Lunar Rover Competition

Preliminary Design Review

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Introduction

This interim design report outlines progress made thus far on the StrathSEDS entrant to the UKSEDS Lunar Rover Competition. The team is primarily formed of 4 students who recently began studying for various engineering degrees. Guidance and mentorship is provided by level three Electrical and Mechanical Engineering students.

The primary objective which the rover must meet is to drive down a slope to a specific point where a soil sample will be taken. The sample is then returned to the starting point. Robustness must be considered throughout the design and build process as a vibration test will be undertaken before a second demonstration. The performance of the rover should be consistent with the first demonstration.

With reference to the *LRC Rules and Requirements* document, some notable challenges were identified. These are listed in Table 1.

Table 1: Proposed Problems and Solutions

#	Problem	Proposed Solution
1	Rover must traverse loose sandy surfaces.	Wheels to be wide and feature deep tracks.
2	Rover must traverse smooth rocky surfaces of up to 30deg.	Wheels to use pliable material.
3	Rover must deal with rocks of up to 40 cm. (note that rover will be up to 30 cm in height)	Highly maneuverable as to avoid these rocks.
4	Rover must be capable of travelling 60 m.	High capacity battery.
5	No visual line of sight to rover, information must come from one (provided camera) along with onboard sensor information.	Spherical (360deg) camera to be incorporated into design.
6	Rover must collect up to 500 g of material. Particles will be between 1 cm and 5 cm in length.	Auger, Scoop/bucket system

Project Management

Assigned Roles & Team Roster

Name	Role	Year/Course	Contact Details
Gregor Baird	Project Manager	3rd Year, Electrical and Mechanical Engineering	gregor.baird@live.com 07863933794
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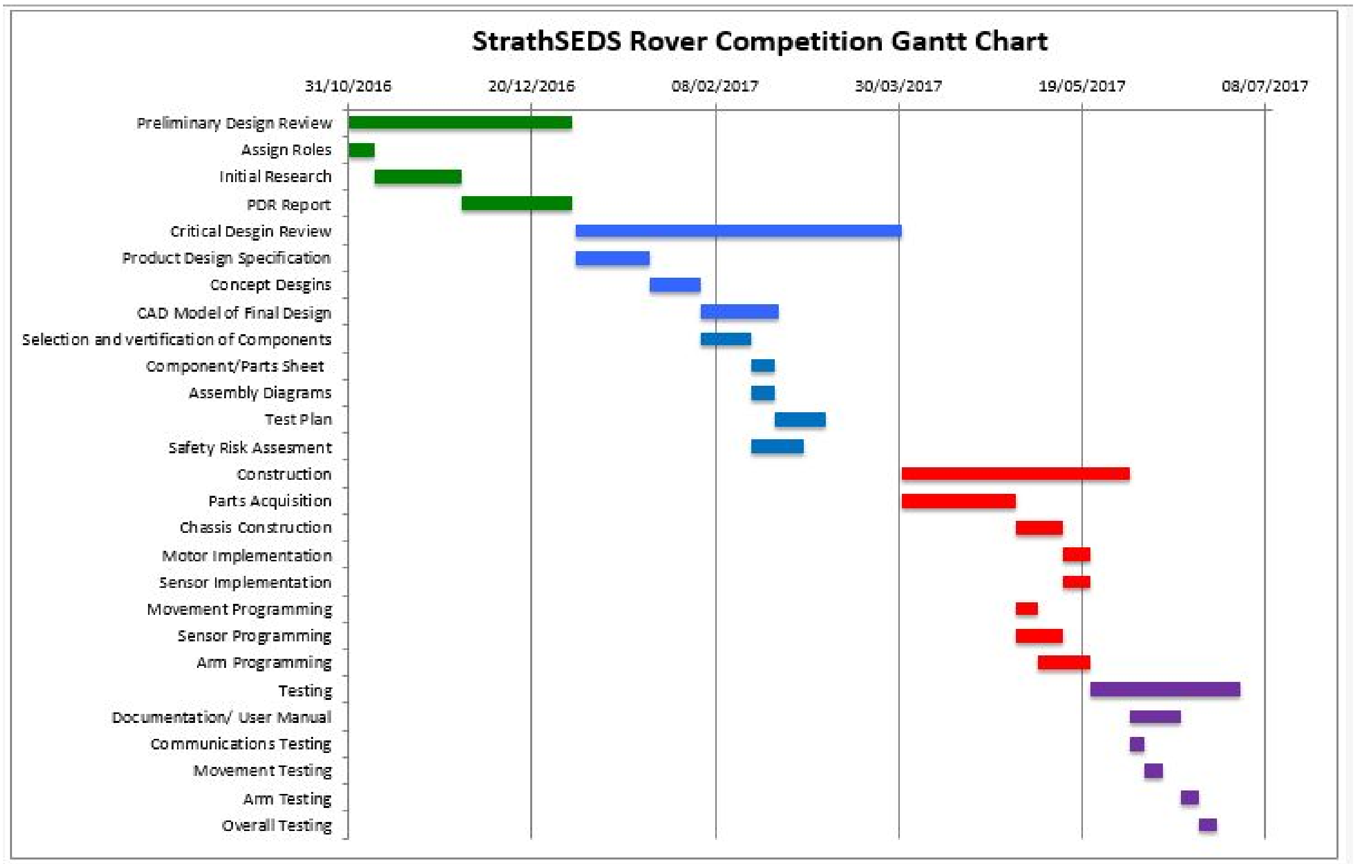
Julie Graham	Mechanical Systems	1st Year, Aero-Mechanical Engineering	Juliekategraham@icloud.com
Caitlin Callaghan	Electrical Systems	1st Year, Electrical & Electronic Engineering	caitlin.callaghan@btinternet.com

