Lunar Rover Competition

StrathSEDS

Meet the team

	Role	Year/Course
Julie Graham	Project Manager & Mechanical Systems	1st Year, Aero-Mechanical Engineering
Chadha Degachi	Engineering Lead & Software Design	2nd Year, Software Engineering
Niamh McCormick	Mechanical Systems	1st Year, Aero-Mechanical Engineering
Caitlin Callaghan	Electrical Systems	1st Year, Electrical & Electronic Engineering
Daniel J Devine	Engineering Consultant	3rd Year, Electrical and Mechanical Engineering
Gregor Baird	Engineering Consultant	3rd Year, Electrical and Mechanical Engineering

The Proposal

The elevator pitch

Weight	~ 2kg
Length	28.5 cm
Width	30 cm
Ground Clearance	13 cm
Maximum Speed	0.2m/s
Power Supply	15V Li-on Battery
Range	120m

Figure 1.1: Inspiration

Our favourite features

- ★ Mesh wheels
- ★ VR enhanced control room
- ★ Rocker-bogie suspension
- ★ Smart sample collection

System breakdown

A breakdown of rover components

… and on to the nitty gritty

Control

- Rover will be equipped with infra-red sensors in the rear and the front of the rover as well as 360 degree and single angle cameras to relay information regarding its surroundings back to base allowing ground control to make informed decisions regarding the rover's movements and trajectory.
- Ground control can use keyboard, mouse or joystick input to direct the rover's actions.
- Ground control software will be written in C and will implement a basic but easy to follow user interface

Communication

- A Raspberry Pi 3 will be used as the rover's microcontroller where the Pi will be responsible for interfacing with the rover motors, sensors and cameras as well as communication with ground control.
- Where the operation base consists of a standard PC with two monitors; one to receive and display all data transmitted by the rover, and the other to allow interaction with software, ground control will be able to communicate via 802.11n Wireless LAN and Bluetooth 4.1. Ground control can also take advantage of the Raspberry Pi's Linux OS to remotely SSH into the rover.
- WiFi and Bluetooth Range: approx. 100m but must test more thoroughly for interference and dropouts so to select the best signal booster

Drive

- Locomotion
- Suspension System
- Structural Dimensions
- Structural Members
- Breakdown - Joints and Counter-rotating differential
- Stability
- Drive train

Locomotion

During the PDR stage several types of locomotion were considered, to determine the most suitable choice for the mission brief:

- Wheels were chosen to fulfil accurate steering, as well as providing familiarity and a greater range of research from previous, successful rover missions.

Rocker-Bogie Mechanism

One of the key stages between the PDR and CDR stage, was the investigation of suitable suspensions systems for a lunar mission.

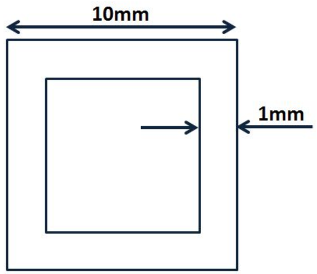
The Rocker-Bogie system was chosen for:

- The stability created, by allowing the mass to be equally distributed across the 6 wheels.
- It’s design to ensure maximum contact with the lunar surface.
- Greater ability to traverse obstacles.

Structural Members

From the CDR stage, square faced tubes have been chosen to maximise strength whilst minimising mass.

