Student Formula Japan

A guide to how a new or inexperienced team can design and build a competitive Formula Student car in a reasonable time and on an affordable budget.

Introduction

Formula Student is not a motorsport event!

It is an educational event with a motorsport theme.

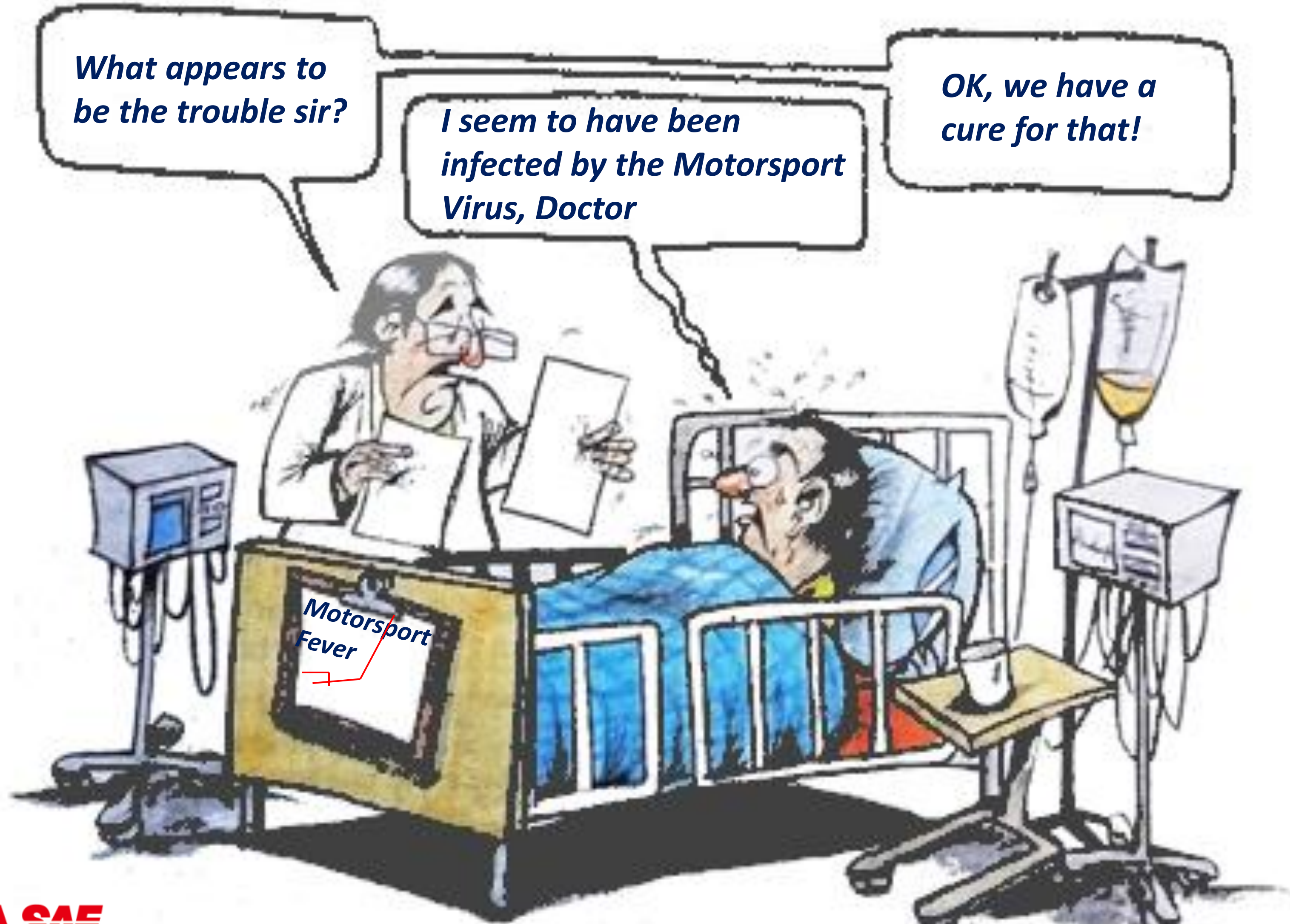
For this reason, you should design to the rules, not slavishly follow mainstream motorsport design trends.

The Team

A Formula Student team is usually formed when a group of like minded students get together to "build a racecar'.

Invariably, they underestimate the complication and cost of the exercise.

Hopefully, this presentation will help overcome some of those difficulties.



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So, the team set out on a project that will enhance their education at University.

This means that the 'bait' set by the organisers, (who have an ulterior motive) has been taken and the fish has been hooked.

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Immediately, there will be a show of hands!
"I'll do the engine"
"And, I'll do the suspension"
"I want to do the wings" and
"I'll do the Chassis" …
and similar cries from the attendees, depending on their area of interest.

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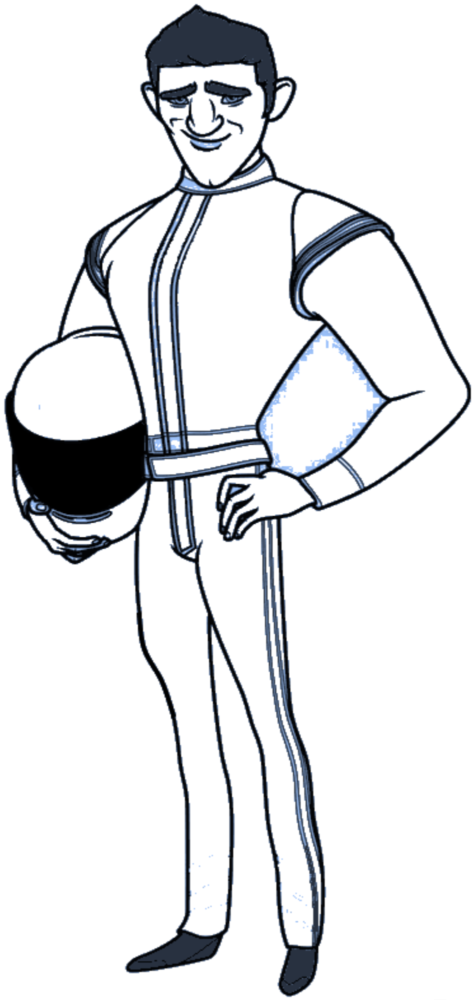
And every team has this guy!

"I'll drive"

This guy can be an absolute pest!

All team members should contribute!

But driving should not be a right of the Designers or Builders.