Preliminary Schedule



Preliminary Budget

Items	#	Estimated Cost	Notes
Chassis	**1**	£50	Self built within university facilities
Motor	**2**	£60	Geared DC motors
Camera	**2**	£150	One 360, one toward tools
Microcontroller	**1**	£0	Arduino (already owned)
PC	**1**	£0	Raspberry Pi (already owned)
Communications Link	**1**	£0	Wifi Antenna, Router (already owned)
Sensor Kit	**1**	£80	Ultrasonic Sensors, etc.
Tracks	**2**	£50	Sprockets, chains, pipes, nuts and bolts
Battery	**1**	£50	Li-ion
Motor Controller	**1**	£20	Arduino Shield
Sample Collector	**1**	£40	Self built within university facilities
Bolts/Screws etc		£0	Salvaged / Already owned
Wiring		£0	Salvaged / Already owned
Total:		£500	

Project Risks & Management

A risk register was created to identify project risks to be evaluated and mitigated. It is worth noting that the risk scores are based on a scale of 1 to 5 with 5 being greatest risk and LMH refers to Low, Medium and High.

Task	Description	Probability	Impact	Risk score	Mitigation	New Score
Hardware	Parts do not arrive on time	L	M	3	Order parts far in advance of construction carefully choosing suppliers with alternative suppliers identified.	2
Hardware	Hardware Breakage	L	M	3	Members to be familiar with component datasheets and handle with care.	1
Hardware	Communications loss	M	M	4	Minimise interference from other sources.	2
Manufacture	Manufactured components not correct	L	M	3	Ensure that the CAD model is correct	1
Component Integrity	Components are damaged	M	L	2	Have spare components	1
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 sub-systems	2
Storage	Project is kept in inadequate condition	L	M	3	The project should be stored in a dry and secure place	1
Computer files	Files Lost/Corrupt	M	H	5	The software should be version controlled and backed up	2
Working with Electricity	Chance of electric shock	L	H	4	Only work with circuitry when battery has been disconnected	1

Personnel	Loss of Team Member	L	H	4	Detailed logbook to be maintained.	2
Project Delivery	Project goals and milestones are not met	M	M	4	Have weakly reviews of progress to assess current/future goals	3
Final Design	Design is insufficient for task	L	H	2	Ensure collective understanding of design requirements	1
Project Completion	Lack of time to complete project	L	H	2	Set weekly deadlines to achieve project milestones	1
Final Report	Lack of time to complete	L	M	3	Template structure to the report	1

Brainstorming

Before moving forward, initial brainstorming was undertaken. Some of the most innovative or interesting solutions brought forward are described below.

