Jaguar Land Rover
4x4 in Schools Challenge 2014

Project Portfolio
Team FMRC

The Latymer School

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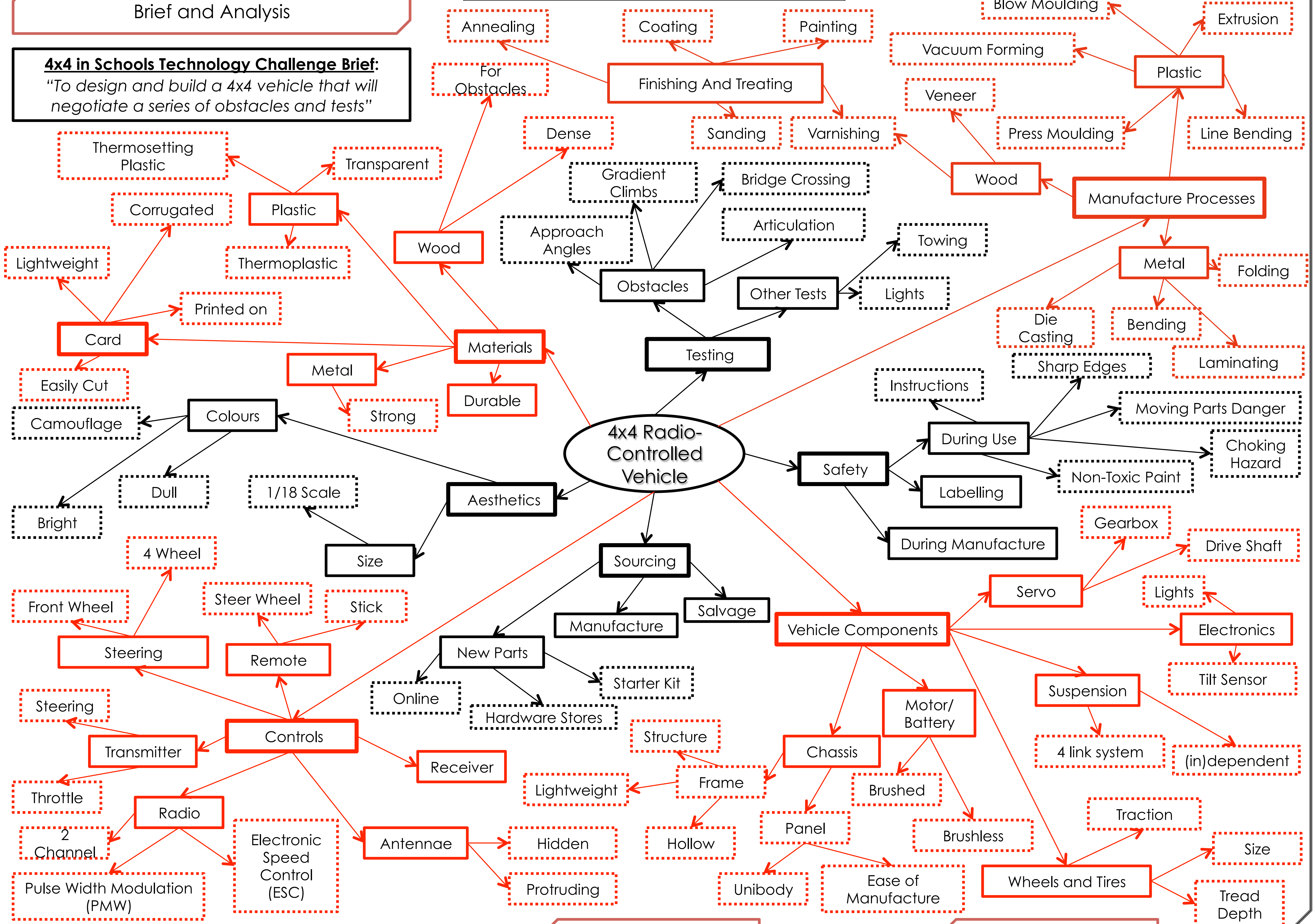
Brief and Analysis

4x4 in Schools Technology Challenge Brief:
"To design and build a 4x4 vehicle that will negotiate a series of obstacles and tests"



Suspension- acts to smooth out bumps, keep tyres touching the ground and control the vehicles stability. The spring absorbs the energy acting on the wheel, with the shock absorber helping to dampen their vibration after hitting the bump.

Wheels- generally made out of a mixture of steel and carbon, they are strong enough to withstand impacts from off road hazards. Many offroad vehicles also use beadlock wheels, meaning that the tyre bead is clamped to the wheel, preventing the tyre coming off or spinning when at very low pressures, which are needed to reduce some shock when headed offroad.

Clearance- this can be achieved with lift kits that raise the body above the frame of the car. This is useful because it provides room for larger tyres which increases traction. It also provides an increase in suspension travel which means that the car can be at harsh angles, yet still have all four wheels on the ground, vital for when a car is rock crawling.

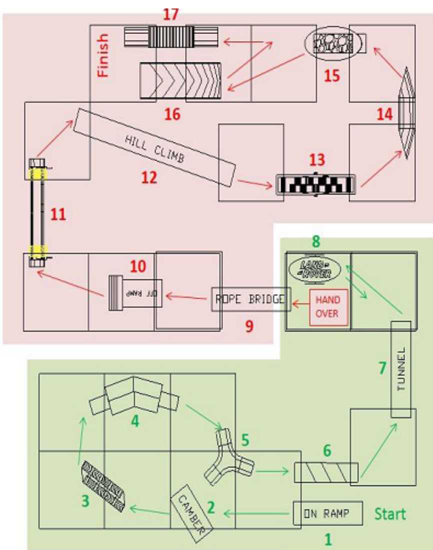
Four wheel drive- a drivetrain that allows all four wheels to receive torque from the engine. It is needed in a 4x4 because it provides maximum torque transfer to the axle with the most traction, allowing the car to navigate over adverse terrain.

Mud terrain tyres- they have aggressive tread patterns and larger lugs offering superb grip. They also have super strong sidewalls, meaning that they absorb impact from rocks and other offroad hazards.

Brakes- most 4x4 cars use disc brakes for the front wheels and drum brakes for the rear. This is to reduce costs. Drum brakes contain all the braking components in a drum like structure which rotate within the wheel. They work when a shoe presses against the drum, hence slowing down the wheel. Disc brakes, stop more effectively however. They are made up of a rotor, a caliper and a set of brake pads which work in unison to push the brake pad against the wheel, hence slowing down the car.

Chassis and body- 4x4 cars are very rigid and have high torsional rigidity. This is so that the chassis doesn't act as suspension when it hits off road obstacles. This means that suspension is easier to tune and also means that the framework will not go out of shape. Additions to the body such as bumpers mean the front of the car is protected from rocks, hills etc.

Example Circuit

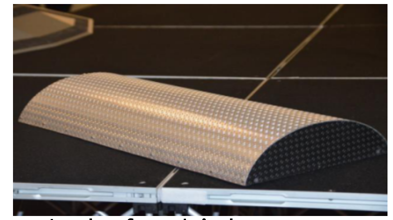


- Tunnels may be included to test the car's automatic light sensors.
- Possibility of a 25 degree slope to test the vehicle's lateral tilt detection system.
- The track may be split into a number of stages, which upon successful will award teams with a number of points.
- The track may or may not be elevated.
- The track may or may not have water at a maximum depth of 50mm.
- If a vehicle experiences a break down during the course it may be repaired during the allotted time limit. Once fixed the car may continue the course.

V' Gully Transverse

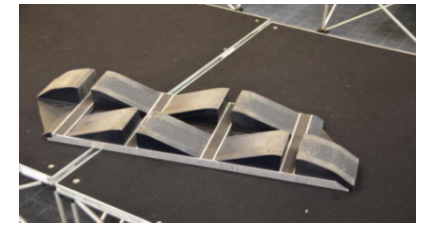
2 wheels on each side of 'V'

Camber Dome



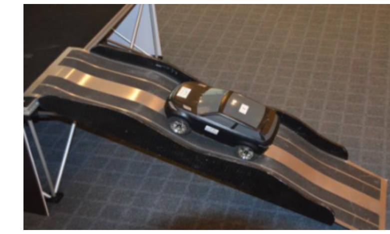
Control of vehicle on ascent and descent (takes diagonal route, minimal wheelspin)

Articulation



Car should move in a straight line with no wheels in between humps

Entry Ramp



Car should stay on ramp and not touch barriers

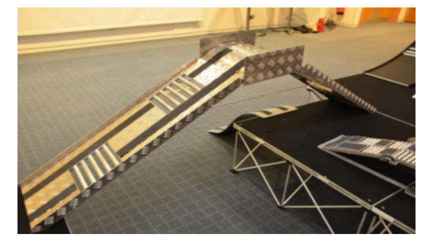
Hub

Tests control and manoeuvrability , car should keep all wheels on hub

Seesaw

Controlled drive. Front axle held over line for 3 seconds

Hill Climb

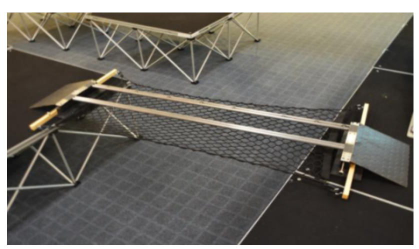


Car should stay on ramp and not touch barrier. Car should pause on descent for 3 secs.

Rock Crawl

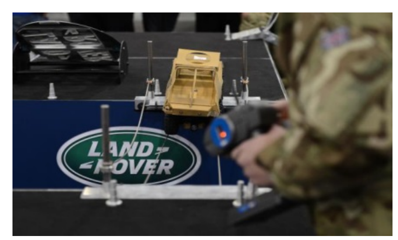
Controlled drive. Car should not touch barriers

Pipe Bridge



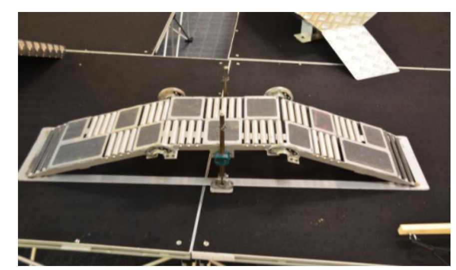
Tests control on bridge, wheels should stay on pipes

Rope Bridge



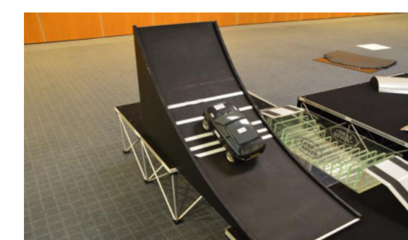
Vehicle controlled over bridge. Wire in centre of tyre, minimal wheel spin

Low Mu



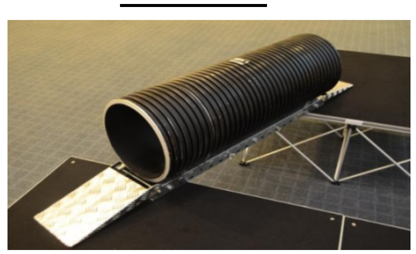
Controlled drive, not touching central posts

Variable Hill



Points for front axle passing through each white line. Must reverse out.