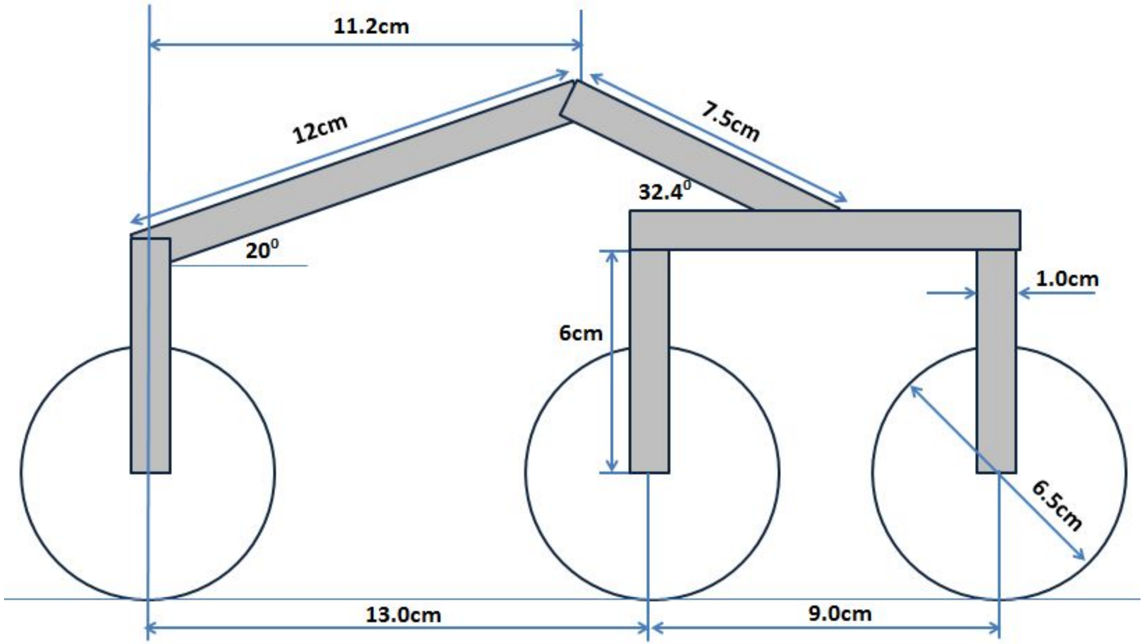
Anodised aluminum tubes were chosen as they are both lightweight and strong.



Square Tube Dimensions

Member	Relative Bending Stiffness	Torsional Resistance
Square Hollow	7.2	105.0
Round Hollow	4.3	62.0

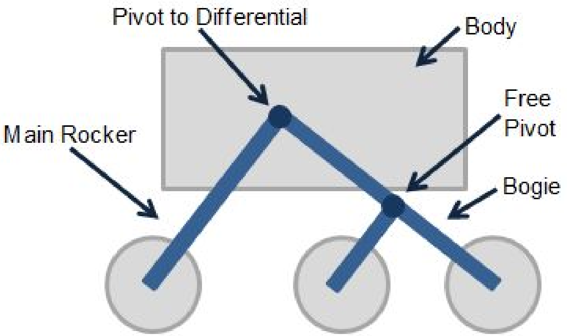
Structural Dimensions



Breakdown

The key elements which allow a Rocker-Bogie to function as it does are:

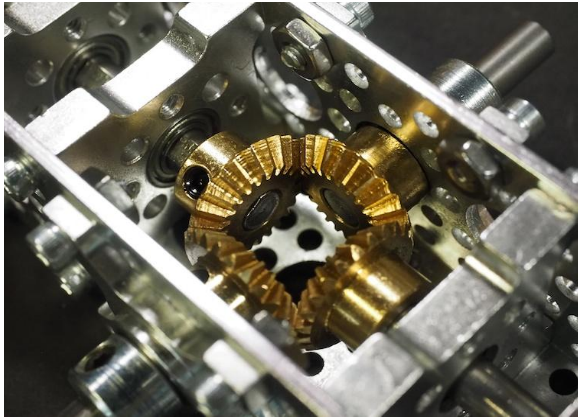
- The Counter-Rotating Differential
- The Free Pivots



Counter-Rotating Differential

To ensure that the majority of the rover's wheels remain in contact with the surface whist climbing over obstacles, a counter-rotating differential is used.