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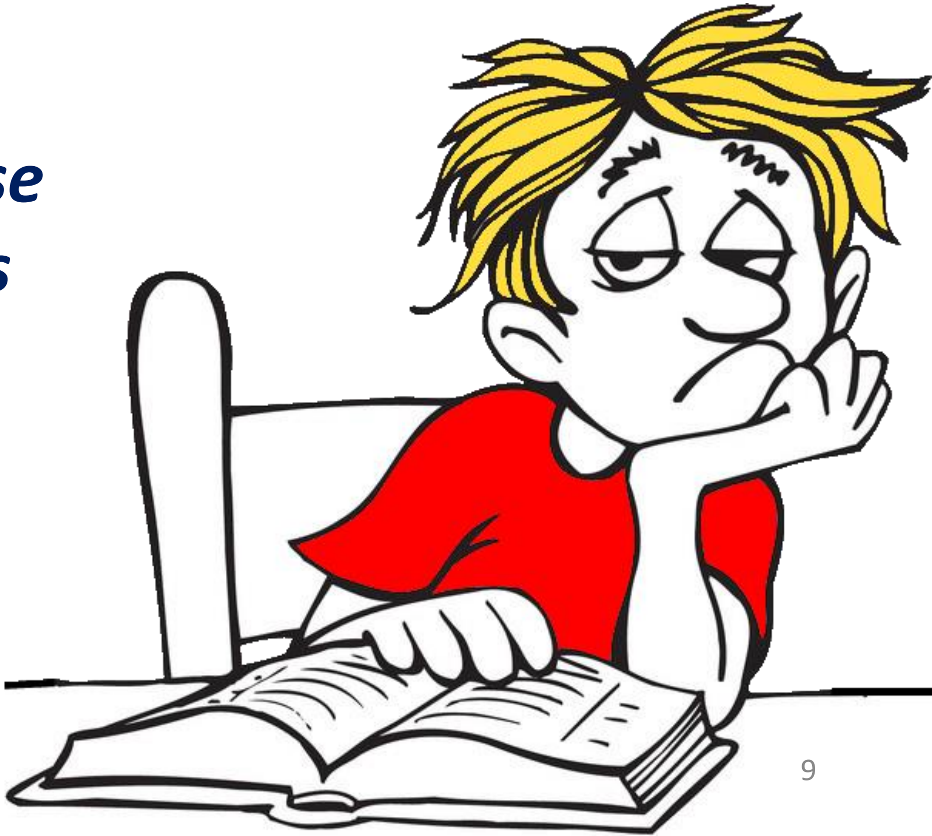
STOP

The Rules

First, it is important that ALL team members read and understand the Rules.

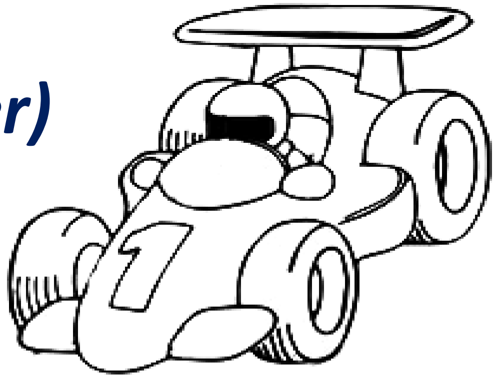
ALL the Rules, not just those that concern an individuals area of interest.



The Task

The task you have been given, when stripped to absolute basics is…

- *To accelerate a mass (car and driver)*
- *From this point (Here)*
- *Back to this point (Here)*



in the shortest possible time and on the least amount of fuel, using only the forces generated at the tyre contact patches.

Sounds simple, doesn't it?

The Reality

Poor (or non existent) Project Management will ensure team cohesion in focusing on the goal.

More than anything else, Formula Student is attempting to train Project Management!

The team needs a capable overall manager.

There are many online courses in Project Management, and the various managers within a team should study the subject!

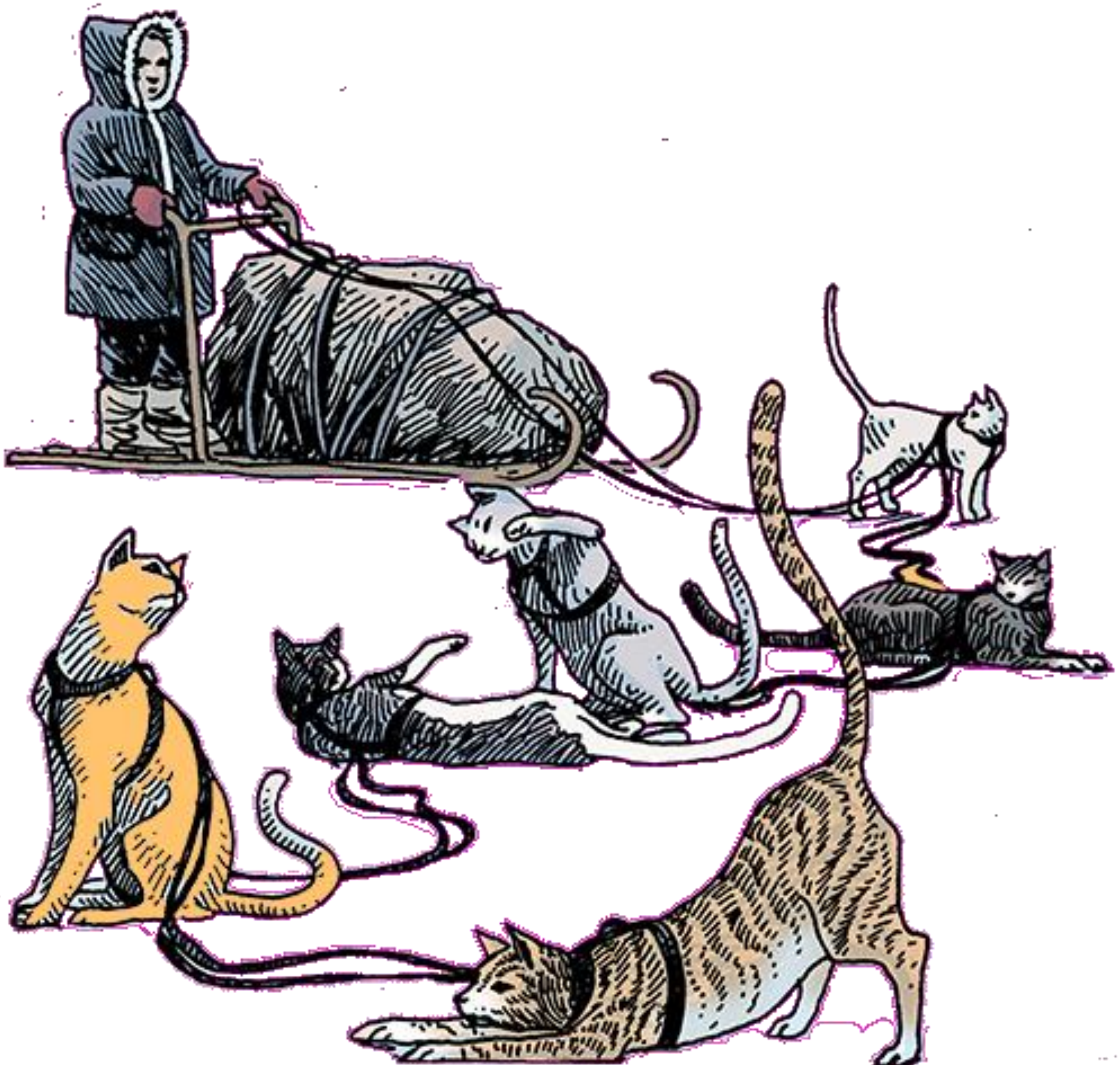
Reference URL:
https://www.linkedin.com/in/emilyanthony/detail/recent-activity/posts/

Every team needs a strong management structure with a recognised leader.

Democracy might sound like a great idea, but in a SFJ team it invariably leads to mediocrity!