Concept 1: Rolling Rover

Spherical rover with grippy outer casing, the casing will be driven by an unconstrained chassis within. This is conceptually similar to a Sphero [1] or BB-8 Droid[2].

Pros	- The rover is designed specially to move across rocky or steep terrains and is more reliable across these landscapes than wheeled rovers. - Unrestricted, flexible movement in any direction across a flat plane. - The rover saves energy when rolling down slopes.
Cons	- The rover has a limited maximum slope degree of approximately 9 degrees, and cannot climb a slope of greater angle than this. - Complex engineering. - A design like this, is more suited for a initial high altitude, rather than climbing to a height. - The rover will require an additional system to coordinate the camera - increasing complexity further.

Concept 2: Spider Rover

Rover with six individually controlled legs connecting to the main body. This would be a similar concept to NASA's 'Spidernaut'[3].

[1] http://www.sphero.com/sprk-plus
[2] https://en.wikipedia.org/wiki/BB-8
[3] https://spidernaut.jsc.nasa.gov
[4] http://www.microrobo.com/omni-wheels.html

Pros	- The rover would be able to move up and down sloped surfaces with ease in a way wheeled rovers are not. - Due to the additional height this rover is granted, it would be able to pass over obstacles which it may otherwise have had to manoeuvre around
Cons	- There would be a great deal of complexity involved in individually controlling six robotic legs.

Concept 3: Rocker Bogie Wheeled Rover
Conventional rover design, with four treaded wheels which can pivot to allow greater motion. Using a rocker bogie to maximise its ability to move across obstacles of up to 40cm high.

Pros	- Each wheel has a greater range of motion, giving the overall rover greater flexibility across the terrain. - The rocker bogie keeps the rover balanced when overcoming obstacles. - The wheels allow it to travel across the thin surface.
Cons	- This design is not as practical for steep or rocky surfaces which the rover will experience. - It will not exert as much traction as tracks can, due to the reduced surface area.

Concept 4: Tracked Rover
Rover with two tracks.

Pros	- The rover would be able to move up and down sloped surfaces with ease in a way wheeled rovers are not. - Comparatively simpler engineering. - Surface pressure exerted is low, good on sand.
Cons	- Reduced control. - Reduced speed.

Concept 4: Flying Rover
Rover with the capability to both drive along the surface or fly across it. A possibility for the wheels to drive along it are omni-wheels[4].

Pros	- Capability to completely bypass obstacles and slopes. - Omni-wheels give a greater range with greater manoeuvrability.
Cons	- Needs to land to collect samples which will require extra power for take-offs and landings - Additional weight due to extra elements. - Greater risk due to landings on uneven terrain. - Omni-wheels do not always have the greatest tread, so can result in the rover rolling down the hill. They further complicate the design.

Preliminary Concept

Proposed Concept

Drive

The primary candidate design sits atop two directly driven continuous tracks. The additional surface area afforded is likely worth the weight trade-off. In addition, to achieve equivalent traction from a wheeled structure, more than two wheels would require drive power. Simplifying the design to two motors keeps control manageable.

Pre built tracks systems to our scale are prohibitively expensive, and would require modification to suit the vehicle. A number of DIY methods are documented online, it is likely the team will self construct by creating gripped spars between parallel chains, driven by sprocket[4].