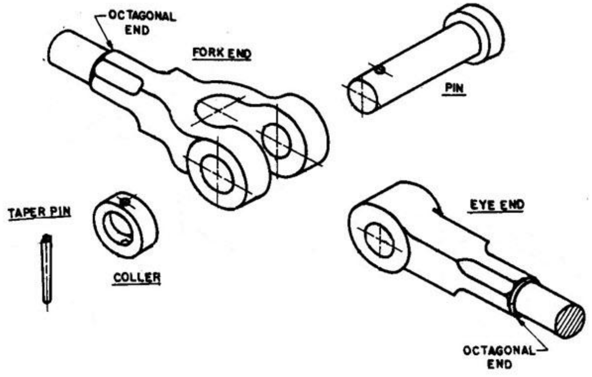
- The differential allows the rotation of one set of wheels to be translated to the other using a Bevel gears of a 1:1 ratio.



Free Pivot Joints

To allow the rover a greater range of motion whilst climbing over obstacles it has two pivots; one at the bogie and another to the central differential.

Joint 1 :Using a key mechanism to the differential shaft
Joint 2 : Using a simple knuckle joint.



Drive Train

- The rover will have a motor mounted directly at each wheel, to ensure the maximum power is translated to wheel rotation.
- By powering all 6 wheels we are able to limit the possibility of the rover becoming stuck whilst overcoming an obstacle.
- The rover will steer using skid steering, typical in crawler which allows for a simplification in controls.

Motor Selection

- The velocity of the rover was chosen to allow for accuracy over speed, as Rocker-Bogie suspension systems are known to have a much slower speed whilst traversing rough lunar terrain.
- To accommodate our new wheel diameter of 6.5cm the linear velocity was determined to be 0.2m/s.
- Conversion equations were carried out that concluded a 52 RPM motor was suitable.

Next Steps for Drive: Stability

Taking into consideration the feedback from the CDR, the stability, related to the traction and Static Stability Factor will be further explored to ensure our rover will sufficiently complete tasks.

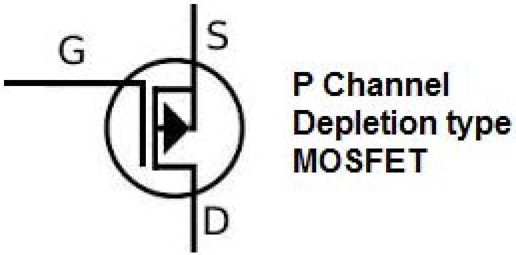
Power: Battery

- A 15 V 2200 mAh lithium-ion battery was chosen to be the power supply.
- The battery chosen has an internal protection circuit to prevent over-charging, over-current, over-voltage, undervoltage and over temperature.
- Reverse battery installation will be prevented by placing a high value diode in series with the battery.
- A fuse will be inserted into the circuit for additional protection.

Power: Microcontroller

- The rover’s microcontroller has input voltage 5 V and input current 2 A, meaning the microcontroller cannot be directly connected to the battery.
- A LT1076 buck converter will be placed in between the microcontroller and the battery, stepping down the 15 V output to 5 V.
- The Raspberry Pi will be mounted to a breadboard and all connections to the Pi’s GPIOs will be soldered to the breadboard.

Power: Kill Switch



- A kill switch will be placed between the battery and the rest of the circuit, and will be activated in the event of an emergency.
- A p-channel MOSFET will be used in depletion mode. When the switch is triggered, a voltage is applied to the gate and current can no longer pass through the transistor.

Power: Motors

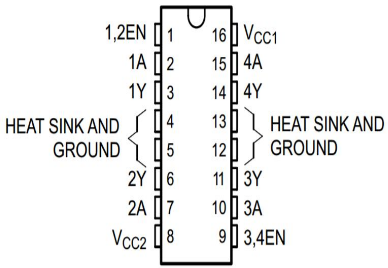


Figure 2.2: Labelled pins for the L293D motor driver chip

- The connection to the motors can be established using a L293D motor driver chip allowing the Pi to send signals to the wheels and control the rover movement without damaging itself. The L293 motor driving chip can withstand voltages up to 36 V and a maximum of 2 A as well as temperatures of up to 150°C.
- The motors themselves operate at 6 V so another buck convertor will be added into the circuit to step down the voltage.