There is a Reason we have Dog Sled Teams

And Not Cat Sled Teams

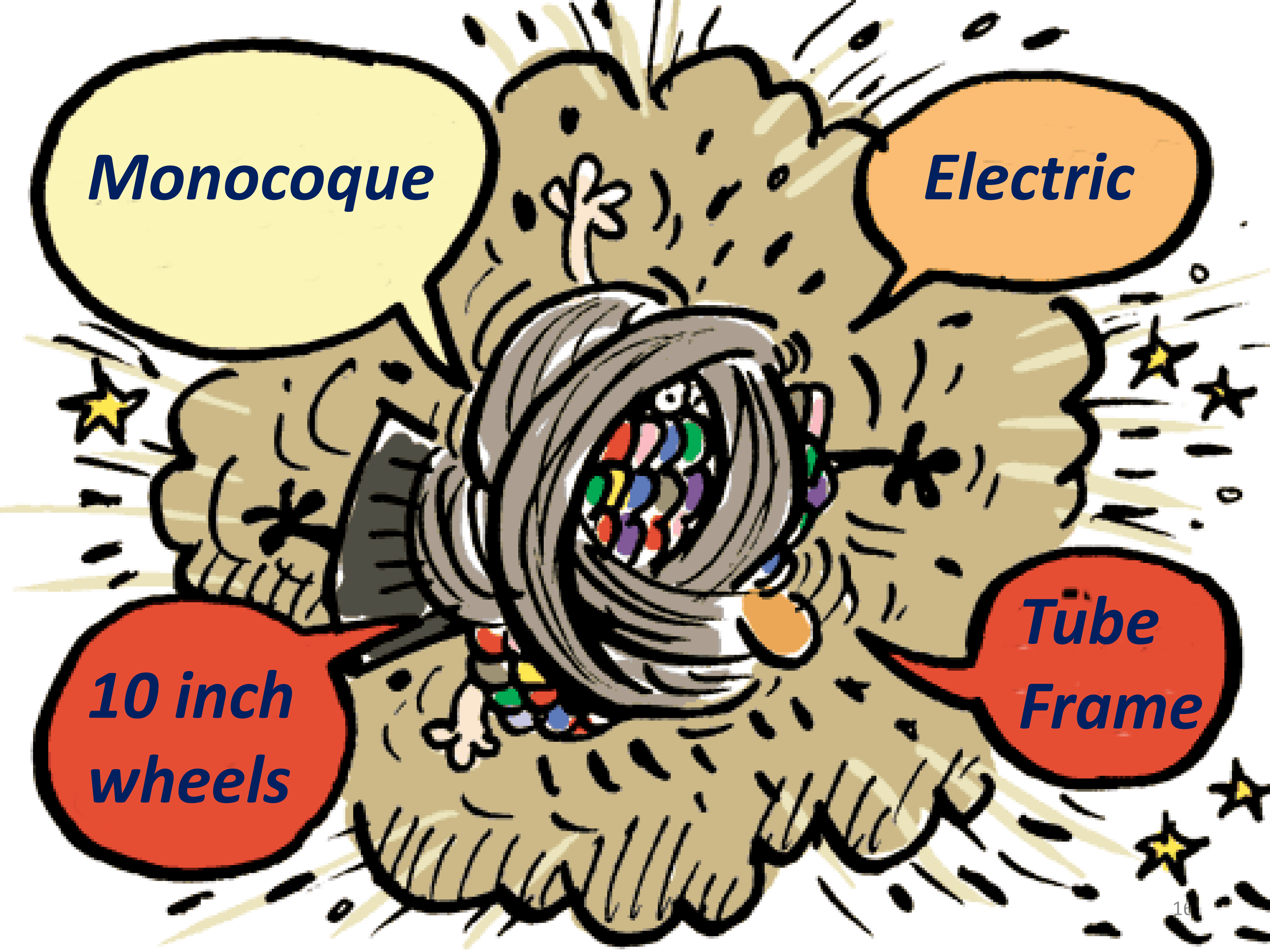


The Commencement

Let us assume (a dangerous proposition!) that managerial issues are determined.

- ***That suitable funding has been found (Critical!).***
- ***That the team has a workshop and equipment to build the car.***
- ***That the team has a realistic budget to build the car, do some testing and attend their chosen event.***

What decisions do you have to make first?


Monocoque
Electric
10 inch wheels
Tube Frame

Funding

No team ever has enough money. One of the tasks given is to raise funding and to properly manage the budget.

Sponsorship comes in three forms:

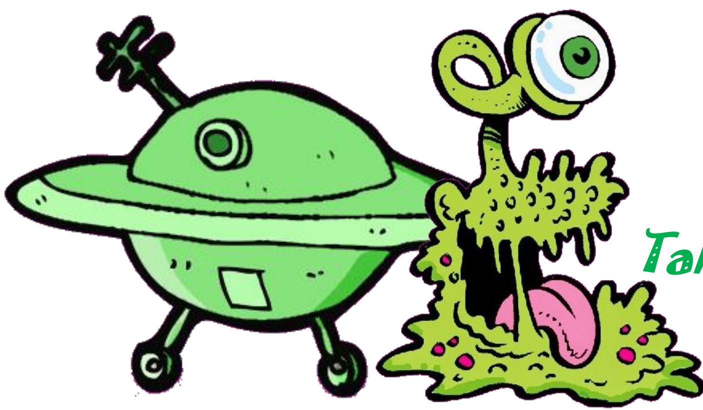
1) ***Cash***
2) ***Goods***
3) ***Services***

Each has its own benefit, but cash is need to start and someone must be appointed to manage that cash!

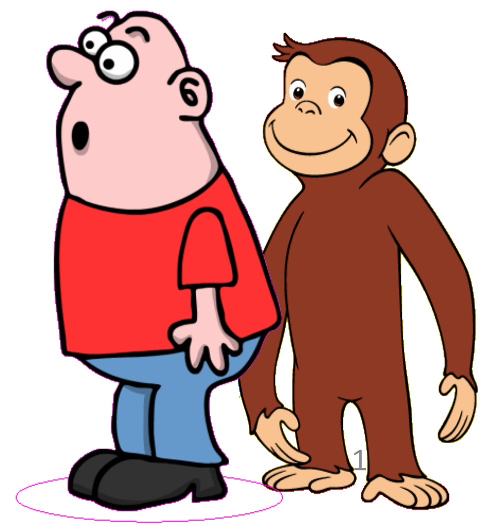
Knowledge Shortfall

First, you MUST admit that you don't know anything! You might think that you do, but the truth is that you don't know what you don't know!

You are operating in a SFJ knowledge vacuum, but don't simply follow the 'Monkey see, monkey do' ethos.



Take me to your leader !



All the pictures on the Internet.

All the advice on ‘Pat’s Corner’ or the various Facebook, Reddit and internet sites will give you some understanding, of ‘What’, but they will not give you the ‘Why’ answers.

But the ‘Why’ questions will be asked by the Judges So understanding is Necessary.