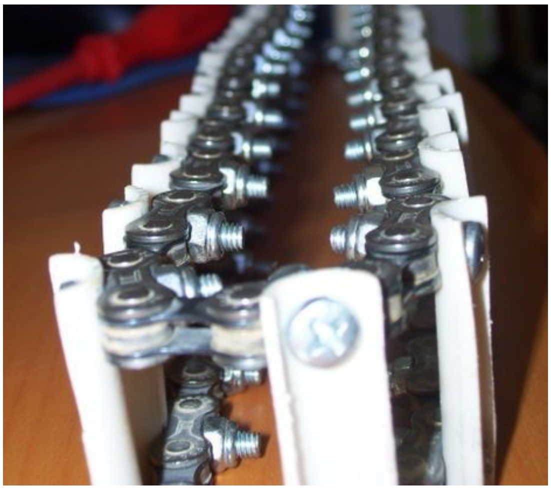


Figure 1: Example track system[3]

Power

A lithium-ion battery will be used to power the lunar rover. They are not only rechargeable but are a cost efficient option in comparison to lithium-polymer. There are many examples within budget and around 15V 2200 mAh. The high energy density helps when trying to stick to the competition's regulations involving size. Li-ion batteries can withstand a moderate amount of movement and can be turned upside down without causing damage to the battery, a useful feature within a moving vehicle. Lithium-ion batteries also have a relatively high power to weight ratio compared to other types of batteries[5].

For the Arduino being used, the 15 V from the battery could be connected directly. For a Raspberry Pi, a 5 V regulator would need to be inserted between the Raspberry Pi and the battery.

To protect the battery from reverse current a high value diode can be placed in parallel with the battery, only allowing it to flow one way which also serves as protection from placing the battery in the wrong way. Overcharging is a safety concern with li-ion batteries, many li-ion batteries include charging circuitry. In the case this is not included, a suitable module will be sourced. The same applies to temperature monitoring. An external kill switch will be included in case situation arises where the battery

[4] http://www.instructables.com/id/How-to-make-custom-and-strong-tank-tracks-for-very/
[5] http://web.mit.edu/2.009/www/resources/mediaAndArticles/batteriesPrimer.pdf/

needs to be immediately disconnected from the circuit i.e. a collision or fire. The switch itself will be located on the controller and would need to be pressed by the operator.

No exposed area of the rover will have a live voltage across it. All points of connection will be insulated and there will be no exposed wiring to reduce the risk of causing short circuits that serve as a fire hazard.

Good battery practices would need to be used when using the battery to reduce the risk of any damage to the battery. This includes checking all connections between the battery and the circuit are insulated, checking the battery's terminals are clean and free of corrosion, checking the battery is sufficiently charged before use and waiting for the battery to discharge to 10% before recharging.

Control

This section will discuss the various hardware and software solutions which, once implemented, will allow the final product to navigating challenges with the aid of environmental sensors. Further, this section will describe the microcontroller which will interface with the aforementioned sensors and which allow communication with the operating base.

The first such environmental sensor is a rotational sensor or rotary encoder, this allows the operating base to collect information on the rotation of the rover's wheels and their current direction, information which in turn can be combined with pre-existing information regarding the rover's dimensions to eventually create a programmable method of measuring distance crossed[6] by the rover as well as providing a way to instruct said rover to move specific distances. Moreover, the rover will be equipped with a combination of infrared and ultrasonic[7] sensors as well as a 360 degree camera to relay information regarding its location and surroundings back to base. This information can then be filtered through SLAM (simultaneous localisation and mapping) algorithm for accurate obstacle avoidance and surface mapping[8].

While the possibility of using an Arduino microcontroller to interface with the various sensors installed and communicate with the operating base, the Arduino being a more robust and cheaper option, it was eventually decided that a Raspberry Pi should also be used for this project as its complexity allows for better multitasking and more processor intensive programmes to run on the finished rover.

