ gaps sealed. No gaps at sides or bottom	Visual / Physical Check		
MI.11.5	Floor closeout panel	Required from foot area to firewall; solid, non-brittle material; multiple panels are OK if gaps less than 3mm. System Sealing: 1 or 2 drain holes min 25mm must be provided in the structure or belly pan at locations, lowest point of chassis or rearward of driver position forward of any fuel or liquids.	Visual / Physical Check		
MI.11.6	Belt attachment fasteners	Attachment bolt must be a minimum of 10mm Metric Grade 8.8 (3/8" SAE Grade 5). Applies to each belts. **Sample of Harness insert +** **Eye bolt** 	Visual / Physical Check		
MI.11.7	Head restraint / head rest	Meets SFI or FIA listed materials. Min 38mm thick, min 15cm wide, min height 28cm. Max 25mm from helmet, Helmet contact point 50mm minimum from any edge. Adjustable or changeable for different drivers.	Visual / Physical Check		

MECHANICAL INSPECTION					
					
MI.11.8	Roll bar padding	Meets SFI or FIA listed materials. Rollbar or bracing that could be hit by driver's helmet must be covered with 12mm thick (hard) padding. Pipe insulation and foam not permitted.	Visual / Physical Check		

MECHANICAL INSPECTION



MECHANICAL INSPECTION					
MI.11.9	Vehicle controls	All controls, including shifter, must be inside cockpit. No hands, arms or elbows outside side impact system to actuate.	Visual / Physical Check		
MI.11.10	Visibility	100 deg. minimum field either side. Head rotation OK or mirrors. If mirrors, must be firmly installed and adjusted	Visual / Physical Check		
MI.11.11	Drivers' foot protection	Feet must be rearward of the Front Bulkhead and no part of shoes or legs above or outside the Major Structure in side or front views when touching pedals.	Visual / Physical Check		
MI.11.12	Drivers' leg protection	Covers inside cockpit over sharp parts or moving suspension and steering components.	Visual / Physical Check		

POWERTRAIN				Reinspect	Passed
MI.12.1	Scatter shield materials	For chains, 2.7mm minimum thick STEEL, 3 x chain width. For belts, 3mm minimum thick aluminum 6061-T6, 1.7 x belt width	Visual / Physical Check		

MECHANICAL INSPECTION					
					
MI.12.2	Scatter shields general	Required for clutches, chains, belts, CVT rotating parts, etc. No holes. 6mm diameter M8.8 or 1/4" diameter Grade 5 fasteners minimum. End parallel to lowest part of front and rear sprockets	Visual / Physical Check		
MI.12.3	Catch tanks	Coolant overflow, crankcase breather & lube system vents must have separate catch tanks. 1 qt minimum each. 100°C material. Behind firewall, below shoulder level. 3mm minimum diameter vent, away from driver. PCV OK if routed to intake sys upstream of restrictor. Cannot attach breather to exhaust. Trans or diff., unless sealed, require 50 mL catch bottle.	Visual / Physical Check		

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MECHANICAL INSPECTION					
					

BRAKE TEST

SPECIALISED TESTS				Reinspect	Passed
MI.13.1	Driver template position PERCY	Seat adjusted to rear most position, pedals to forward most position, Bottom circle placed in seat bottom and between centre of circle and rear most face of the pedals is no less than 915mm. This dimension must be retained. If not it must comply before Dynamic events. Loss of points for Design Score.	Visual / Physical Check		
MI.13.2	Cockpit opening	Template passes down from above cockpit to 25mm below lowest point of the top of the Side Impact Structure to less than or equal to 320mm above the lowest point inside the cockpit.. Steering wheel & column, seat & padding may be removed. No removing firewall. Fore/aft translation of template OK.	Visual / Physical Check		
MI.13.3	Cockpit Internal cross section	Pedals in most forward position. Vertically and may be moved horizontally, Template to pass from cockpit to 100mm rear of pedals. Steering wheel and padding removable with no tools & with driver in seat. Seat remains, Steering wheel can be removed.	Visual / Physical Check		

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