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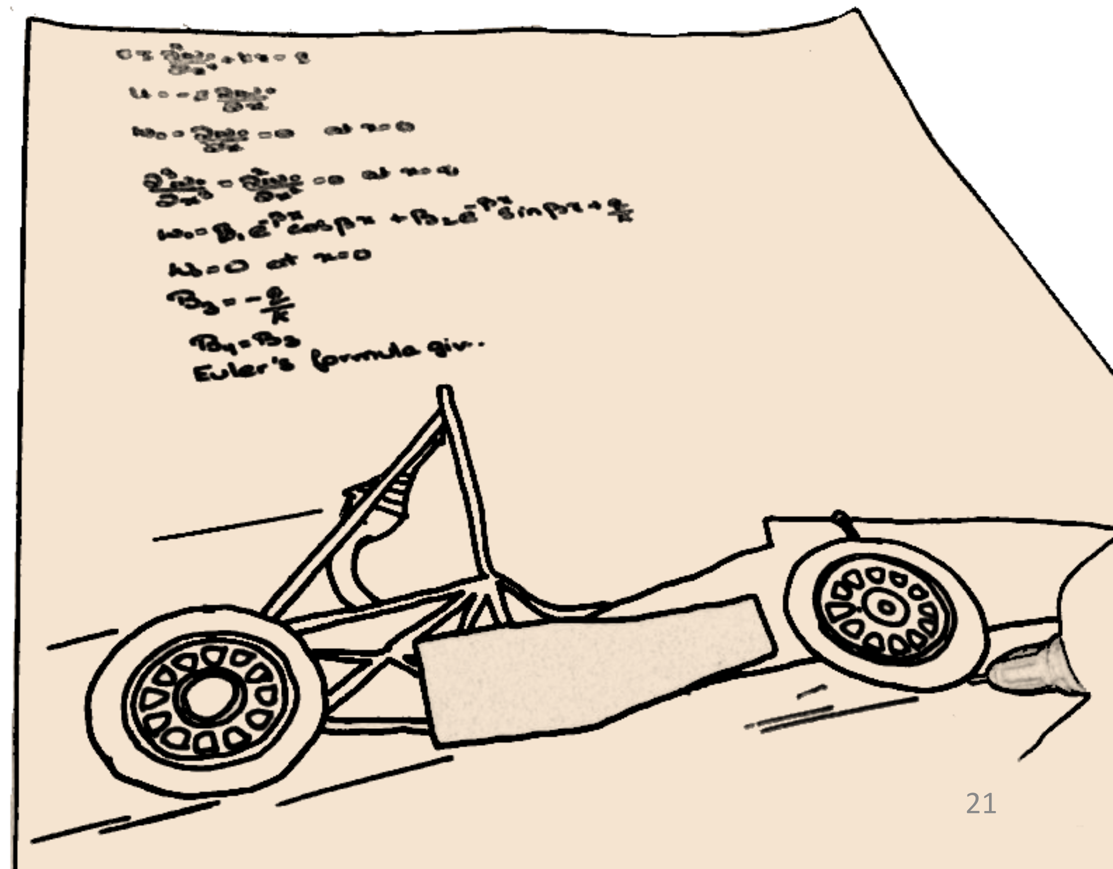
The only person who knows 'Why' is YOU!

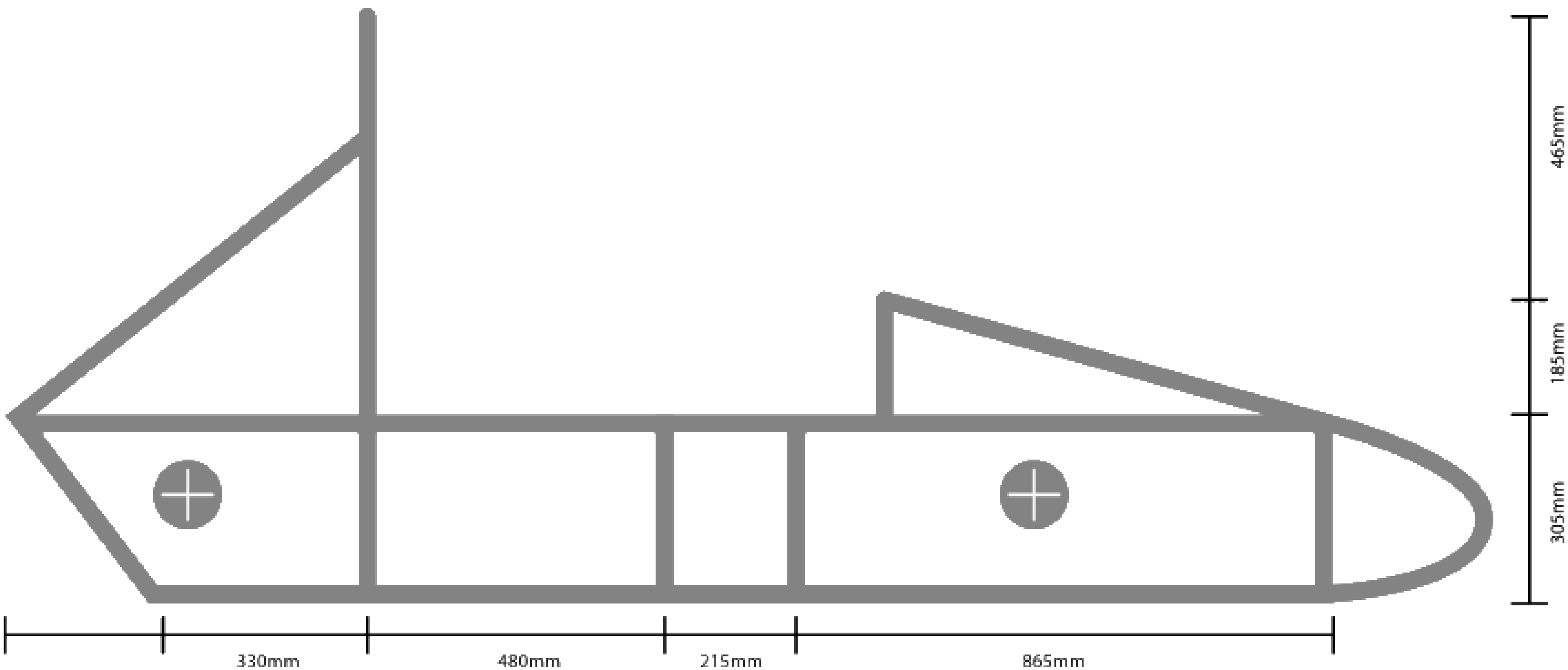
Making Choices

Before commencing Design, the team needs an agreed idea of what they want to build.

This is the 'dreaming' part of the project.



Big Picture Outline



All things being equal

1) *The car with the least weight will win.*
2) *The car with the lowest centre of gravity will win.*
3) *The car with the lowest Polar Moment of Inertia will win.*

Pat's Rules

1)Reduce the vehicle mass
2)Lower the vehicle mass
3)Centralise the vehicle mass

Every design decision should be tested against these rules!

Choices to be made include…

- *Which event to attend*
- *Combustion or Electric*
- *Chassis (spaceframe or monocoque)*
- *Tyres*
- *Engine (or motor)*
- *Brakes*
- *Driveline*
- *Suspension*

There are more, but these are the big ones. I will address them one at a time, with reasons for my suggestions.

The GOAT

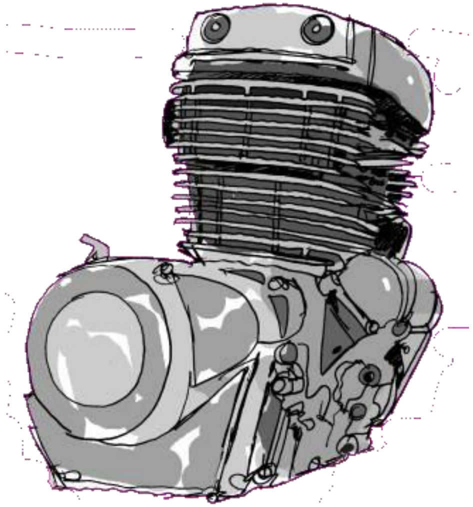
If you follow my recommendations, your first car will not be a ‘Goat’!

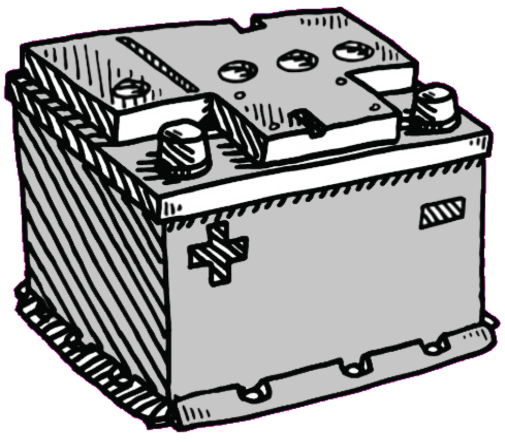
But, despite what you might think, it will not be a ‘G.O.A.T’ (Greatest Of All Time) either.