Tunnel

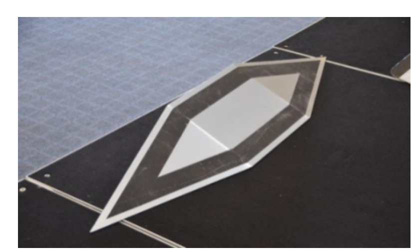


Car should be in control through tunnel and lights should turn on

Off Ramp

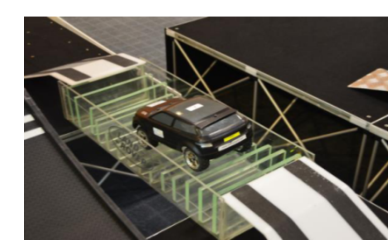
Controlled descent without flipping

Side Slope



Tests control and tilt sensor system

Water Test



Tests control and balance of car

Chassis and Suspension

The suspension of a car is actually part of the **chassis**, which comprises all of the important systems located beneath the car's body, including:

The **frame** - structural, load-carrying component that supports the car's engine and body, which are in turn supported by the suspension
The **suspension system** - setup that supports weight, absorbs and dampens shock and helps maintain tire contact
The **steering system** - mechanism that enables the driver to guide and direct the vehicle
The **tires and wheels** - components that make vehicle motion possible by way of grip and/or friction with the road

What is the purpose of a chassis?

A chassis is the framework of a vehicle, supported on springs and attached to the axles, that holds the body and motor.

Common Types of Chassis:

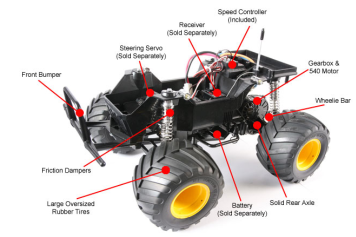
Ladder
A ladder frame car chassis is a common type of frame used as a base for vehicles, creating a solid base from the shape that the name suggests.

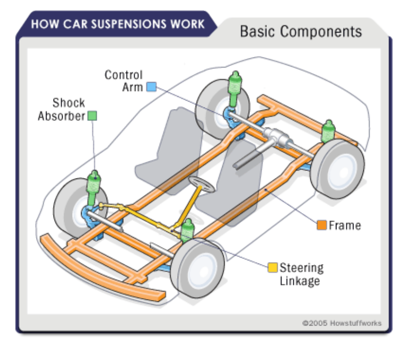
Backbone
A substantial central component is necessary for a backbone car chassis, connecting the front and rear of the entire frame. The half-axles have better contact with ground when operated off the road. The chassis gives no protection for side impacts.

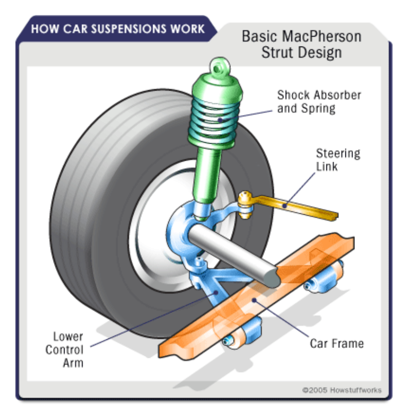
Monocoque
Monocoque is a structural approach that supports loads through an object's external skin. Its used to indicate a form of vehicle construction in which the skin provides the main structural support, although this is rare and is usually confused with either semi-monocoque or a unibody.

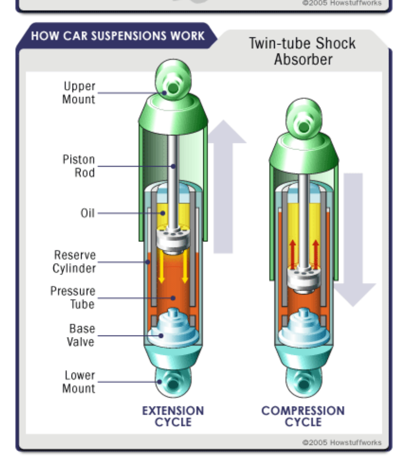
Space(frame)
In a spaceframe chassis, the suspension, engine, and body panels are attached to a skeletal frame of tubes, so that the body panels have little or no structural function, unlike in a monocoque chassis where body panels are part of the structural support.

Combination: The majority of modern vehicles do not use a single chassis type but instead take elements from each to create a version that is best suited for the vehicle's purpose.









What is the purpose of suspension?

The four wheels of a car work together in two independent systems -- the two wheels connected by the front axle and the two wheels connected by the rear axle. That means that a car usually has a different type of suspension on the front and back. In a **dependent system,** a rigid axle binds the wheels; whilst in an **independent system,** the wheels are permitted to move independently.

The **shock absorber**, controls unwanted spring motion through a process known as **dampening**. Shock absorbers slow down and reduce the magnitude of vibratory motions by turning the kinetic energy of suspension movement into heat energy that can be dissipated through hydraulic fluid.

4x4 Front Suspension Systems:

The most common front suspension system of a 4x4 vehicle is a **solid axle with leaf springs**. In this **dependent system** the wheels are connected laterally so that they move together as a unit. Leaf springs attach to the frame of the vehicle and then, via U-bolts, to the axle housing. A sway bar mounted to each side of the axle controls body roll.

Solid axle with coil springs, another **dependent system** that replaces multiple-leaf springs with coil springs. Many off-road drivers prefer coil springs because they have a compact design and deliver a quieter, smoother ride.

Independent front suspension (IFS), a type of suspension in which the two front wheels move independently. In an IFS system, an upper and a lower control arm attach to the wheel on one side, to the frame on the other side. Springing is accomplished either with **torsion bars**, which act like straightened-out coil springs, or **coil struts**, which combine a coil spring and a shock absorber into a single unit.

Twin-traction beam (TTB), or twin I-beam, a suspension designed by Ford to combine the best of dependent and independent systems. A TTB system has two beams at the front of the vehicle. Each beam mounts on a pivot on one end, on the wheel on the other. The beams overlap quite a bit, so they act in essence like long control arms. A U-joint in the centre allows for independent movement of both beams.

Rear Suspension: The majority of 4x4 vehicles, have a solid axle with leaf or coil springs. Off-road drivers often mount shock absorbers on opposing sides of the axle - one in front and one behind the axle - to reduce **axle tramp**, a rapid up-and-down motion of the rear axle caused by sudden acceleration.

MOTORS

Brushed Motors

A brushed motor contains brushes which transfer the electricity from the battery pack to the motor. Springs apply tension to the brushes which rub against the commutator. The commutator acts as a switch to turn the current on and off to energise the motor in order to provide propulsion. The commutator is part of the armature which also contains stacks. The copper wires are turned around the stacks the number of turns determines how fast the motor is and how much torque it has. The if a motor has less turns it will have less resistance allowing the motor to be faster. However it will be less powerful generating less torque and also have a shorter battery life. Another way in which these motors are rated is winds. Wind refers to the number of wires around the armature. A single wind would generate power at low RPM (rotation per minute) making it suitable for short racing tracks with a lot of turns. However double, triple or quad winds would produce power at higher RPM which could be reached on a longer track with more straights. Brushed motors also come with either open or closed end bell; open end bell would allow for more customisation and modification. 2 wire positive and negative. Brushed motors come in different classes some common ones: Stock (27 turn), 19T Spec (19 turn), Unlimited (any amount of turns). All brushed motors are DC and have two wires coming out one negative and one positive.

Brushless Motors

In general brushless motors produce more power but less RPM. Brushless motors are more expensive than brushed however need far less maintenance. Brushless motors contain a magnet called the rotor and the stator where the wiring is housed separately which allows the stator to be changed without changing the other components. Brushless motors are rated in kV which stands for the RPM of your motor per volt with no load. A motor with a higher kV will have more top end speed, but not as much acceleration/torque whereas a motor with a lower kV will not be as fast, but will accelerate faster. Brushless motors also come sensored or sensorless. Sensored motors allow the ESC to monitor the position of the rotor in the motor ensuring smoother power delivery especially at lower RPMs however is more expensive.

ELECTRONIC SPEED CONTROL (ESC)

ESCs control the speed of the motor. The ESC's limit is the lowest number of turns it can handle however the lower the turns the more expensive the ESC. This means when choosing your ESC you want its turn limit to be around the number of turns in your motor. Brushed and brushless motors require different ESCs.

BATTERIES

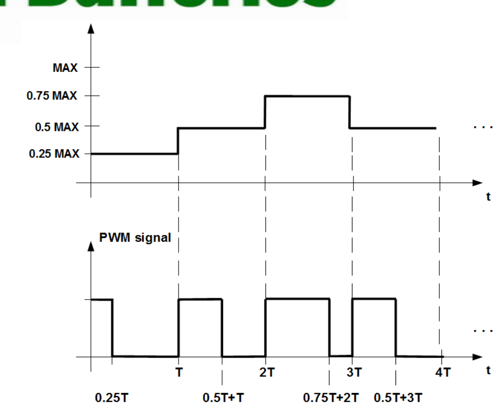
There are two main types of batteries used today in RC cars:

Nickel Metal Hydride Batteries NiMH

These batteries are fairly inexpensive and common in beginner RC cars. They come in a pack wired together to increase the voltage (normally around 6 to 7 cells in a pack). NiMH batteries can be dangerous when overcharged.

Lithium Potassium Batteries LiPo

LiPo batteries are becoming more commonly used as their price is becoming more affordable. LiPo batteries have some advantages over NiMH batteries in that they have larger capacities (allowing the RC to run for longer in one session. They also have higher discharge rates and tend to be lighter containing 1 to 3 cells.



Receiver:

This component will be in the RC car. It contains the antenna and the inductor. The receiver receives the radio signals from the transmitter and strengthens them, so that the signals can be used by the ESC.