Power: Safety

- Good battery practice must be followed.
- Good soldering practice must be followed.
- There will be no uninsulated areas carrying a live voltage.
- Damage will occur to the battery if used at sub-zero temperature so if the rover was to be used to explore the dark side of the moon, a resistive heating coil could be added to the circuit.

Component Derating

- Component derating is a technique used in EEE to prolong a component’s lifespan by operating it at less than their rated maximum power dissipation.
- All components will operate in such a fashion that the ECSS guidelines will be respected and the longevity of the components increased.

Sample Collection

- Sample collection will be achieved by mounting a clamshell bucket onto the end of a robotic arm controlled by the Raspberry pi, which will transfer the sample from the ground into the container on the rover.
- Assuming an average density of $1.5 g/cm^3$ for the ice, the clamshell bucket should be able to pick up approximately 40g of sample per scoop.

Wheels

- The extra set of wheels in a six wheeled rover (in relation to a four-wheeled rover) allows for greater traction, to provide greater forward thrust.

- These wheels consist of n aluminium wheel hub, with a tyre of woven wire mesh, able to deform and reposition when it experiences a load, meaning the wheels would be able to effectively travel over obstacles. The wheels also include a stiff inner frame of aluminium, which acts to prevent over-deflection of the wheels.

- Part of the tyres would be covered with thick tread strips, in the form of metal chevrons, which increase the traction of the wheels.

- The outer mesh frame of these wheels will be manufactured using metal wire (nickel alloy stainless steel) which will then be attached to a stiff inner frame, around a hub of steel. The piano wire will be woven into net-like mesh cylinders, which will be heat treated before being attached to the inner aluminium frame and the steel hub.

- Tread strips will be added to the wheels, partially covering the wire mesh, to give additional protection to the wheels, and preventing plastic deformation.

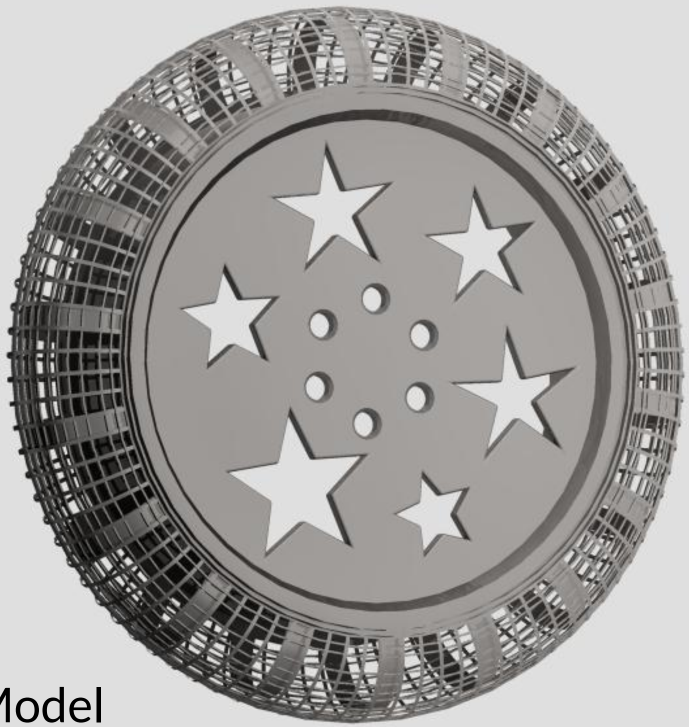


Figure 2.3: Wheel CAD Model

Key Risks

Task	Description	Probability	Impact	Risk score	Mitigation	New Score
Hardware	Communications loss	M	M	4	Minimise interference from other sources.	2
Project Delivery	Project goals and milestones are not met	M	M	4	Have weakly reviews of progress to assess current/future goals	3
Manufacture	Injuries to hands whilst using files and hand saws to manufacture structural members	M	M	2	Care taken whilst using tools, always use a vice when cutting or filling, wear gloves	1
Manufacture	Awkward posture due to repetitive movements causing back problems	M	M	2	Allow appropriate work areas and restrict time on repetitive tasks	1