Combustion or Electric

For an inexperienced team, there is only one answer, Combustion!

Electric might sound simple and attractive, but for a new team, the rules are very complex and rules compliance is difficult.





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Combustion or Electric

Chassis Type

Again, for a new team, there is only one answer, multi tube space-frame!

Rules compliance with a space-frame chassis is much easier than proving equivalency with a composite or aluminium monocoque chassis.

An added benefit is, when the inevitable mistake is made during construction or found after testing, it is much easier to rectify.

Tyres

Most would recommend the team join the TTC and make their tyre choice based on data from that site.

My recommendation is to choose a 13” tyre from one of the several suppliers of FS tyres and then make that choice work.

The TTC is a wonderful resource, but the data is useless to a team working in that knowledge vacuum. Worry about the TTC data next year (or the year after!).

Engine Choice

Having already recommended to use a combustion engine, the task becomes what engine to choose.

- ***Question… What engine is best?***
- ***Answer… Whatever engine you can get!***

Cars in SFJ competition spend less than 5% of their time at full throttle, so power is not an issue. But drivability is, especially for inexperienced drivers.

Throttle and Restrictor

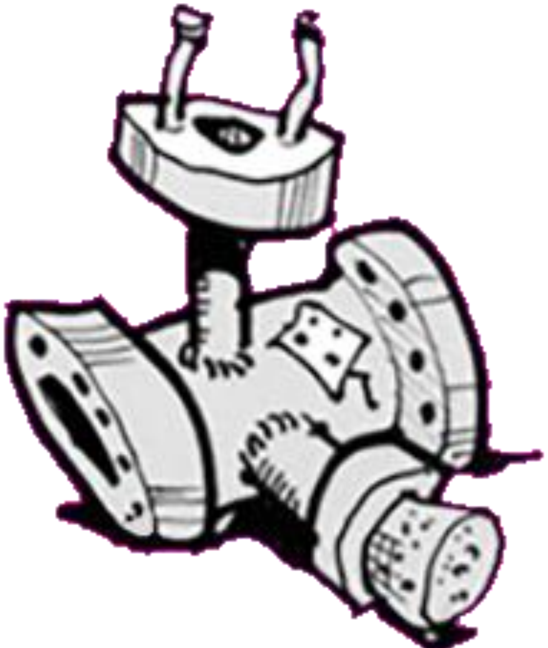
The Rules require fitment of a 20 mm restrictor and this causes some tuning issues.

On the single cylinder engines, using the standard throttle body can cause huge drivability issues and even cause engine damage.

Throttle Body

The large (typically <40mm) will saturate the restrictor at less than 30% throttle opening.

This gives the driver an 'On/Off' throttle action and seriously over-fuels the engine if the driver uses more than about 30% throttle opening.



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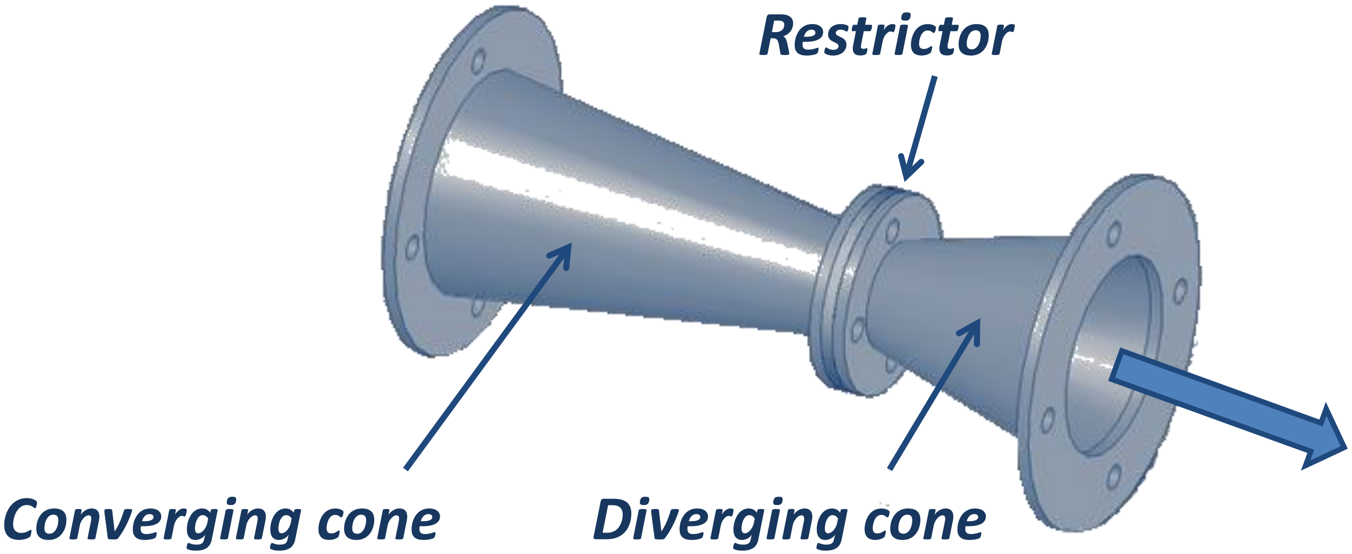
Intake Restrictor



SFJ rules require a 20mm intake restrictor.
Using a converging/diverging cone to aid in pressure recovery is perfectly legal.
Most of the power lost to the restrictor can be recovered.

Exhaust Silencer

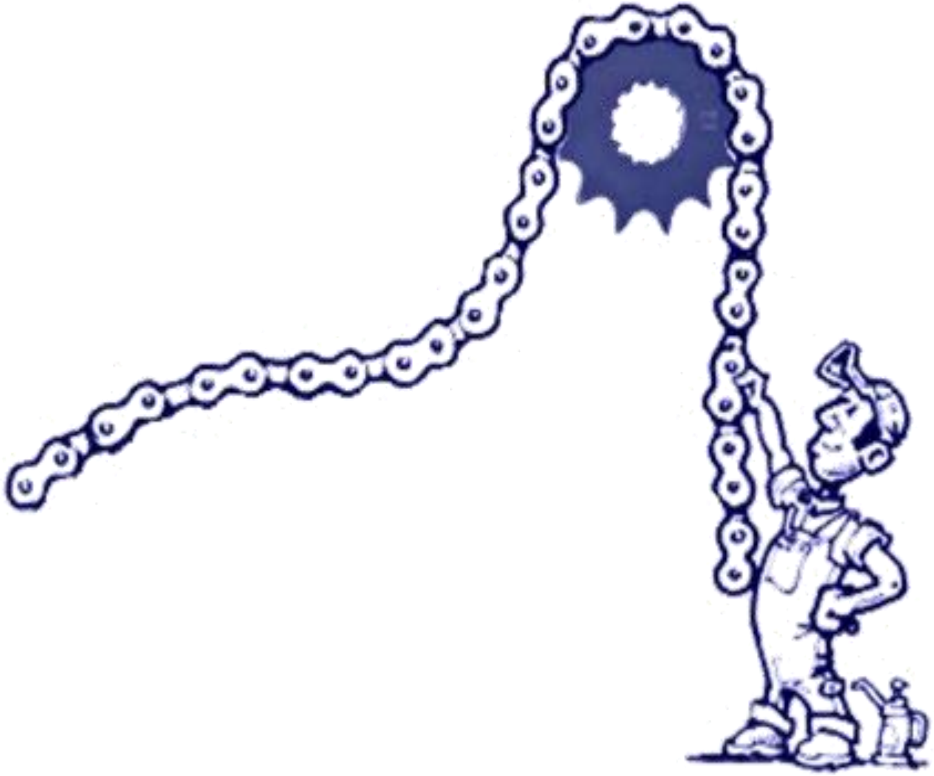
SFJ rules set a maximum exhaust noise level.