Transmitter:

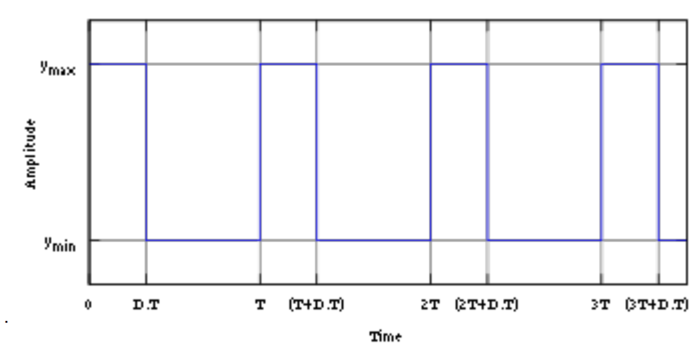
This is the controller for the rc car. We would need two separate channels, one for the steering control and one for the throttle. These two channels will be controlled by gimbals (joysticks). The gimbals will either work like potentiometers, with continuous values or with set values.

Antenna:

The purpose of the antenna in the receiver is to pick up PWM signals from the transmitter. The antenna from transmitter creates a disturbance in the electro-magnetic field around it. This disturbance causes the electrons in the receiver's antenna to move, in the same pattern as the disturbance (the disturbance being the PWM signals). The signal picked up by the antenna would be very weak, so the signal is amplified before it goes to the ESC.

Pulse Width Modulation (PWM):

This is the type of signal most commonly used in small rc cars. This seems like the cheapest and easiest signal to use, since most ESCs are compatible with PWM signals. The gimbals on the transmitter will control the PWM signal. The diagram below shows the PWM waveform.



The length of D.T determines what the ESC reads and how the servo moves. The diagram to the left gives us an idea of how different PWM signals would affect the servo, with the y axis displaying the voltage going into the servo.

Steering

As Tank and Skid steering systems do not lie within the regulations of the challenge, we are left with the choice between two and four wheel steering:

Two Wheel Steering

Two wheel steering has been the staple of RC cars dating back to the first mass-produced Remote-Controlled cars of the 1960s from establishments such as 'Mardave' and 'Elettronica Giocattoli'. Two wheel steering requires the use of a single servo which interprets the electrical signals from the receiver and transforms them into physical movement of the front two wheels. Two wheel steering is advantageous as it is considerably easier to drive, especially in the hands of an inexperienced RC car handler. The need for only one servo also results in fewer problems from a design perspective.

4 Wheel Steering in action as the 'Venom Creeper' tackles the rocky terrain with ease

Practicality of 4 Wheel Steering (4WS)

Since it's introduction in the 1980s, four wheel steering has become a popular addition to an RC enthusiast's arsenal. 4WS is not advantageous in terms of pure speed, and thus is not necessarily suited for a car designed to race. However, the steering system gives the driver precision control over the vehicle that cannot be matched by it's two-wheeled counterpart. This precise aspect of 4WS lends itself perfectly towards Rock Crawlers and Off-road RC cars, wherein the terrain must be tackled carefully, with little room for error. A Rock Crawler must deliver power in a controlled manner as opposed to raw speed and thus benefits greatly from 4WS.

Technicality of 4WS

Four Wheel steering can be achieved by adding a second servo to a traditional 2WS RC car. One servo controls the front two wheels, the other controls the back two. The controller and receiver will have to be programmed so that instructions regarding all four wheels can be interpreted. This can be done using Arduino.

Real life application of 4WS

Although unusual, some modern vehicles give drivers the option of 4 wheel steering, including the Honda 'Prelude' and BMW's '5th series'. Four wheel steering results in improved handling response and increased vehicle stability at high speeds. 4WS is most often used nowadays in Monster trucks due to its ability to manoeuvre within the confinements of the arena.

What is a Servo?

A servo is essentially comprised of a motor and a gearbox which rotate around an arc. The servo provides the necessary force to apply the throttle and steer wheels. Servos can be categorised as analogue and digital. We will use analogue servos as they are cheaper.

Back-wheels servo

Front-wheels servo

Decision

We would have decide to implement 4 wheel steering as it suits the particular course we are assigned with navigating as part of the 4x4 in Schools challenge. 4WS makes it possible for our team to manoeuvre effectively in confined areas while avoiding the cones scattered around the course. However, it would have been too time consuming and therefore we hope to implement it into our project next year.

Tyres

Pro-Line Racing Hole Shot 2.0 Buggy Rear Tyres 2.2" - M3

M3 soft compound tyres

Angled outer pins stops catching ruts

Internal webbing reduces tyre expansion during acceleration

Refined small pin tread pattern increases grip

Regular tread pattern and square lug technology for consistent performance

Tamiya Monster Spike Tyres Set RC

Soft Rubber compound increases traction

Specialist CA glue required to adhere rims to tyres

2.2" Diameter

High Clearanc e Design

Combination Split-V topped with 4 row spikes

Ansmann Racing 1/8 Truggy Tyre & Rim "Disc" Red

Rims suitable for any RC car with 17mm hex-type wheel fittings

Aesthetically pleasing metallic-red tyre rims

Pre-mounted with foam inserts

Regular, grooved tread pattern

1/8 scale

Optimum rear tyre in regards to the 4x4 in Schools challenge

All three of the options are designed to cope with off-road conditions and have features that help increase grip and decrease wear. However, the pro-line hole shot buggy rear tyres are best suited to manoeuvre the 4x4 in Schools track we are tasked to navigate.

Pro-line are regarded within the RC enthusiasts community as one of the best and most reliable tyre manufacturers and distributors. The small-pinned tread pattern is ideal for the hard-packed surface typically used in the challenge. In addition, the angled outer pins prevent the tyres from catching on metal extrusions on the obstacle.

The 1/10 scale is neither too large not too small and if they do not fit perfectly, the chassis can be adjusted with relative ease. Other aspects such as the internal webbing and cutting-edge square lug technology are also advantageous.

Tilt Sensor

Purposes of a tilt sensor:
1. To make people aware if their car is being towed away
2. To warn the driver if their car is at too steep an angle

Its purpose in the competition:
To signal when on the "side slope"

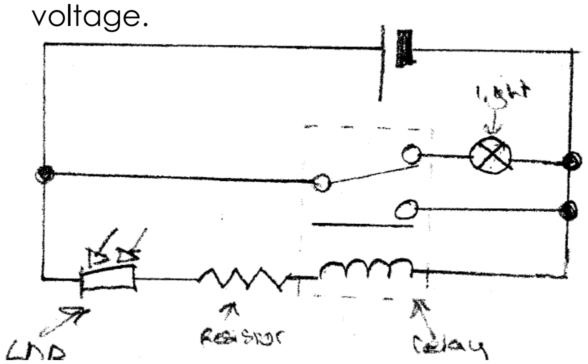
How they work:
A mercury switch (type of tilt sensor) has two contacts within a sealed container, with liquid mercury in it. Since mercury is a conductor, when it passes over the contacts, the current flows through. This would be connected either to a buzzer or light, to produce a signal.

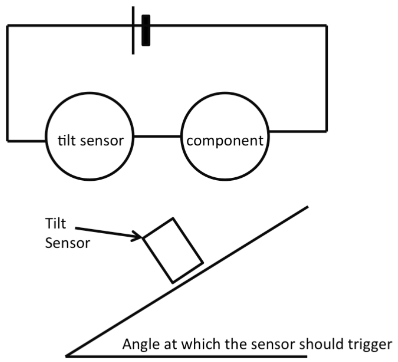
Light Sensor

Purposes of a light sensor:
To turn on in darkness, allowing the car user or rc car driver to see the path in front of the vehicle.

Its purpose in the competition:
To turn on when passing through the tunnel

How they work:
We would use a LDR (light dependant resistor) to measure the drop in light levels and tell when the vehicle is in darkness. As the light intensity increases on the LDR, the resistance of the LDR decreases. This is because the LDR contains a semi-conductor. The more frequently the semi-conductor absorbs photons, the more energy is given to the electrons in it, allowing them to pass through the component. There would also be a need for a relay, since we only want the light turning on in darkness and not being partially on all of the time. A relay works by turning a switch at a certain voltage.





Servo

What it does:
The RC servo will be used for steering. The position of the servo's arm should correspond to the position of the gimbal on the transmitter i.e. If the gimbal is all the way to the left, the servo should've turned the component all the way left.

Brushless motor in servo:
As the name suggests, no brushes are connected to the commutator of the DC motor. This reduces resistance with the commutator, which increases the torque and rpm of the servo.

Coreless motor in servo:
Coreless servos remove the heavy steel core which conventional DC motors have. This reduces the weight of the servo, which probably wont be a problem, however this increases the acceleration of the motor. This design results in more torque.

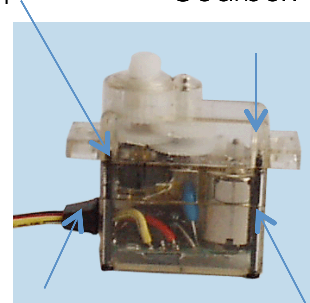
3pole/ 5pole motor in servo:
The number of poles in a DC motor determine the acceleration at start up. The more available poles means that the force exerted on the rotor is increased, so it accelerates the motor quicker at start if we have 5 poles. This increases initial torque aswell.

Different Servo weights:
Giant - weights around 100gr (3.5oz)
Standard - 45gr (1.6oz)
Mini - 20gr (.70oz)
Micro - 8gr (.28oz)
Pico - 5.5gr (.18oz)
Wes Technik - 2.1gr (.08oz)
Falcon Servo - 1.7 gr
39.9×20.1×38.1 mm

Range of different servos' torque:
1.6 kg-cm to 24 kg-cm
Range of different servos' speed (to turn the drive shaft 60°):
0.28 sec/60° to 0.05 sec/60°
Range of different servos' dimensions:
21.0×12.0×22.0 mm to 39.9×20.1×38.1 mm

Drive Shaft

Gearbox

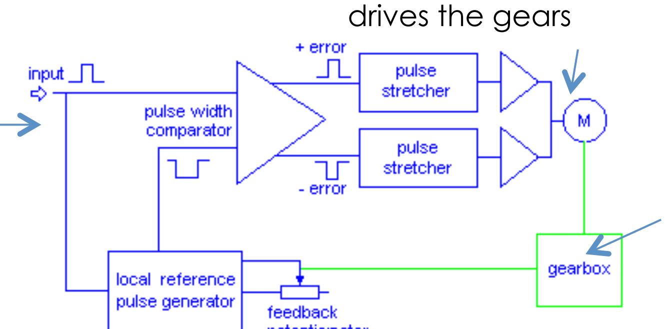


Feedback Potentiometer

Motor

PWM signals from the receiver

Small DC motor that drives the gears



The gearbox is what turns the drive shaft. The nature of the gears determines the rpm and torque of the servo.

The feedback potentiometer is just below the driveshaft, so as the drive shaft moves, it changes the resistance of the potentiometer. This allows the servo to know what angle the driveshaft has turned through.

Existing Vehicle Analysis

Super–firm **shock absorbers** and springs: plastic body, fluid filled – pivot balls make them less likely to break.