Manufacture	Fumes from soldering	M	H	3	Ensure a ventilated room with frequent breaks	1
Manufacture	Damage to hands due to the repetitive movements during weaving the wheel mesh.	M	M	3	Take frequent breaks and split the tasks across the team.	1
Manufacture	Entanglement in moving parts of machines	M	H	3	Ensure long hair is tied up, jewellery is removed and lab coats are worn to reduce potential injuries	2
Budget	+/- on given budget	H	L	3	A costing log will be used to track spending	1
System Integration	Systems do not integrate	M	H	4	Constant communication between subsystems	2
Computer files	Files Lost/Corrupt	M	H	5	The software should be version controlled and backed up	2

Our plan part 1: from zero to hero

- Initial requirements were to select a drive mechanism which traded-off precision and speed in an acceptable manner, design a power system which minimised the risk of electrical complications, and to decide on a sample collection implementation.
- Over the process of CDR development the team decided against using tracks to implement rover drive and instead to use a six wheel system, the control system was downscaled to one Raspberry Pi, a robot arm was selected for sample collection and a full risk analysis of the power system was completed and so overall the team was able to meet the initial requirements.

With the new developments in mind we had outlined some further requirements which needed to meet should we wish to be able to start building this rover, those are detailed below:

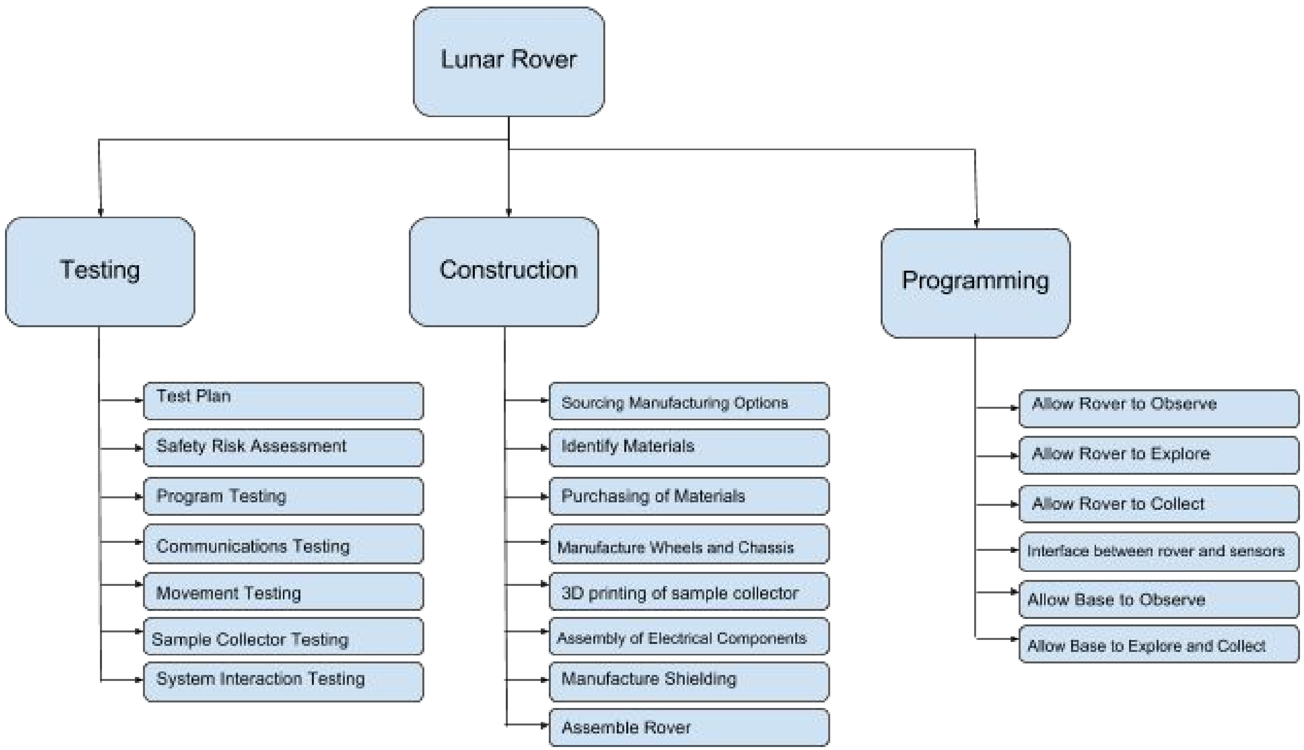
- Complete dimension analysis for suspension boogie
- Analyse the stability of the rover, regarding traction and climbing ability.
- Complete a CAD model prior to the manufacturing process.
- Compute the amount of time and weight taken by the sample collection arm when at work
- Complete an analysis of communication channel range and dependency