Exceed this and you will not be permitted to compete in the Dynamic Events...

A really dumb way to be disqualified!

Final Drive

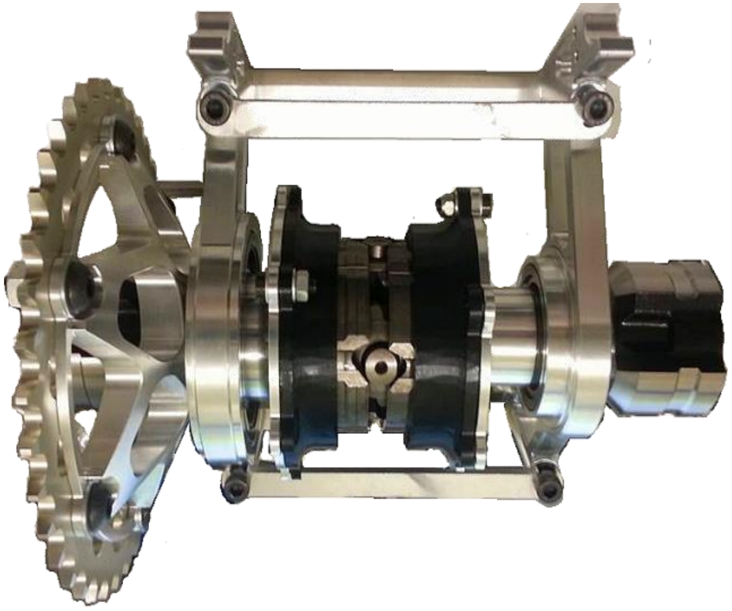
The Final Drive in a FS car usually consists of a chain drive to a differential and then to the wheels via articulated axles.



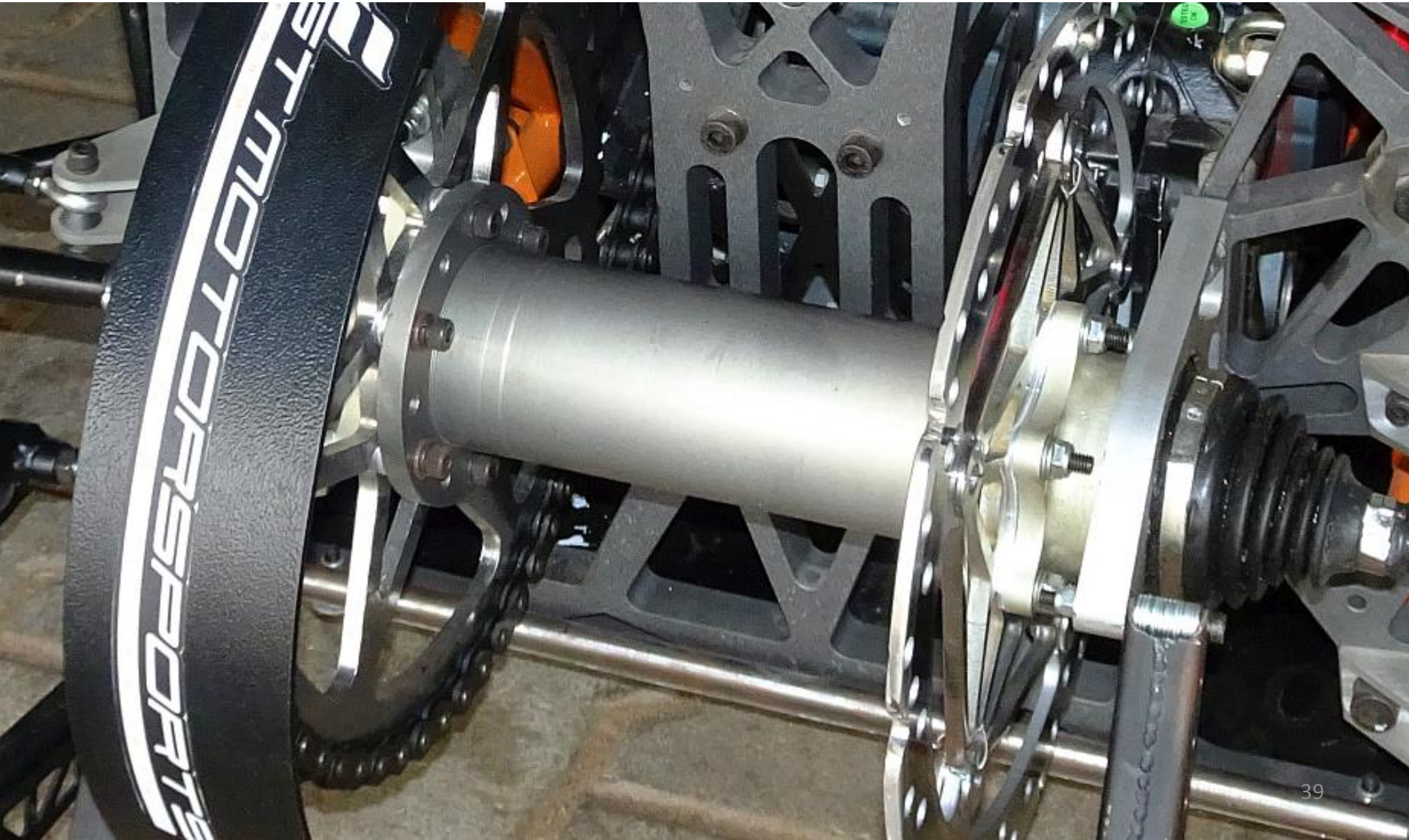
Final Drive and Differential

Most FS cars are fitted with a differential to balance rear wheel speeds.

Usually this is a 'limited slip' differential of some kind, but there are other options.



A Spool!



Making a Spool Work

Conventional wisdom says a car must have a differential to turn without binding up and generating understeer or 'push' in corners.

Go karts manage to corner at speed whilst being fitted with a solid rear axle.

How do they achieve that?