Relatively high **centre of mass** due to the battery position which may cause vehicle to be unstable when on steep gradients.

Axial AX10 Scorpion

Chassis: Aluminium side panels and cross braces with moulded plastic body plate.

3-Link Suspension: two of the four links join before they reach the axle. The triangulated links prevent the axle from moving from side to side but still allow a good connection.

Tyres: Axial 2.2 Rock Lizards, standard compound – a good compromise for all surfaces i.e. rock/sand/ wet rock.

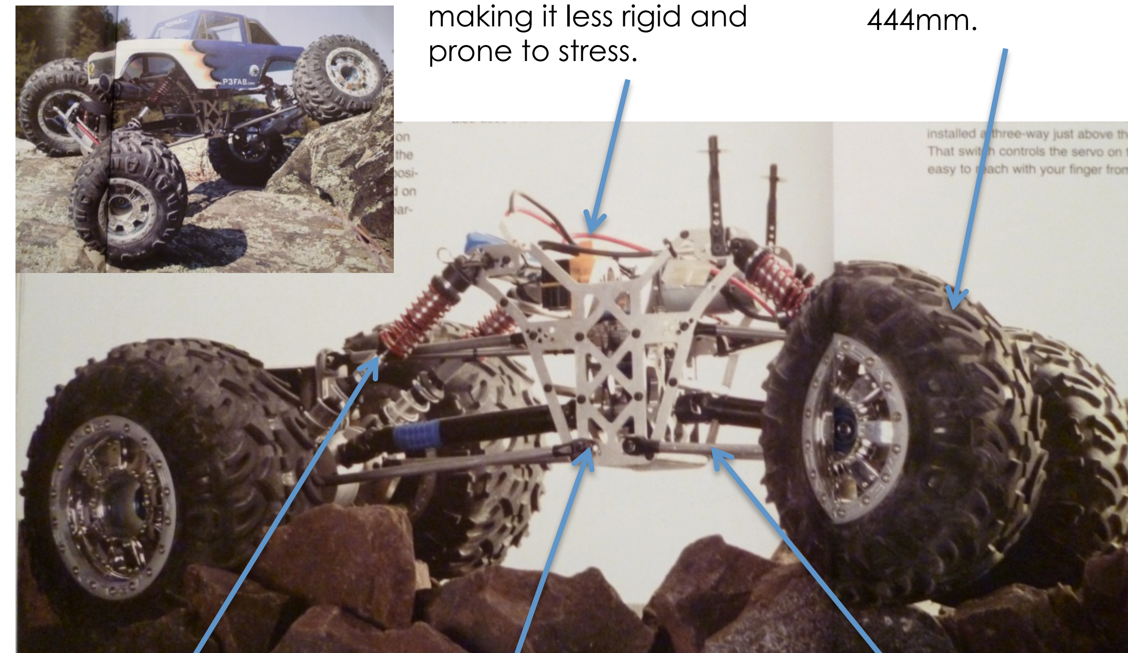
Wheels: Axial Black Rockstar beadlocks, 12mm hex.

Axles: The link and shock mounts are behind the axle tubes and the bottom of the axle housing is smooth to prevent the vehicle getting hung up on objects it passes over.

Custom-Machined Crawler

Battery: Mounted on the upper link mount on the axle and allowed to pivot across a rod attached to a chassis cross member – making it less rigid and prone to stress.

Pro-Line Moab XL **Tires** with beadlock **rims:** wheelbase – 444mm.



Dual Shock Absorbers: two Traxxas Revo dual shock absorbers are mounted on each axle.

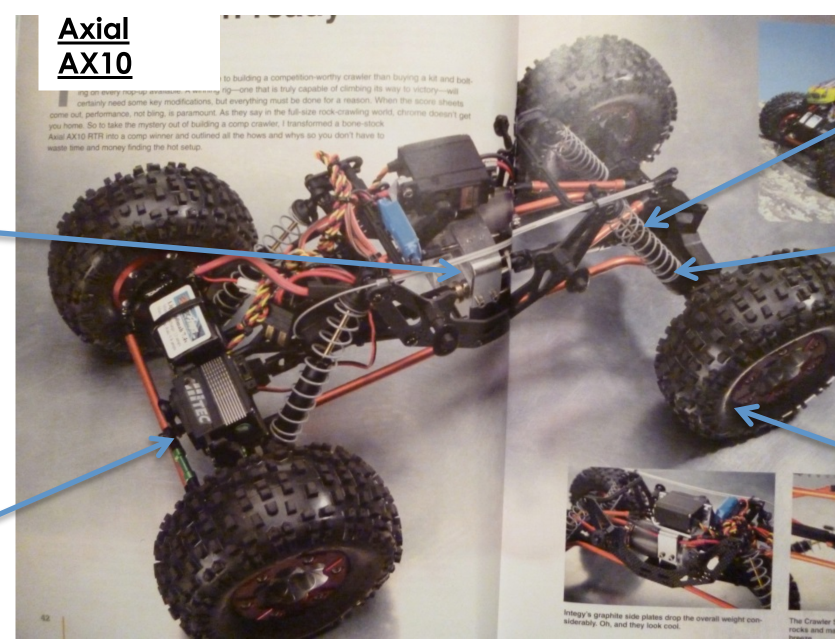
Chassis: holes in the front, back and side plate both reduce weight and add to aesthetics.

4-Link Suspension: it has several available mounting positions on the thick aluminium axle - the lower links of the suspension are mounted on the axle's centreline for the best possible ground clearance.

Chassis: Graphite side plates have been used to reduce weight and lower centre of mass to add stability. A replacement skidplate on the underside of the vehicle puts the lower links to the inside of the chassis, smoothing the profile and making it less likely to get caught on rocks.

Servo and Gearbox: Axial servo/battery mounting plate is placed on the front axle – this makes the weight lower and further forward on the chassis.

Axial AX10



Shock Absorbers: Standard stiff-springs used on the back and soft springs used on the front axle.

Suspension: Axial bent rear links are used to allow for greater ground clearance in a 4-link system.

Tyres and Rims: Pro-Line Badlands with memory foam inserts which provide needed support to such a soft compound tyre. Removable weights can be added to load the front tyres – offering an advantage in steep gradient crawling.

Specification

As a team entering the Rookie Class, we must manufacture our own vehicle body as well as the vehicle electrics (light and tilt sensor).

Presentation

Our presentation should last no longer than 8 minutes at regional level and 10 minutes at the UK National Final.
A presentation should be produced using PowerPoint and should include the following:
- Bright and exciting colour scheme and graphics
- First page – Team logo and name
- Second page – Team members (name, age, job roles, etc)
- Good and relevant pictures of your vehicle and the various stages of your build
- Video clips (if possible)
- Design Brief, Design Ideas, Final design
- Sponsorship
- Financial review – Budget
- Manufacturing and testing
- Continuous improvements
- Team image / branding

Display

- Pictures and video clips
- Try to have your design sketches and ideas displayed along with the final outcome.
- Display our team name as clear as possible.
- Have all our models, prototypes and final vehicles on display.
- Think of a colour theme and style for our stand that matches our team colours and logo.
- If possible, have some team outfits (t-shirts, shirts, overalls, etc) made with our team name, logo etc.
- Have our portfolio on show but try to display different evidence on the stand to what's in our portfolio.
- Produce leaflets about our team and vehicle to hand out to judges, other teams and visitors.

Vehicle Dimensions
Length............. 350mm - 200mm
Width.............. 200mm - 100mm
Height (excluding aerials) 200mm - 100mm

Vehicle Weight
Our vehicle must not exceed 1.8 Kilograms in weight.
Vehicles that exceed 1.8 Kilograms will occur penalty points.

Tow Bar
Our vehicle must be fitted with a tow bar which must be carried by the vehicle throughout the competition. The tow bar will be used to tow a trailer by all vehicles through a set course laid out on the day of the competition by Land Rover 4x4 in Schools.
- It is permissible to retract, fold or pivot the tow bar providing this is done without the use of any tool.
- The towing eye on the trailer is rigidly fixed to the trailer – there is no rotational movement.
- The towing eye is a ring type.
- Land Rover 4x4 in Schools will provide the trailer on the day of the competition.

Vehicle Body
The vehicles body must have a shell that covers all the main mechanical elements including the Battery, motor(s), wheels and tyres from plan view.
The vehicle shell must fit within the overall dimensions and should realistically resemble a vehicle.
Our vehicle must display the challenge logo below on a minimum of two different panels of the vehicle.

Vehicle Electronics

The vehicle must have a lateral (Side to side/left to right only) tilt detection system to trigger lights or a buzzer on the vehicle when the angle tilt is greater than 25°.

The vehicle must have an automated system to turn the vehicle lights on when the light level drops to 25 lux (below a set level – dark).

These scrutineering rules and regulations are critical rules. If a team breaks any one or more of these critical rules they will not be eligible to win the following awards:
- Overall Winner (Regional and UK National Champions)
- Best Engineered Vehicle
- Best Track Performance

- Vehicle Dimensions – 5 points (-15 points maximum penalty)
- 4 Wheels and 4WD – 5 Points (-2 points maximum penalty)
- Vehicle Body shell – 6 Points (-5 points maximum penalty)
- Vehicle Weight (1.8kg Maximum) - 5 Points (-5 points maximum penalty)
- Tow Bar - 5 Points (-5 points maximum penalty)

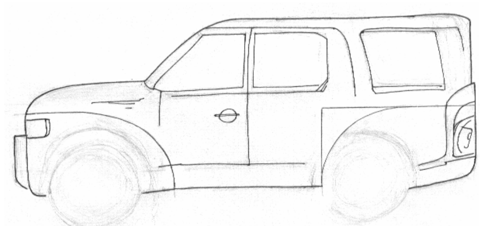
Team Accounts

Our team is to required record an account of all the team's income and expenditure. The accounts must clearly show all sponsorship, in-house made components and the team's budget.

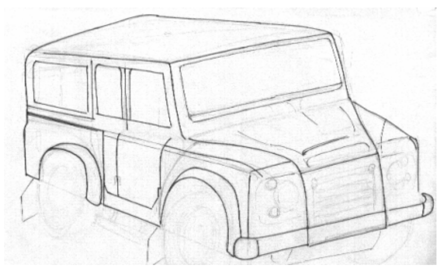
- Any parts made in-house can be costed as free and not included in the £175 budget.
- Any parts received free due to donations, recycling components from previous model or sponsorship should be included in the budget at 33.33% of their RRP price.
- Any components bought in should be included in the £175 budget at the full cost price.