Communication

This section will describe the solution arrived at to allow wireless communication between the operating base and the rover. In this case, the operation base will consist of two monitors one to receive and display all data transmitted by the 360 degree camera onboard the rover and the other to allow interaction with APM Planner 2 (an open source, ground station control software)[9], further employed will be a Virtual Reality headset to be paired up with the existing video live stream to allow a more nuanced understanding of the rover's current location. The rover will be able to communicate with the base and receive instructions from it by using the Raspberry Pi, employed as a microcontroller, as an ad hoc 802.11 wireless network or in case of network failure, using bluetooth[10][11][12]. This option provides

6 http://www.education.rec.ri.cmu.edu/robots/4H/roboticsandyouonline/probe_content/Probe_2/rotation_sensor_dist.pdf
7 http://www.bajdi.com/simple-obstacle-avoiding-sketch-using-an-ultrasonic-sensor/
8 https://opensource.googleblog.com/2016/10/introducing-cartographer.html
9 http://ardupilot.org/planner2/docs/installing-apm-planner-2.html
10 https://spin.atomicobject.com/2013/04/22/raspberry-pi-wireless-communication/
11 http://www.cs.cornell.edu/~ja275/nasa/nasa%20final%20report.pdf

significantly less interference than radio communication would, although it may limit communication range somewhat. Finally, the operating base shall also be equipped with the means to allow manual control over rover movements should such actions become necessary.

Collection of Samples

The design specifications call for dry ice samples to be collected from the lunar surface. One method for collecting these samples is a scoop system. Using a clamshell bucket system, the sample could be passed to a shaker bed which would separate the sand from the dry ice allowing the pure sample to be collected.

Figure 2: Clamshell Example[13]

This system could be mounted on a robotic arm to allow greater control over collecting samples.

An alternative system would be to use an auger system to pull the samples out using a rotating screw like system. The advantage of this system is that the sample and sand could be directly deposited onto the shaker system.

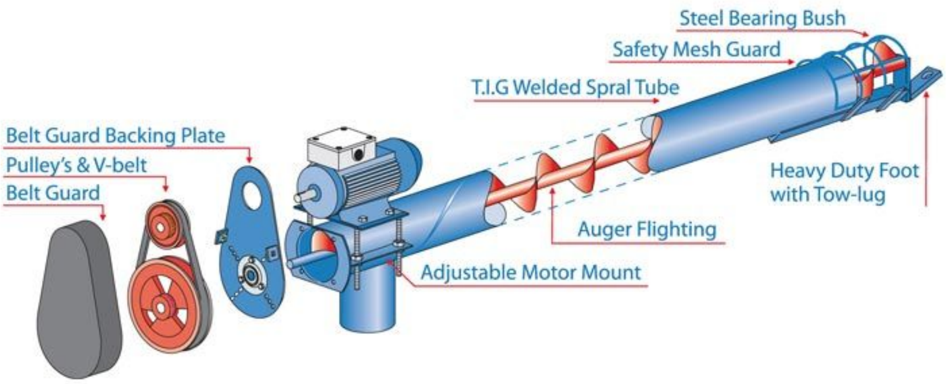


Figure 3: Auger Example[14]

[12] https://www.raspberrypi.org/forums/viewtopic.php?f=37&t=82510
[13] http://www.eikengineering.com/clamshell.htm
[14] http://www.grainline.com.au/content/pencil-augers

Summary of Requirements & Design Choices

The concept is still at a fluid stage of development, with the design not yet confirmed. Progress has been made in breaking down the main technical challenges, and finding workable, realistic, solutions.

With respect to drive, the in-house track system is a cost effective way of maximising surface area and maximising traction. There are trade-offs in precision and speed, however speed is deemed of lower priority than traction. Taking the course more leisurely will reduce the adverse impact of tracks on control.

As stated above, a lithium-ion type battery will be used. A 15V battery, around the 2000mAh range should suffice for 30mins run time with two DC motors of around 30W draw.

Sensors and motors will interface with an Arduino, which in turn is managed by an on-board Raspberry Pi. The Raspberry Pi will be hardwired to the Arduino and cameras. A wireless network will be created at the base station with the Raspberry Pi connected and communicating over it.

The sample collection method is yet to be decided. Examples of both will be sourced and practical testing will be performed. From this, a bespoke system will be constructed. If an auger is selected, this may be mounted on a salvaged model robot arm.