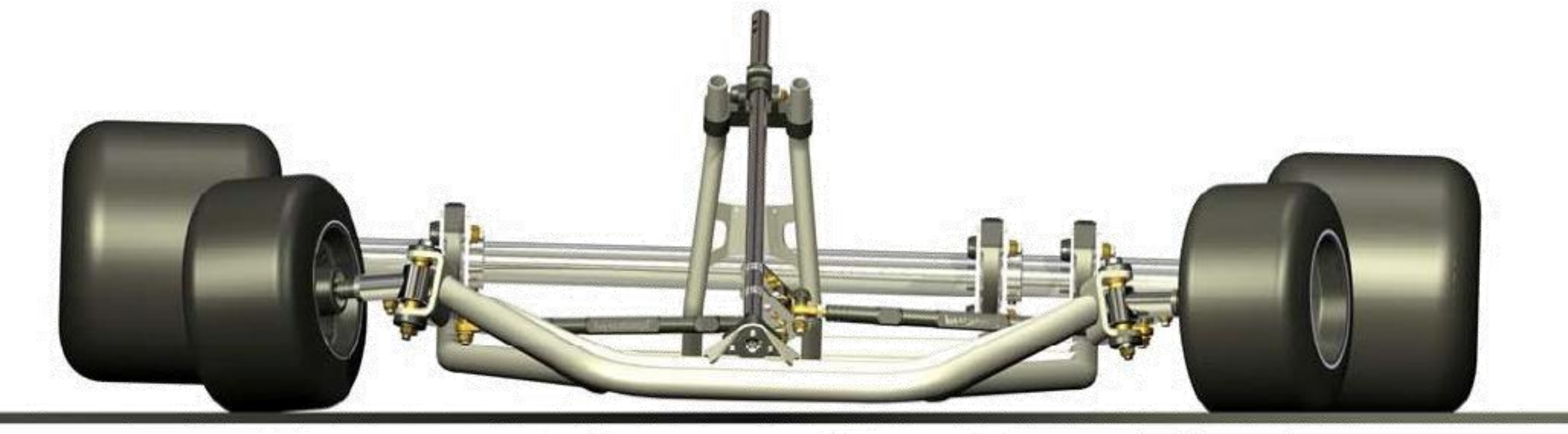
This picture might help you understand

The chassis has somehow twisted.

But here it is not twisted

Diagonal Weight Jacking

This illustration shows how the steering geometry has caused the chassis to unload the inside rear wheel. This permits the kart to turn without the live rear axle trying to drive the kart straight ahead.



Inboard Rear Brake

Another benefit of using a spool drive is that a single inboard rear brake can be used without the complications of braking across a differential.

This reduces the weight, the cost, the rotational inertia and un-sprung weight as well as removing the braking forces from the suspension control arms.

The example shown is the 2014 car from Stuttgart, with 13" wheels and aligned driveshafts.

Suspension

There has been more nonsense written and more time wasted on 'suspension geometry' than on any other aspect of Formula Student design!

The SFJ rules require only 50mm of suspension travel.

Do not use any more (remember what Chapman said!)

So, how much camber change can be generated in 50mm of travel?

Answer… Very Little!

Unless there is excessive compliance!!!

Compliance

We will assume that the bare chassis has adequate torsional stiffness (1000 NM per degree is plenty!)

So the designer must concentrate on feeding all the wheel loads into the chassis with a minimum amount of compliance in the parts and assembly.

Question…

Who can tell me the greatest force the chassis must react?

Answer …

The brake torque generated around the front spindle in a maximum effort stop! And most of this is concentrated in the front lower control arm.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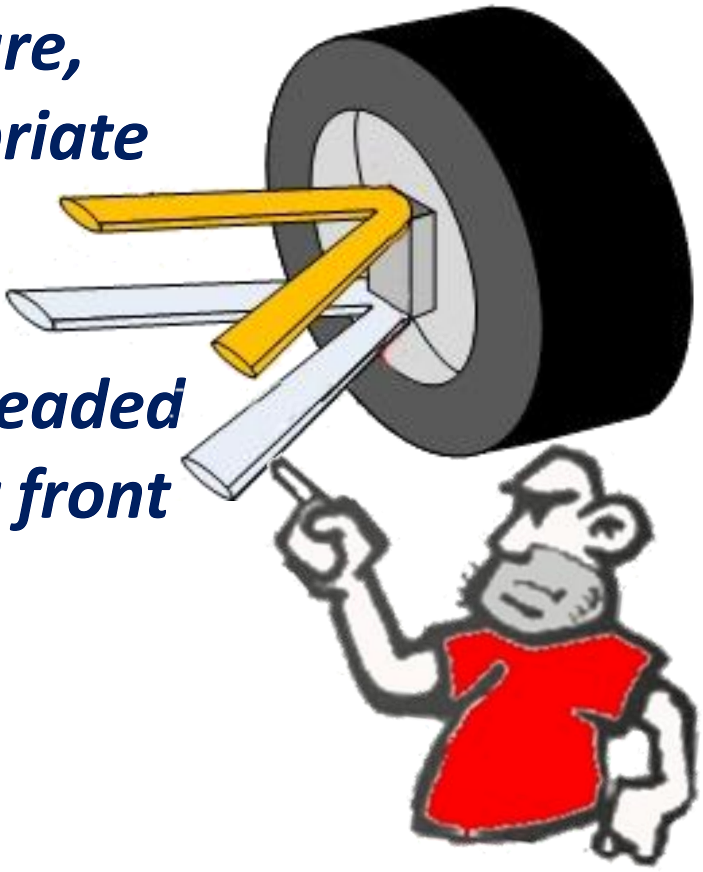
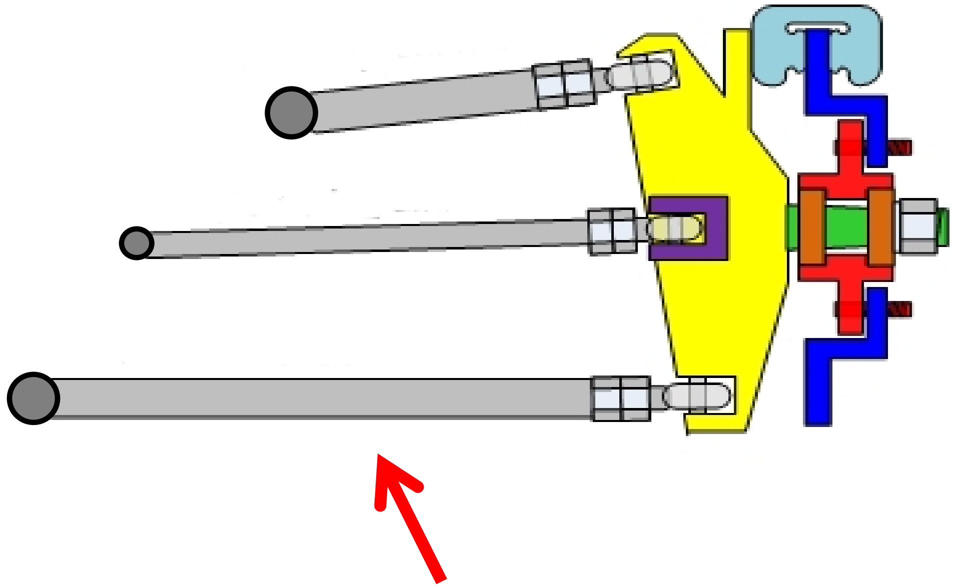
Front Suspension

The front lower control arm should be a broad based triangular structure, pivoted on the chassis at appropriate nodes.

The team should avoid using threaded rod ends anywhere on the lower front wishbone.





The design should have the lower wishbone parallel to the ground in the normal ride height position.

The longitudinal axis of the wishbone pivot should also be parallel to the ground.

The two areas where compliance can be very detrimental to handling is in rear toe compliance (the rear of the car steers when the driver doesn't want to) and wheel diaphragm flexure, which can lead to wheel failure as well as unwanted camber angles.

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Whilst on the subject of 'toe', what toe settings should a team start with?

Front should be set to about 3mm static toe-out.
Rear should be set to about 3mm static toe-in.

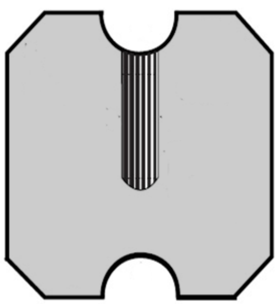
These are a starting point and should be optimised by measuring tyre temperatures in testing.