Initial Ideas

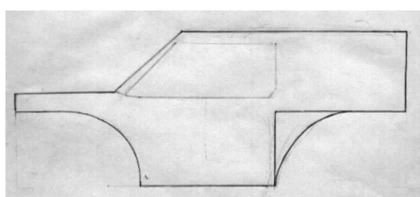
SHELL Design 1



INITIAL IDEA SIDE VIEW

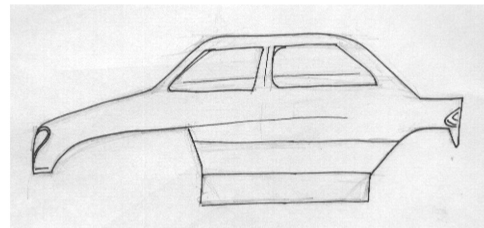


INTIAL IDEA

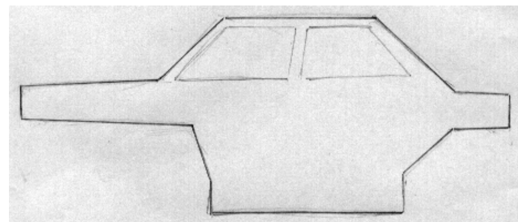


INTIAL IDEAS SIMPLIFIED

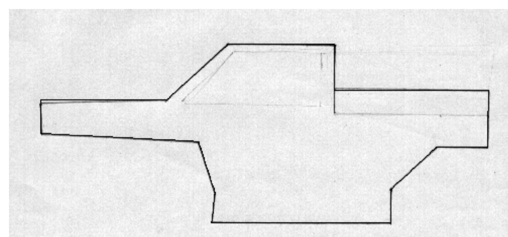
SHELL Design 2



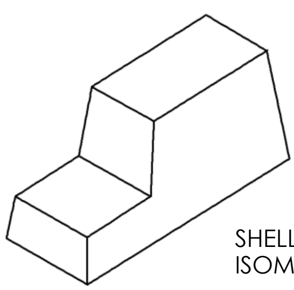
INTIAL IDEA SIDE VIEW



INITIAL IDEA SIMPLIFIED

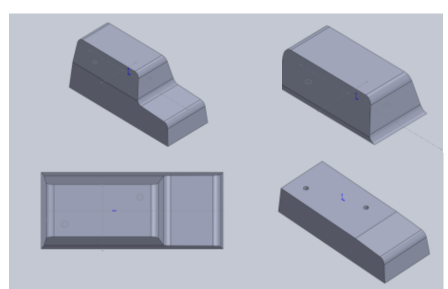


INITIAL IDEA WITH TRAILER DESIGN SIMPLIFIED

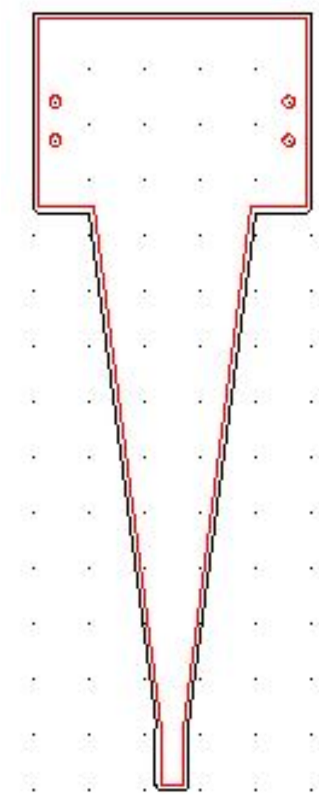


SHELL MOULD ISOMETRIC

SHELL MOULD CAD DESIGN

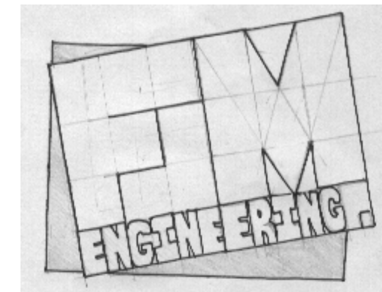


TOW BAR Design 1



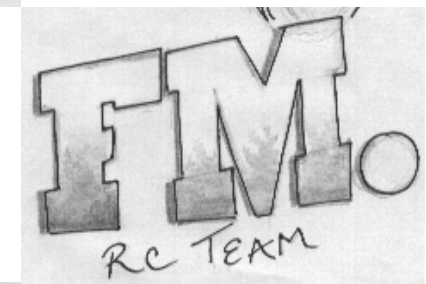
TOW BAR Prototype 2

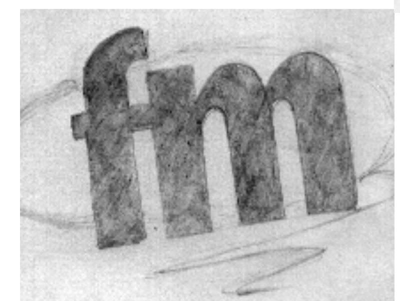
Logos



INITIAL LOGO DESIGN 1

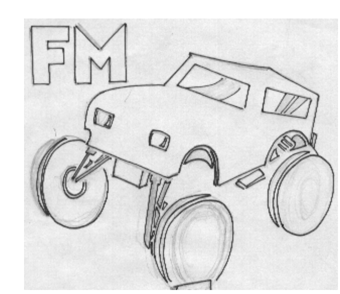
INITIAL LOGO DESIGN 2



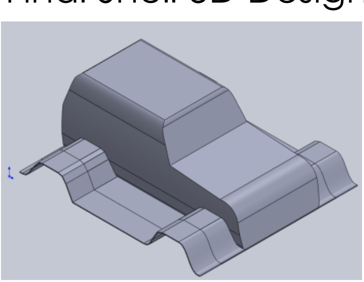


INITIAL LOGO DESIGN 3

CHOSEN LOGO DESIGN

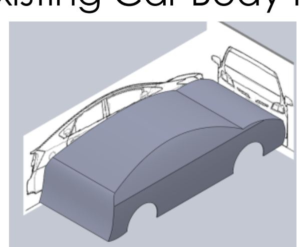


Final Shell 3D Design

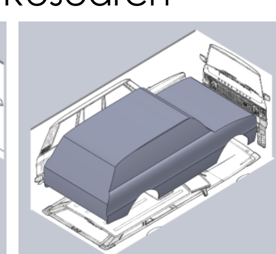


Inspired by the classic Range Rover, with the addition of wheel arches

Existing Car Body Research



Toyota Prius



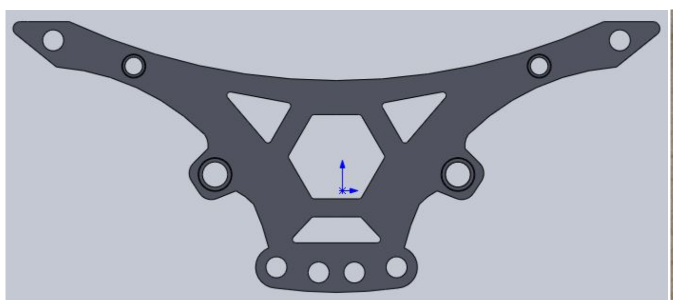
2013 Range Rover

1. Research into Chassis

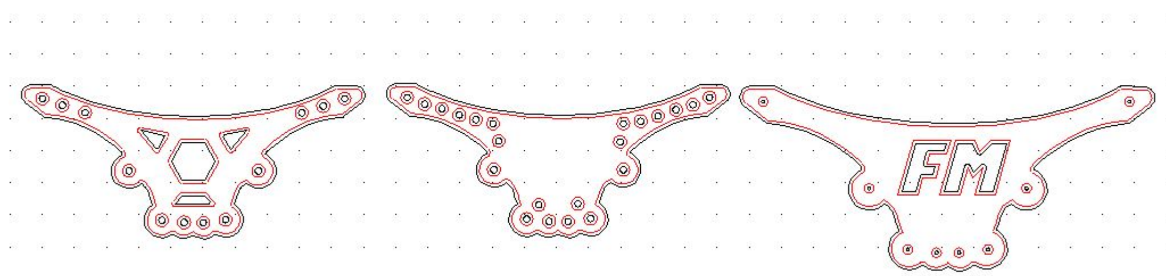
Our research into vehicle chassis showed us that there are many different types used on different vehicles ranging from monocoque 'shells' to ladder bases. The majority of full-scale vehicles used a combination of chassis types for optimum weight, structure and support. The majority of mini rock crawlers also used combinations of chassis types – often using testing and prototyping to find the choices that worked best.

2. Designing the Chassis

As a group we decide that the first chassis we would produce would be based on the already proven chassis in the starter kit – this would then enable us to optimise the chassis design for our particular vehicle after testing alongside the other components of our rock crawler.



We used Solidworks to model the chassis virtually in 3D and then used the measurements to also draw the chassis in 2D Design. To find ways to optimise the chassis, we tried positioning the connector holes in different places on the chassis, however we came to the conclusion that keeping the same shape chassis meant there was no advantage gained by repositioning connector holes.



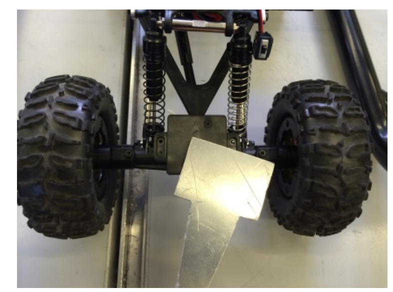
As we did not find an advantage by changing the functioning of the chassis, we decided to instead focus on adding to the aesthetic design of it – drawing up our own version with team branding on.

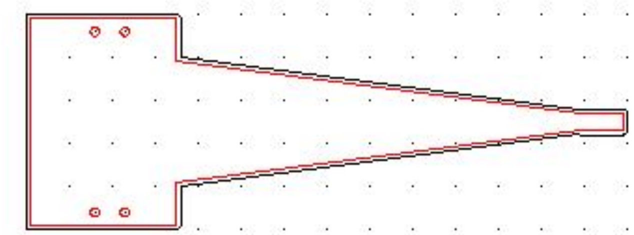
1. Aims for the Tow Bar

Our vehicle was required to have a tow bar fitted that would be carried by the vehicle for the duration of testing. This tow bar would be in use for the trailer tests, where it would need to carry the trailer given to us by the 4x4 In Schools Competition Judges.

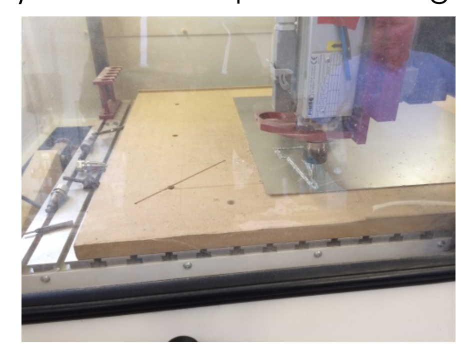
2. Designing and Manufacturing the Tow Bar

To start with, we came together as a team to share our ideas about the tow bar for our vehicle. We all quickly came to the conclusion that the mount on the rear axle of our vehicle (which was identical to the servo mount on the front of our vehicle) would be the best place to attach our tow bar as there were already holes we could fit screws through and we did not need to mount a servo on it.





