Soft Four Interchangeable Units Rescue System

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Abstract

This paper presents a conceptual design for a soft and inflated modular Lunar Robotic Rescue System. The proposed system consists of four compact, lightweight, self-balancing robotic platforms capable of autonomously or manually transporting an injured astronaut over lunar terrain. Each unit is under 5.5 kg and integrates inflatable wheels, high-efficiency motors, telescopic CFRP frames, and energy-efficient battery systems. The report details calculations of lunar weight, energy consumption across terrain types, power requirements, and structural analysis. Additional design considerations include system redundancy, rapid deployment, and compatibility with lunar environmental constraints such as dust, vacuum, and thermal extremes. The study evaluates material and battery choices for space suitability and emphasizes modularity, low mass, and operational reliability for enhanced lunar safety.
Keywords - Moon, rescue, soft, robot, modular

The main parameters

Initially, the project was developed for NASA's lunar south pole mission and had to meet the strict requirements of the NASA mission.
The mass of the astronaut with a spacesuit is: $m_{\text{astronaut}} = 343\,\text{kg}$.
The maximum mass of the Lunar Rescue System is: $m_{\text{rescue}} = 23\,\text{kg}$.
The weight of the loaded system on the Moon is: $W = m_{\text{total}} \cdot g_{\text{Moon}}. = 366 \cdot 1.62 = 592.92\,\text{N}$.
Climbing angle is 20 degree.

Scenario	Distance (m)	Force (N)	Energy (J)
2 km Flat	2000	59.48	118,960
2 km Inclined at 20°	2000	262.96	551,928
1.3 km Flat + 0.7 km Inclined at 20°	2000	–	270 ,429.3
Sufficient Energy Deposit (270*4)	**4000**	–	**1,100,000**

Table 1: Energy consumption on different Moon movement profiles

Necessary (excessive) energy deposit is: **1.12 mJ** per single platform

General concept

The lightest-weight device for evacuation can be constructed as a human-force-powered towing track or cloth. While suitable for Earth conditions evacuation, such a simple practice like towing a person on the tent seems extremely unfortunate in the Moon's conditions.

Additionally, we can take into account the possibility of both persons being injured, or even one being injured without the ability to walk while the other is dead. In such cases, it is better for the rescue system to be propelled by a motor (with some functions of autonomous or remote control operating) and have a possibility to be operated manually as well in case technical failure. Additionally it has to be modular with easily exchanged parts.

We can calculate the necessary energy to move an astronaut and the safety carriage in different modes .

The main idea for the safety rescue system is the system of four two wheel inflatable balancing bots with platform 75x75cm. The system have to be compact as possible and light weighted.

The system of connected with the use of rigid clamps three such platforms can sustain six wheel rescue system.

The forth platform can serve as a scout for adhering a better route and as a supportive tow system in case the main platform got slip. It can get to a more steady terrain and tow the main system with a long cable.