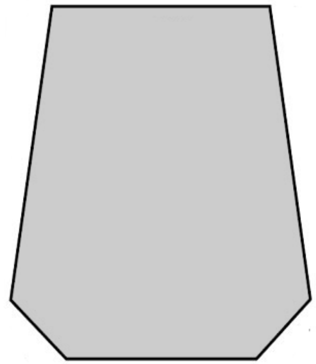
(The team needs a proper tyre pyrometer, not an infra red gun!).

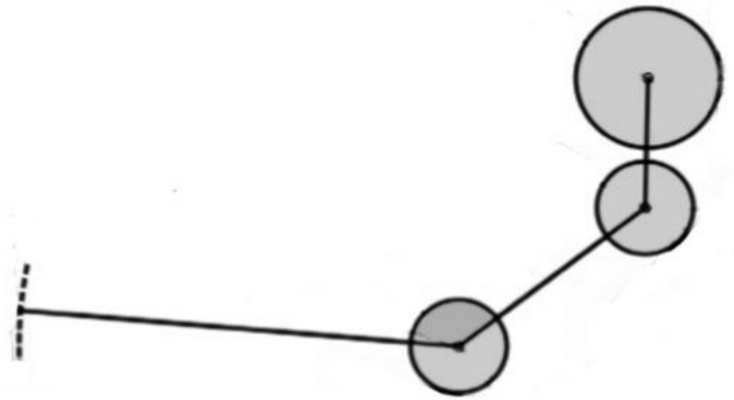
Templates

The chassis must accept all three templates, plus the tallest driver (and possibly, the 5% female if you get to the design finals!).

It is very difficult to rectify template issues after the chassis is built, so, for the sake of a centimeter here and there, always err on the conservative side!







Ergonomics

When the driver sits in the car, he must be comfortable and well supported. It should be possible to sleep in there!

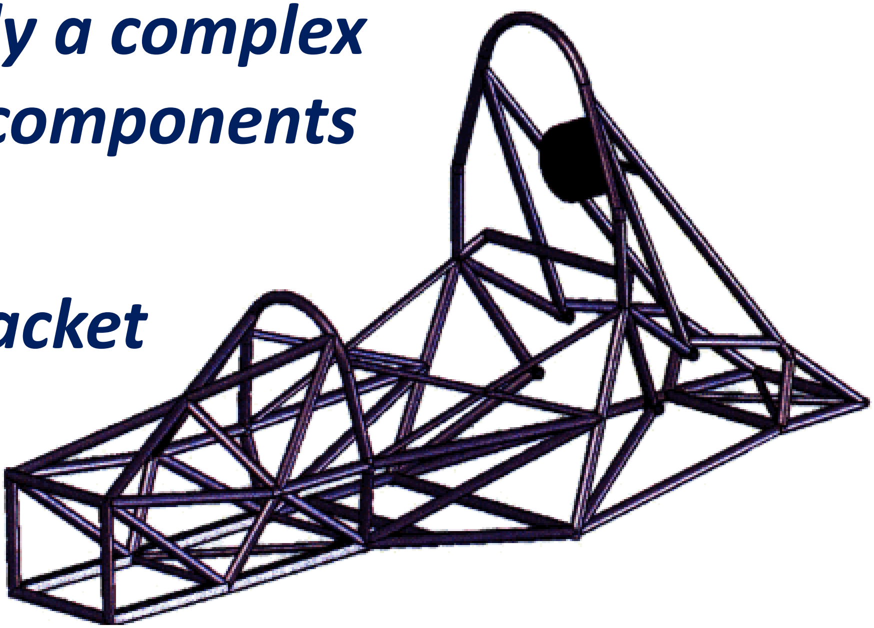
Think about the support given by a child's safety seat!

Chassis

A very common error made by beginner teams is to 'design' the chassis first.

In fact, the chassis is simply a complex bracket that holds all the components of the car in alignment.

How can you 'design' a bracket when you don't know what you are going to attach to it?



In fact, the chassis design comes late in the project.

Time to get started

- ✓ ***Build a simple steel space-frame car!***
- ✓ ***Use 13" wheels!***
- ✓ ***Designed a simple suspension system!***
- ✓ ***Chosen our engine!***
- ✓ ***Chosen a differential!***
- ✓ ***Frozen our design!***

Now it is time to 'keep it simple' and build a car!

Question Time

(We are not finished yet!)

Alternative Solutions

Formula Student cars have become very similar in conception.

Either a single or four cylinder IC car in a spaceframe or Carbon Chassis.

Or an EV in a similar chassis, sometimes with 4WD.

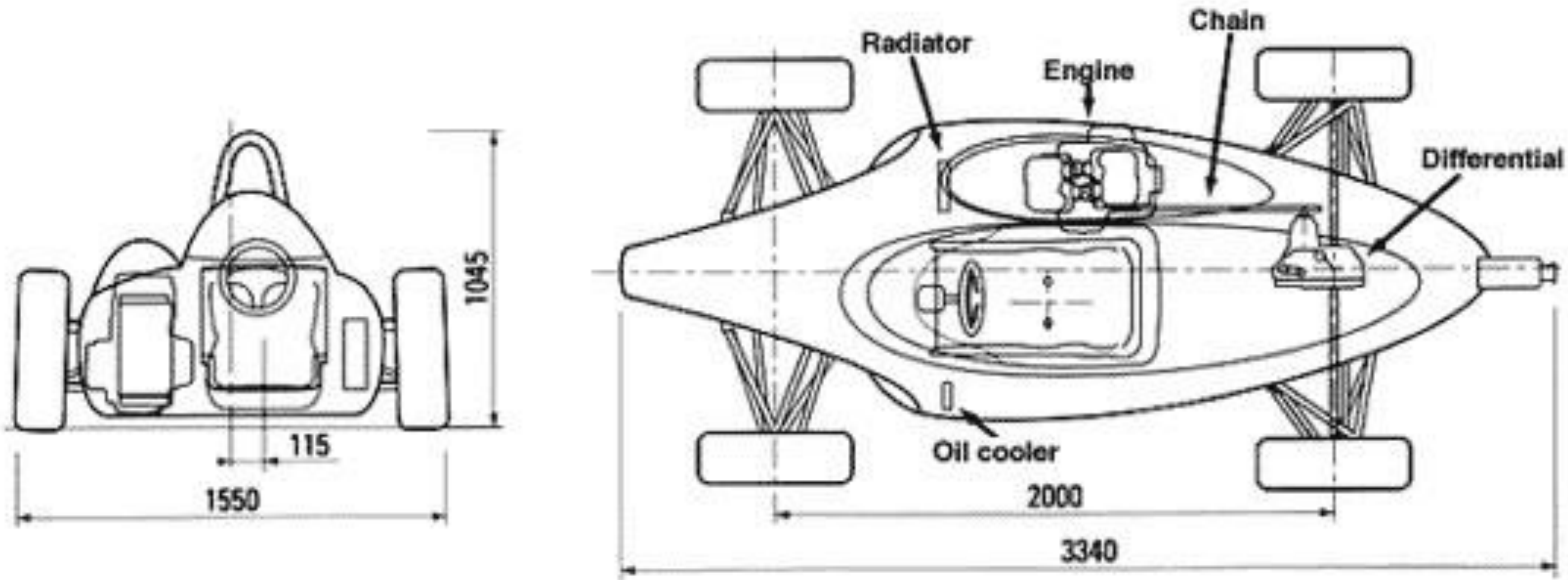
But there are other possible solutions as will be seen in the next slides.

Front Wheel Drive

“Sidewinder”

Honda Project Car

Honda 'Hobby' Car



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Now we really are finished.

Thank you for your attention.

Come talk with me later in Pat's Corner.