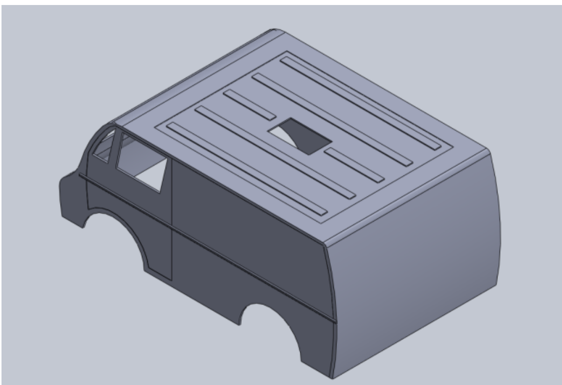
We then sketched our ideas a tow bar that would fit onto the mount – taking into account that there would need to be hook on the end to fit through the eye on the trailer. The best idea (shown below) was drawn up on 2D Design to scale.



We then used the Denford 6600 Pro Router to cut out our tow bar design from a sheet of aluminium. The reasons for using aluminium were its strength as a material (as is would be under strain) and that we could bend the metal so that it was at the correct height to be connected to the trailer.

1. Research into Shell Body Designs

When going about designing a shell body, we decided to both study and then recreate existing designs on SolidWorks to see what features make them effective in terms of both aesthetics and practicality.

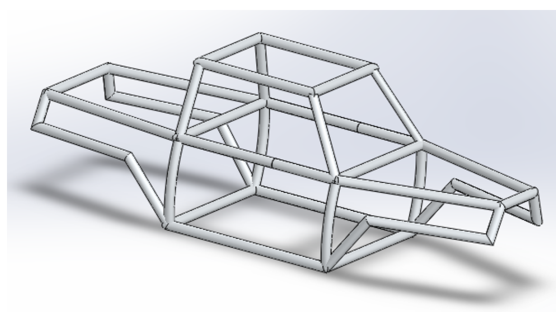


"Lunch-Box" Body

The Lunch-Box was one of the first commercially-available RC cars. The shell is comparable to that of a van and is block-like in structure. The body would be relatively easy to make.

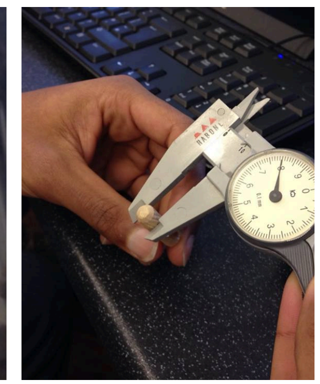
Losi Mini Rock Crawler

As this is the body currently on the Starter Kit, it is important to analyse the shell in-depth. The tube-like structure is aesthetically pleasing and greatly influenced our final design.

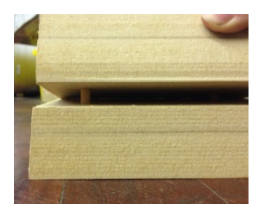


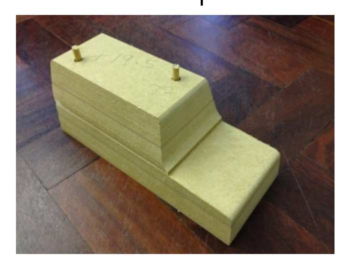
3. Manufacturing and assembling the mould

Once the design was complete, the SolidWorks file was converted into .stl form, ready to be manufactured.



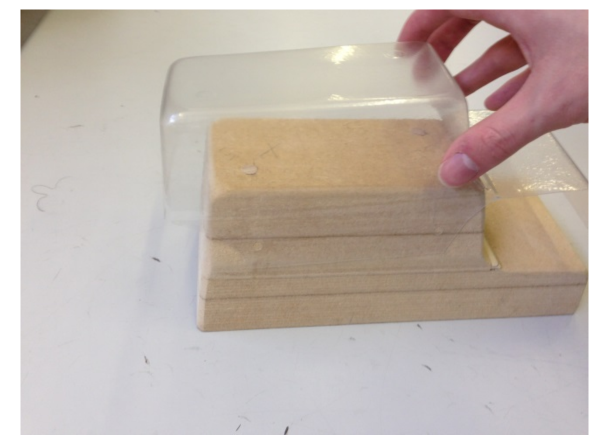
The two parts were then glued together using dowels for help with aligning.





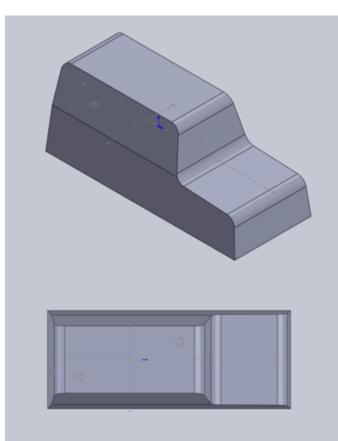
4. Vacuum Forming

To create the shell, we used High Impact Polystyrene due to its relative strength compared to its weight. The process was fairly simple: a sheet of plastics was cut, heated over the vacuum former and then vacuumed over the mould. There were concerns that the steep angles and sharp edges of the initial mould would affect the shell's outcome, however we sanded it down to create a suitable mould, leading to a successful shell!

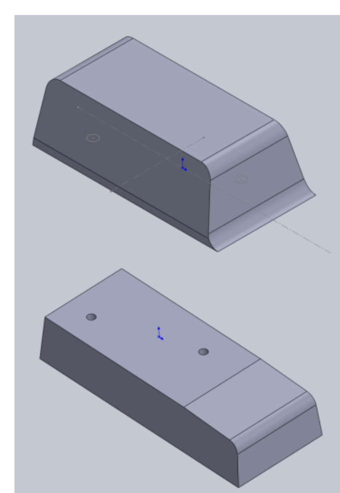


2. Designing on SolidWorks: Complications and Compromises

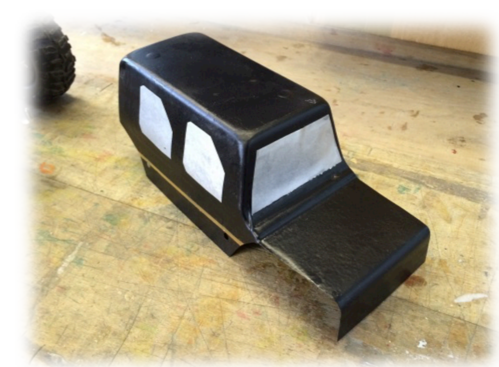
Originally we planned to create a wooden mould of the shell on SolidWorks which could be cut out using the Denford and then Vacuum-Formed. However, the Denford could cut mid up to a thickness of only 50mm.



In order to overcome this obstacle, we decided to split the design into two parts which could be cut out separately. They could then be glued together. Holes were fitted for the placement of a dowel which helped with the alignment of the two pieces.

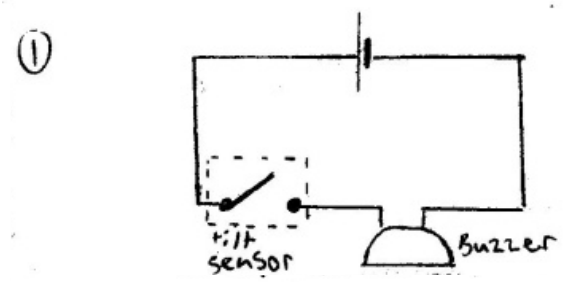


5. The Final Body Shell

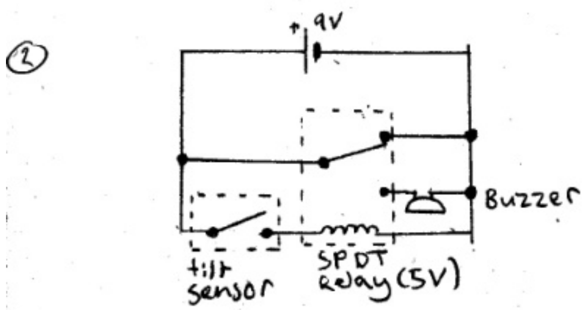


This is our final shell after spray painting and adding details.

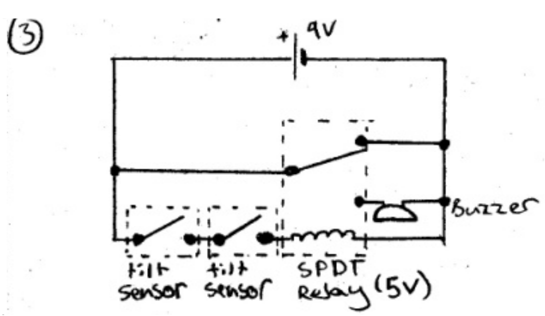
Electronics



This was the initial concept. The idea was that the buzzer would ring when the tilt sensor was switched.



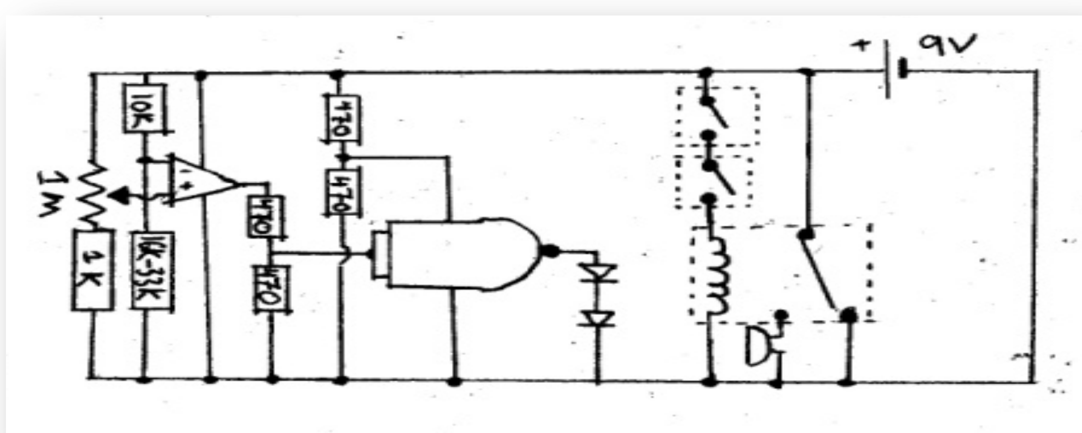
However due to the resistance of the tilt sensor, the buzzer wasn't loud enough. In order to overcome this problem, we implemented a relay into the circuit.