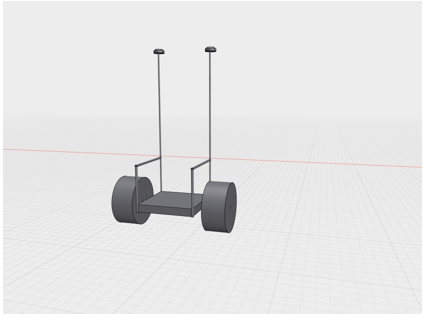

Figure 1: Single platform

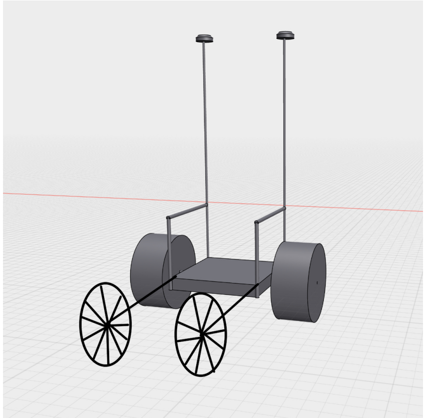

Figure 2: Platform stabilized with additional light-weighted passive wheel

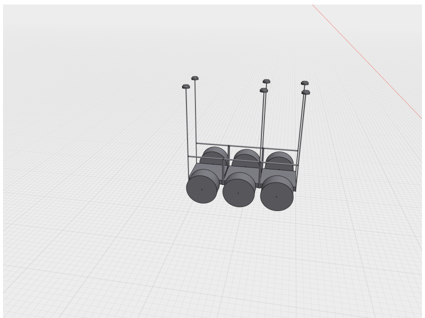

Figure 3: Combination of platforms

Additionally it may serve a purpose of transporting three other platforms and some additional baggage during a Moon surface wandering. Each platform equipped with two rotating cameras to help orienting on the Moon surface. Units are connected with a short range communicating system akin Bluetooth. This helps exchanging information on position and terrain conditions, and to coordinate the wheel rotations of three-connected-unit system. If the mass limit for four units , that is 23kg does not allow to make each unit robust enough we can get rid of one of them and turn to three units that affects only possibility for scouting and getting out from the Moon's dust 'swamps'. In this case the mass limit for one unit will get 7.6 kg.

In case self balancing for this platform is problematic on the Moon's surface, it may be equipped with additional 1-2 light-weighted passive auxiliary wheels for stability.

Now demonstrate that it is possible to construct such a platform with a mass $< 23/4$ kg and minimal storage volume.

- System could be operated by human power.
- System can be moved by engine power.
- System has doubling parts (in order some parts are broken, it still operates).
- System should be able to be deployed in a fast manner.
- System is compact and can be returned to compact condition after deployment.
- System, by competition conditions, is intended to move 2 km a distance. We expect that to move this distance, it has to travel a path around 4 km. Additionally, we expect that the system can participate in some other operations, but not more than 20-40 km altogether. This implies that parts exposed to friction do not need to be very durable (not 200 km of movement, for example).
- Having, that the person is injured, we can demand that the system can lift it from the level of Moon's surface and then let get it to the surface.
- The forth leading transport bot-platform may have increased battery to accompany astronauts.
- Theoretically, even one such platform with additional 2 wheels and elongated beams (6-7 kg) can transport an injured person to the Moon base, but the system of four communicating platforms, three of which is connected into a single unit can do it with better guaranty.

1 Single Bot Construction

1.1 Frame (rigid, inflatable)

The base for frame are telescopic tubes, from High quality CFRP. This are aproximate parametrs for one tube (13 segments, overlaping 2.5cm):

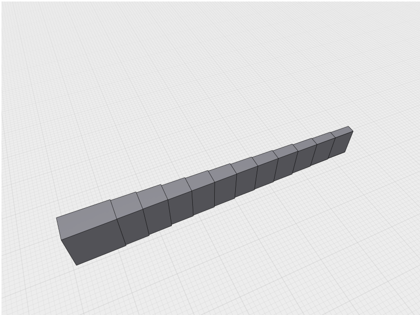

Figure 4: Elongated tube (12 segments)

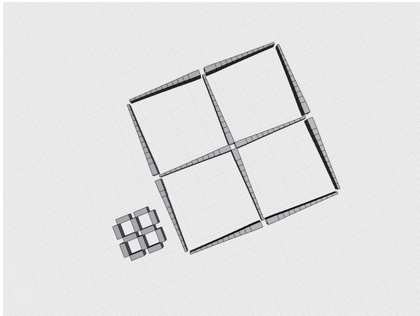

Figure 5: Compact and elongated frame

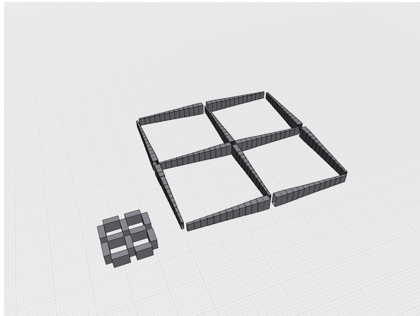

Figure 6: Compact and elongated frame

There are empty spaces on the picture in the corners of the frame: in the center and in the center of the edges. This spaces may be used to nest a motors for example or elongated masts or detectors, or simply contain a rigid jointing construction, as the design conceptual and preliminary - the place kept empty on this picture. Compact frame is approximately 12x12x4 cm. The mass of the frame itself is approximately 0.8 kg (the mass of one tube is 45g, the mass of the components presented on the picture is 540g, 260 g - are connectors e.t.c) if it is performed from CFRP. Alternative to this bench platform contraction may be when vertical rigid plates are combined in an inflatable construction but it may be lighter but not so much rigid as the presented one.