Our plan part 2: looking to the future

Item to Test	Test Description
Microcontroller interfaces with infra-red sensors	Ensure that the microcontroller can connect to the infra-red sensors, can turn it on/off, can receive data from the sensor, data is not corrupted in transfer
Microcontroller interfaces with camera	Ensure that the microcontroller can connect to the cameras, can turn them on/off, can receive data from the camera, data is not corrupted in transfer, data can be displayed in such a way that it is useful to ground control and without time delay
Microcontroller interfaces with motors	Ensure that the microcontroller can connect to the motors, can turn them on/off, can direct their movement
Communication testing	Ensure that ground control and the microcontroller can connect to the same network, ensure that ground control and the microcontroller can transfer data between them, ensure that data is not corrupted in the transfer

Item to Test	Test Description
Inclination testing	Ensure that orientation data read from sensors is correctly computed to return the rover’s current inclination
Surface mapping testing	Ensure that data from the ultrasound sensors is translated into a correct sonar interpretation of the obstacles on the current surface, ensure that SLAM algorithm is implemented correctly
Collection testing	Ensure that the microcontroller is capable of directing the robot arm motion as triggered by the load sensor readings. Work out power consumption and time requirements for the robotic arm to complete its collection manoeuvres.
Input testing	Ensure that the ground control software correctly parsers user input, validates and then calls the correct function based on said input
Data analysis testing	Ensure that data received from sensors is stored and tracked, ensure that ground control is pinged when data is outside of expected range

*Automated unit tests will be employed using the Unity testing framework for C programming. This allows the adoption of a test driven development tactic ensuring high test coverage and guarantees correctness.



Lunar Rover
Testing
Construction
Programming
Test Plan
Safety Risk Assessment
Program Testing
Communications Testing
Movement Testing
Sample Collector Testing
System Interaction Testing
Sourcing Manufacturing Options
Identify Materials
Purchasing of Materials
Manufacture Wheels and Chassis
3D printing of sample collector
Assembly of Electrical Components
Manufacture Shielding
Assemble Rover
Allow Rover to Observe
Allow Rover to Explore
Allow Rover to Collect
Interface between rover and sensors
Allow Base to Observe
Allow Base to Explore and Collect

Addressing your concerns

Much of our design and documentation has been updated in light of feedback received on our CDR, these are listed here,

- The scaling down of autonomous features in rover programming, including removing GPS capabilities
- The creation of a test plan
- The completion of a risk analysis
- Changed wheel materials to make them more suitable for the lunar environment

- Further research was conducted into the function and composition of the material collection mechanism.
- Design was altered for more appropriate power distribution (eg. unnecessary powered features were redesigned)
- Extensive research and consideration of the landing site, was undertaken to ensure an effective design.
- The reduction in wheel diameter, to reduce the necessity of a foldable mechanism.