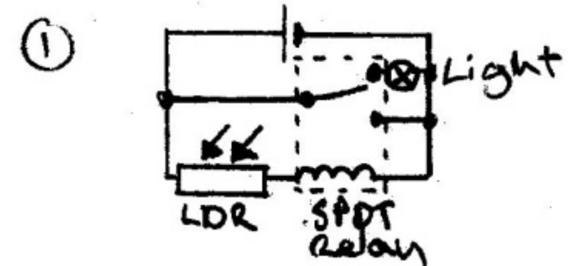


The single tilt switch caused problems as the sensor would go off whenever the RC car went over a bump, so two in different places were required to ensure it only went off when it was tilting.

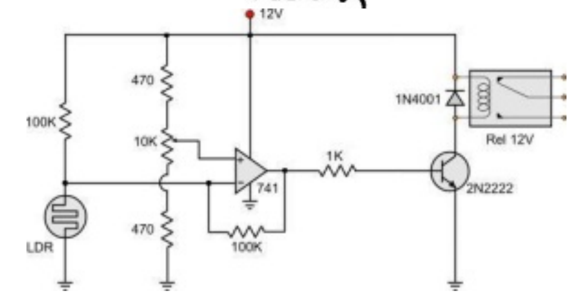
The hinge allows the angle at which the tilt sensor goes off to be adjusted.

Final Circuit:

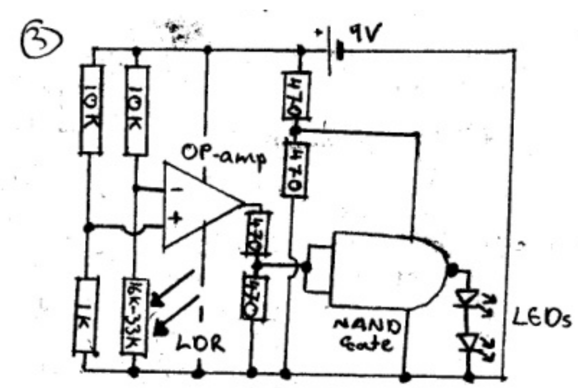




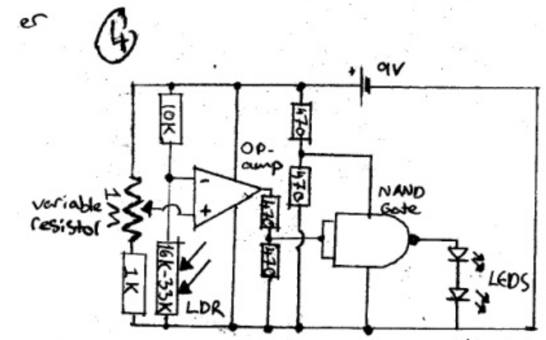
The initial concept was to have a LDR which switches a relay to turn the light on and off.



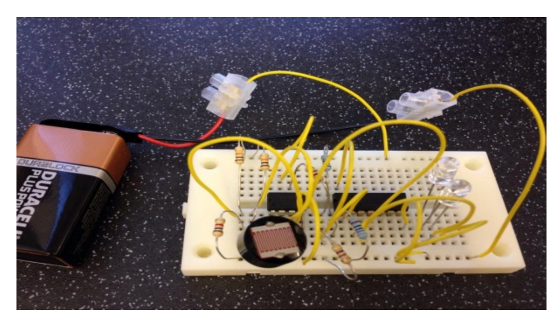
The problem was that we'd need a lot more power than just a 9V battery and that was the best sized battery. So we searched for an example circuit online.

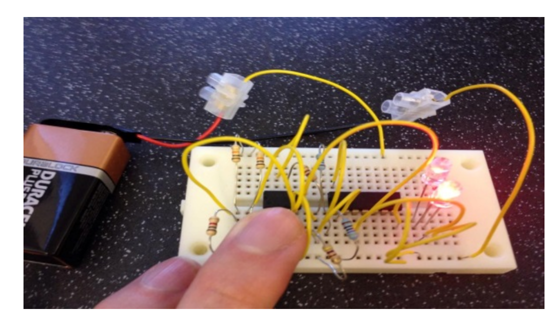


We then came up with a circuit which incorporated components available to us and also avoided hysteresis effects.



This designed worked well however we couldn't adjust the sensitivity so a variable resistor was incorporated. After the design was finalised, we bought a circuit board and soldered the components to it, with wires coming out to connect to the tilt sensors and LDR.


An early example build of the light sensor


The light turns on when light does not reach the LDR

Changes for National Finals

Following the Regional Finals of the competition, we set about addressing the flaws that we had found with our vehicle: to use our time effectively, we created the Gantt chart below to follow until the National finals.

Week Beginning / Task	10/2/14	17/2/14	24/2/14	3/3/14	10/3/14	17/3/14	24/3/14
Body Shell	Design	Finalise	Manufacture	-	-	-	-
Chassis	Design	Finalise	Manufacture	-	-	-	-
Electronics	Research	Work On	Finalise	Add to shell	-	-	-
4 Wheel Steering	Research	Work On	Test				
Portfolio	-	-	Work on	Work on	Work on	Finalise	
Presentation	-	-	-	-	Work on	Finalise	
Display and Leaflets				Plan	Work on	Work on	Finalise
Testing/Practise				x	x	x	x

New Tow bar

As we added a new servo to our vehicle for 4 wheel steering, there was no longer a servo mounting plate free to attach our tow bar to. This forced us into redesigning our tow bar so that it could be attached to our vehicle in another place.

After collecting ideas we settled on a tow bar that could be levered up above the chassis or down behind the car, pivoting on the shell connections. This adheres to competition regulations as the tow bar is not visible when folded.

We made the tow bar from a strip of aluminium that we bent to into a rectangular shape and used a metal ring as a manual connection.

This flexible design meant when not use, the tow bar could be stowed away, but also allowed it to pivot if it touched the ground as the vehicle travelled up a slope.

New Shell

The feedback for our original shell from the National Finals was that it did not fulfil competition specification as it did not cover all of the internal parts of our vehicle from above.

We used the same basic outline when redesigning – the body of a Land Rover. In order for it to fit the specification, we needed it to be much longer and wider. To achieve this, we made a new mould for the central part of the body that was an elongated version of our original and we also made a separate mould to create wheel arches.

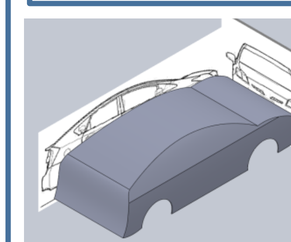
Using the same process as before, we vacuum formed the three separate pieces of our shell and fixed them together with double sided tape.

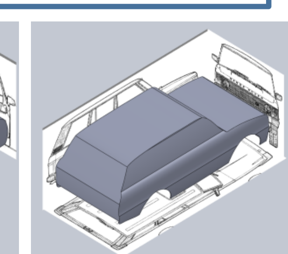
To finish the shell, and improve aesthetics, we spray painted the shell to match our team branding. We then attached the electronics (the lights and light/tilt sensors)

Shell Redesign

While redesigning our shell, we decided to take inspiration from the bodies of real cars. The Design Engineer of the group created several shell designs using the blueprints of existing cars, including a Toyota Prius and a 2013 Land Rover Range Rover.

This research proved very useful when designing our final shell, which is based loosely around a Range Rover with the addition of clearly defined wheel arches





Parts necessary for the implementation of 4WS

LOSB1410 - Steering Links

LOSB1409 - Front Spindles/Carriers

LOSB0822 - Servo

The necessity of 4 Wheel Steering

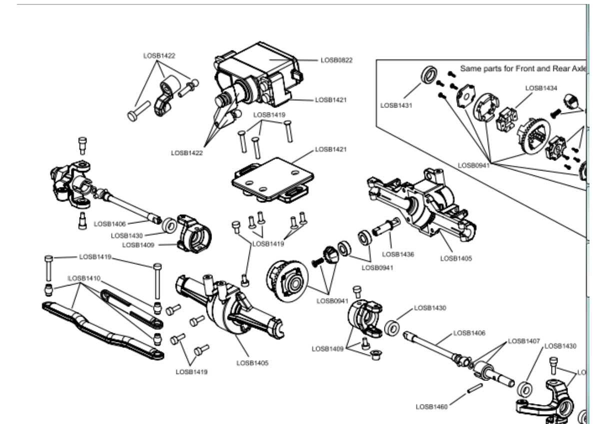
During the Regional Finals, two mistakes were made on the track course, both of which could have been avoided if the RC car had a tighter turning radius. To provide this, we decided to implement four wheel steering. This provides a turning circle with half the radius, allowing us to navigate the track and avoid the cones.

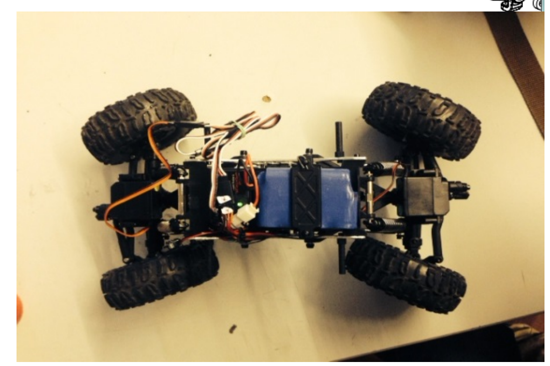
The Engineering of 4 Wheel Steering

We used inspection as well as the official Losi Mini Rock Crawler manual to replicate the setup for the front wheels onto the back wheels. It was imperative that each part was slotted in an exact order, and thus great care and precision was required. Once the steering links were set up with the second servo, a servo signal reverser was required to ensure the 4 wheel steering did not simply 'cancel' each other out.

The back wheel configuration was disassembled and then reassembled with new parts

We were unable to complete this obstacle 'the hub' due to an excessively large turning radius





Front and Back Wheel Steering

Transmitting and Receiving

The standard Mini Rock Crawler Transmitter only has one channel. Ideally, the four wheel steering could be turned on and off, allowing us to toggle between precise and broad movements. However, this was not possible with a single channel transmitter. Therefore, we decided to make a compromise and implement permanent four Wheel Steering. The Y-lead Cable was used to connect to servos to one channel on the ESC.