1.2 From frame to a platform

The frame need to be deployed in a fast manner.And be able to keep at least 1/3 of astronaut weight. The construction suggested is the inner layer of Vectran 0.1mm thickness. It kept loosely with Vectran rings to the compact frame and extends when the frame is extended. Over the Vectran cloth, encompassing the frame , kept by the same manner is a Vectran-TPU air bag, when the frame has to be extended the air pressure of about 0.1 -0.15 atmosphere will apply a force around 300-450 N to the sides of the bag that will extend it and will keep it opened during the journey. The central core Vectran cloth keeps the frame from over-extension and ensure the astronaut's positioning in case of the bumps.

The same principal is applied to the wheels - they extended by controlled pressure from small helium balloon that makes it possible to lift an injured person from the ground level.

2 Wheels

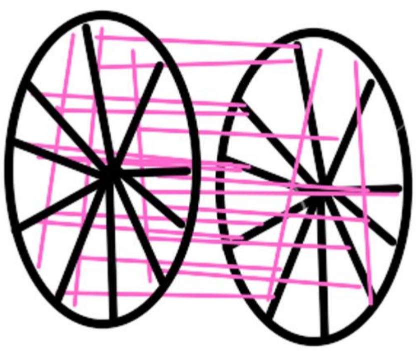

Figure 7: Concept of wheel fiber reinforcement (the width of the wheel is exaggerated; in reality, it should be 4 times narrower compared to the diameter)

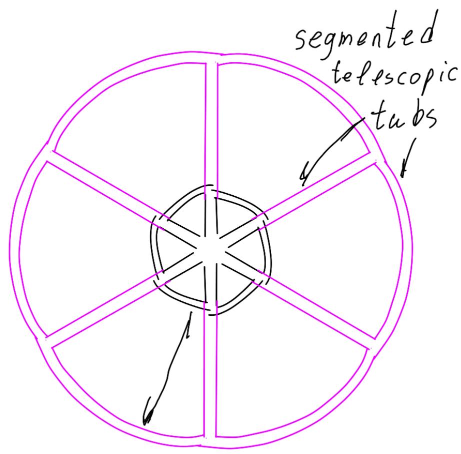

Figure 8: Telescopic mast (caption to be updated)

The wheal preliminary size is 65cm in diameter an 25cm wide. For smother transportation bigger radius is better for better self balance smaller radius is better. The wheel expected to be 15cm from the frame edge so the axis protruded from the frame is around 40 cm. The construction similar to the nested tubes as for the frame. There two main options for contraction of the wheel:

2.1 Inflatable pneumatic wheel.

The wheel with material thickness 0.2 mm will have a mass 0.4 kg, with vectran reinforcement (diametrical and along axis 1 mm vectran cables) is around 0.5 kg

If this material thickness seems not sufficient decreasing diameter to 0.4 m will allow to increase the thickness of material to 0.5 mm.In this construction the axis is elongated automatically when the pressure inside the wheel chamber increases. This set up allows to lift the platform unit from the surface level to the workable level, allowing the injured person to get to the platform from the ground level without being lifted manually.

If we take 0.5 mm Vectran-TPU covering - the mass is 0.42 kg

2.2 Telescopic cable wheels.

The main idea is to make rigid telescopic wheels. The could be pressed by the gas, that will demand proper isolation, alternative approach is to use cable telescopic mast principal. At radius of 30-35cm the bending of the wheel cyclical is not significant, as result it is possible to construct compact wheel that will elongate when taught cables are pulled. The main concern - coordinated pulling in order parts do not get pooled at wrong angles and stack.

3 Overall components mass of the single unit

Component	**Weight (kg)**
Frame	0.8
Motors (2)	0.6
Wheels	1
Central Vectran core (0.1 mm)	0.140
Platform Air Bag	0.3
Batteries (2*0.21)	0.42
Basic Navigation System	0.3
Controllers and Processing	1
Claps (Ti)	0.1
Wires	0.2
Short range Communicating System (Bluetooth, etc.)	0.1
Helium balloon system (3)	0.3
In Sum	**5.44**

Table 2: Component Weight Summary

4 Resume

Before making choice for provided system several setting were considered that included: spherical transportation system akin zorb, flat track system, dust electrocharge levitating system,dust rocket propulsion engine, etc. All of them were either heavier than necessary or not reliable enough, or able to bring discomfort to injured person. The final choice was made for modulus system with interchangeable parts that can serve as a supplementary transport accompanying unit when not deployed as evacuation unit. The provided construction has excessive strength and energy supply. If these parameters are partly sacrificed the mass of the system gets less. The system does not need too much advanced visual or orientation components, just enough to understand location and orientation. Additionally instead of equal complexion of the system's units with controllers and AI blocks we can have one master unit and two-three subordinated that reduces the total mass significantly.