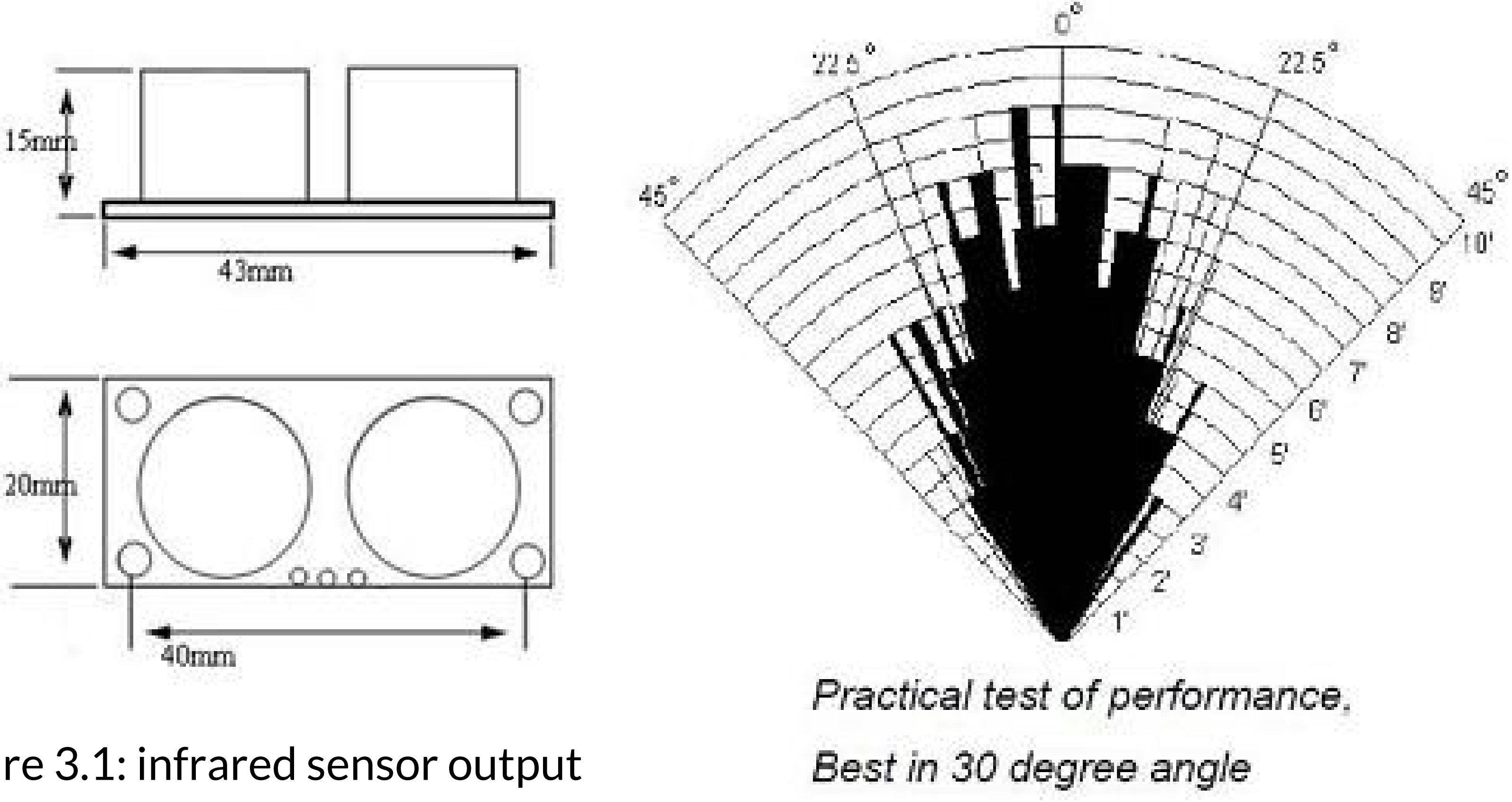


Figure 3.1: infrared sensor output

The budget

Our total estimated cost is **£673** where some of the biggest highlights can be seen below,

Items	Cost	Notes
Chassis	£50	Self built within university facilities
Motor	£90	Geared DC motors
Camera	£230	One 360, one single angle
Sensor Kit	£80	Ultrasonic Sensors, gyroscope, accelerometer and load sensor
Wheels	£50	Wire mesh (self-built within university facilities)
Battery	£50	Li-ion

Thank you