Part Sourcing Problems

As the Losi Mini Rock Crawler is no longer in production, some parts are very difficult to source. LOSB 1409 was vital for the implementation of the 4WS. However, this part is only available in the USA. Fortunately, one of our team members went to Hollywood on an educational school trip in February and was able to pick up the part at the hotel. Although seemingly trivial, the servo could not be mounted without specific screws. The small diameter and large length of the required screw made it hard to source without LOSB1419. To overcome this problem, we found a wood screw with the correct diameter and then cut off the top

Not available in the UK

LOSB1421 -Servo Plates & Mounts

Turnigy servo signal reverser

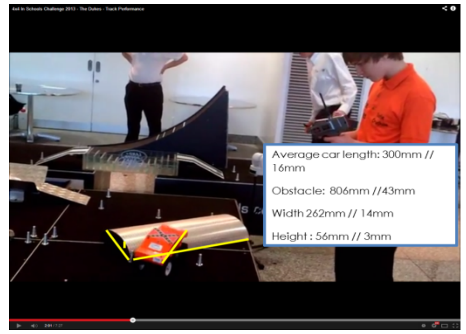
Servo extension Y lead cable

LOSB1422- Servo Saver and Arm Set

LOSB1419- Losi Mini Rock crawler, complete screw kit

Obstacles and Testing

We began by analysing YouTube videos of previous competitions, taking snapshots of all the obstacles. From this, we were able to take measurements of the obstacles relative to the (estimated) size of the car. We then decided on the obstacles that we thought were most significant; the ones that would test all aspects of the car: the variable hill, the seesaw, the camber dome and the water test.



We found that the most difficult object to create was the variable hill, as it required lots of support laterally to prevent it from wobbling from side to side. We were able to solve this by using a number of dowels connecting the two pieces that made up the sides of the ramp. The water test was also difficult to create using wood as the many rectangular pieces used to create the variable ramp had to made very slim. This meant that they were difficult to connect to a board, as we could not nail them down as the wood would have split. Instead we connected each piece with a dowel, making one connected ramp. This allowed us to glue the whole ramp down with PVA, as it had enough support from the dowels, meaning that it would not move. This meant the glue could dry.

We used the obstacles to create a course in which all of our team members completed as fast as they possibly could. This allowed us to narrow down who was driving on the day of the competition. The obstacles also allowed us to practice the precise turning needed to navigate some of them.

In addition to this, the obstacles could help us to test possible improvements. The only thing we tested was the shell, to see whether it allowed enough range of movement without scraping against the wheels or other parts. In the future (e.g. for the next competition) we will be able to use the obstacles to make objective decisions on changes we make to the car. For example if we have to make a decision on whether to use a certain tyre combination, we could carry out a test on each of the obstacles, comparing how each set of tyres perform.

Making the seesaw:

1) Cut out two equally sized rectangles, height 40cm, 20cm width.
2) Drill them to a base, about 60 cm apart.
3) Cut out a 1.5m long plank, 50 cm wide. Cut out indents on either side of the plank
4) Drill one hole into both of the indents.
5) Drill screws into the top of the two rectangles attached to the base.
6) Attach the plank by inserting the screws into the holes.
7) The screws act as a pivot and the plank moves about this pivot

Making the camber dome:

1) Cut out 4 semi-circles of equal dimensions- 15cm tall, 35cm wide.
2) Cut out two pieces of "flexi-wood" width 40cm, length 50cm.
3) Glue and pin the "flexi-wood" at either end of the semi-circles.
4) Attach the two semi-circular prisms to each other by gluing and clamping.

Making the variable hill:

1) Cut out two pieces of wood similar to a shape of an exponential graph using a router. Height 60cm, length 60cm.
2) Drill 6 holes in the side of each of piece. Use dowels (30 cm long) to attach two pieces together.
3) Cut out a piece of "flexi-wood" height 70cm, width 30cm. Glue and pin this to either piece wood.

Making the water test:

1) Cut out two pieces of wood height 20cm width 25cm- these act as the lead up ramps.
2) Cut out another two pieces of wood width 25cm height 15cm. Drill the lead up ramps at 45 degrees to each of these. Drill this structure to a base width 25cm length 30cm.
3) Cut out 2 sets of 5 pieces of wood varying from height 15cm-5cm, changing by 2.5cm in height each time.
4) Drill holes into these pieces and attach them together using dowels.
5) Glue this structure down to the base, clamping it so it doesn't move about.

Final Vehicle and Evaluation

Our final design was originally based on a Land Rover but due to the proportions of the vehicle, the design now resembles an off-road monster truck. The electronics (lights and tilt sensor) were mounted on the shell.

Evaluation

Positives

- The body of the vehicle now covers the entirety of the internal components, as stated in the brief and somewhat resembles the body of a Land Rover, our intention for the design.
- The vehicle's electronics fulfilled their specification – the lights come on when the vehicle is in darkness and the tilt sensors are also mounted.

Negatives

- We wanted to customise the crawler in the starter kit more than we did, however did not have enough time to complete all of the customisations for example changing wheels/tyres and suspension.
- The changes which we did make, were not necessarily aimed to enhance the vehicle's performance on competition day but done to meet specifications.

Lessons learnt

- Time management is key to the success of any project, we had time that was spent unproductively at the start of our project whilst we waited for the delivery of the starter kit – in hindsight we realise this time should have been spent making unrelated components like the obstacles for testing.
- This project, by its nature, has taught us all a great deal about the internal workings of not only remote-controlled rock-crawlers but full-scale Land Rovers too as a result of the research done.

Looking to next year's competition

- Next year we plan to enter Class 1 of the competition, and so make our own car from scratch, this will no doubt be challenging but we feel the skills we have learnt, knowledge we have gathered and confidence we have gained by entering the rookie class this year puts us in a great starting position.
- We will look to implement a full redesign of the chassis and vehicle body as well as again use 4-wheel steering to enhance manoeuvrability over obstacles.
- Greater time for testing should allow us to be sure our vehicle has been optimised for competition, putting us in a strong position to win.

Time-Management and Accounts

Week Starting	Jobs	Comment
21/10/2013	Obstacle course research- Tireni Analysis of past projects - Aidan Design specification- Nev Land Rover/Real 4x4 analysis scientific - Alex Initial Ideas on logo- Jack Theoretical explanations- Callum	Decided team name FMRC Continue research for next week as longer than expected.
28/10/2013	Engines and Batteries - Jack Light and tilt sensor - Nev	Decided to enter Rookie competition Logo chosen
04/11/2013	Suspension and Chassis - Callum Remote control aspect - Nev Wheels, steering and tread - Aidan	Research almost completed
11/11/2013	Analyse Rock crawler - Aidan Mind Map- Callum Research Summary- Tireni Analyse Chassis - Alex	Rock Crawler ordered
18/11/2013	ESCs and servos - Nev Portfolio layout in Photoshop- Jack	Research Complete
25/11/2013	Review what we have done and make a plan of action of what to do after the research.	
02/12/2013	Analyse videos of obstacles and use for measurements for building replicas- Alex and Tireni	Received Rock Crawler
09/12/2013	Design Shell- Aidan Chassis and Tow Bar design- Callum Rest of the group start building obstacles	Started building Variable Hill and Camber Dome Order Electronics
16/12/2013	Alex will lead organising manufacturing	Received electronics Start taking photos
23/12/2013		
30/12/2013		
06/01/2014	Solidworks design of shell- Aidan Finalise circuit design and incorporate it into the RC Car- Nev Shell design drawings- Jack Continue with rest of obstacles	Tested Tilt and light sensors with car Decided on shell design and colour scheme
13/01/2014	Electronics Diagram – Nev Scan in initial designs- Jack Create team banner- Alex Videos of testing the obstacles	Finished Variable Hill Finished Camber Dome
20/01/2014	Vacuum form shell - Tireni & Callum Design tow bar- Aidan Orthographic drawing of final design -Nev	Finished Articulation and Seesaw
27/01/2014	Finalise Costing and Accounts- Tireni Write script for Powerpoint- Jack Spray paint shell- Aidan and Alex Cut out tow bar with 3D Router- Callum Evaluation- Callum	Finished Shell Tested our RC Car with obstacles made Pictures and Videos to add to PowerPoint
03/02/2014	Leaflets about the Team- Tireni	

Understanding Financial Costs
Although we had available finance from our anonymous sponsor, we decided to attempt to minimise costs regardless, as we feel this best replicates the process gone through by real-life car companies. Basic materials such as Wood and Aluminium were at hand. Perhaps it would have been beneficial to source external materials As they would possibly be of higher quality. However, we believe that attempting to minimise costs not only kept us under budget, but also gave us a more authentic engineering experience

As well as using this log to keep track of what we did on a week by week basis, we also took advantage of the Google Drive system which allowed each of us to upload completed work to one folder which we could all access through our own emails. By using this method it was easy for Callum and Jack to let us know on any improvements we needed to make in the content/design of our research. Moreover, we decided to create a Facebook group and chat which allowed each member of our group to be contacted quickly and easily. Using this system also meant that we could upload and send things to each other, especially on weeks where two people were working on the same part of the portfolio.

We met at different pre arranged times during the week in our school's design and technology department, with our weekly Wednesday meeting to review what we had done in the previous week and look forward to what needed to be done in the next week. During these meetings we could look at and review each other's work as well as work together to complete all the various tasks we needed to do to for the competition.

Our teamwork played a key part in our organisation and time management. However, our individual efforts were as important. For us to keep organised and balance our time management, we had to complete jobs that were specific to each of us when they needed to be complete. Callum had a main role of organising us and instructing us on what we had to do and when it needed to be completed. We felt that by having one person in charge of the time management, we would be able to keep to our schedule better.

Understanding Costs and Accounts

Component	Price
470 Resistors	£1.44
Buzzer	£2.39
OP Amp	£1.09
Tilt sensors	£5.18
Relay	£2.39
Nand gate	£0.99
10k Resistors	£0.72
LDR	£2.64
Connector	£1.39
Circuit Board	£3.69
Variable Resistor	£0.64
LED	£1.98
Machine screw	£2.40
Servo y-lead cable	£1.74
Servo signal reverser	£3.74
Digital Mini Servo	£21.45
Front Spindles	£9.26
Servo Mount	£3.87
Servo Saver & Arm Set	£6.42
Custom T-shirts	£42.48
Total	£109.61

Expenditure
Our expenditure was mainly for the electronics need to build the circuits as well as parts necessary to implement four wheel steering. This was because we had a large variety of resources available to us within the technology department at The Latymer School. Whereas we otherwise might have had to outsource to buy some polythene, we were able to use the schools supply of high-impact polystyrene for the body shell.

Sponsorship
We were fortunate enough to have an ex-engineer who is very passionate about encouraging engineering or the future generation to sponsor our project. He was able to finance all costs. Our sponsor wishes to remain anonymous.

Understanding Environmental Costs
We recognise the importance of manufacturing sustainably as well as minimising damage to the environment. Therefore, where possible, we used recycled wood from previous projects as well as recycled MDF. During our extensive testing, the car was switched off during breaks so as to minimise battery and electricity usage.