IAC-07- E1.1.08

STUDENT MINI LUNAR ROVERS PROGRAM

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ABSTRACT

The student organization Students for the Exploration and Development of Space (SEDS) is conducting a design contest for a series of Mini Lunar Rovers in conjunction with the SEDS International Conference at the Vellore Institute of Technology on 22 September in Vellore, Tamil Nadu. The purpose of the competition is to design a series of miniature rovers that could be transported to the moon on a human exploration mission. Students will design a series of solar-powered rovers, each containing at minimum a video camera, science instrument, and communications system. The maximum number of rovers is a design variable, but must include more than one rover. All rovers will be designed to be stored in a single ground station package that will receive communications from the rovers and transmit telemetry to Earth via the communication system of the larger mission. The rovers must be deployable from the ground station without intervention by astronauts. Considering that mass on a human lunar mission would be extremely limited, the mass of an entire package, rovers plus ground station, is limited to 10 kg. Specific details such as the functions of the rovers and ground station, number of rovers, range and mobility, and a program for distributing and employing information from the mission for educational purposes will be left to the imagination of the students and used as criteria for judging. During the development of the project, experts in science and engineering will be invited to give seminars via blogs.seds.org and judge the submissions. The results of this contest will be given in this paper as a case study for small lunar applications that blend public and educational outreach with viable science experiments. The rover designs are intended to represent a feasible mission that can be considered on a proposed mission to the moon.

FULL TEXT

I. Background

The Students for the Exploration and Development of Space (SEDS) Moon Rover Competition is a program of the 2007 SEDS International Conference (SEDSIC), held at the Vellore Institute of Technology (VIT) in Tamil Nadu, India, immediately prior to the International Astronautical Congress from 21 to 23 September. The competition was planned to enhance the technical component of SEDSIC for students, which also consists of a series of paper presentations. A minor goal of the competition was to develop a stronger link between the international community of SEDS and the International Space University (ISU), who sponsored the prize for the competition in the form of a half-tuition scholarship; SEDS and ISU share a common heritage through mutual founders and early leaders, as well as many mutual alumni.

The scenario for the competition was stated as follows.

On a proposed human mission to the Moon in 2020, 20kg has been allocated to SEDS for a scientific payload. The payload will be a series of rovers, allowing students on Earth to explore the lunar surface. The number of rovers was allowed to be variable as long as there were no fewer than two, i.e., there can be two, three, or more rovers. All rovers must be contained within a small shipping container with outside dimensions that fit in a 0.2 m3 rectangular prism. The total mass of the rovers and container can not exceed 20 kg. The container will be transported to the Moon on a cargo lander and transferred to the surface near the perimeter of the base by an Astronaut. The rovers will be deployed from the container by a remote command; no human intervention will be allowed to remove the rovers from the container. The container will serve as the ground station for the rovers, relaying communications to and from the rovers.

Each rover will be equipped with, at minimum, a video imager and an additional scientific payload to be chosen by the designer. The rovers and ground station must survive at least 30 days on the surface and not require any maintenance from humans. Assume that the ground station is placed in a location that is in constant daylight.

Data from the rovers will be freely available to anyone on the internet. Some students will be selected to remotely operate the rovers during the mission. The design proposal should consider how students will be chosen, how the rover data will be distributed, and potential missions.

Several variables for the competition were left open to allow the students to consider creative solutions to the problem. Instead of defining the length, width, and height of the rover container, only the density of the container was defined, allowing unique shapes to be considered. The number of rovers was not strictly defined (only greater than one), allowing different sizes of individual rovers and complexity of communications and data reception to be analyzed.

Students submitted abstracts in August 2007 and final papers in September 2007. The top five papers were selected to make a presentation at SEDSIC. The reports were judged by a collection of SEDS alumni, ISU alumni, VIT faculty, and American Astronautical Society members. Scoring was based on the following criteria: technical merit, 50%; creativity, 30%; paper presentation, 10%; oral presentation, 10%.

Two previous concepts served as the inspiration for this contest. The first was the Mars Pathfinder mission, which used a small rover that was reliant on a base station for communications. The second was Blastoff!, a private venture that planned to land a series of small rovers on the moon for entertainment and educational purposes (the CEO of Blastoff! was coincidentally the founder of SEDS and ISU).

II. Entries

The following is a selection of entries received for the competition.

M. K. Ahamed Muqthar, Vel Multimedia Engineering College

Though many studies had been done, yet there is need for doing research on moon to set up launch bases for future interplanetary missions and to explore the horizons of universe by setting up observatories. In this design of payload, more importance is given to study the celestial objects rather than mere study of moon.

The decision of this payload, Horizon Explorer, consist of three rovers

1. Astron-1 & Astron-2.
2. Lunar Explorer.

Astron-1 & Astron-2:
These two rovers consist of 0.8m radio telescope which can be used to explore heavenly bodies in the radio frequency range. The signal collected is processed and sampled using electronic circuits which is crystallized in rover itself. These data can be transmitted and accessed in computer. Since there are two rovers consisting of 0.8m radio telescope, interferometry can be employed.

Using this interferometry technique, we can collect waves emitted from the same source by two rovers separated by a specific distance. In addition to 0.8m radio telescope and its accessories, a visible & IR camera can be fixed.

The dimension of rover is 30cm×36cm×46cm. The height of the rover is 0.6m. So the 0.8m radio telescope is made into two 0.4m foldable antenna with feed at centre.

Lunar explorer:
This rover, Lunar Explorer, is used to study various factors of lunar surface and its atmosphere. Since the dimension of lunar explorer is limited, we can deploy some of the experiment packages like seismometer, magnetometer, solar wind spectrometer, cosmic ray detector, ultraviolet imaging spectrometer in addition to visible camera. The dimension of rover is 30cm×36cm×46cm.

Dimensions:

- The dimension of container specified is $0.2m^3$.
- The size of each side of container wall including solar panel = 2cm.
- The size of 2 support rods at center (can also used as transreceiver) = 3cm.
- Total length of payload = length of (3 rovers+2 sides of wall+2 support rods) = 90cm+ (2×2cm) + (2×3cm) = 100cm.
- Total width of payload =width of (rover+2 sides of wall) = 36cm + (2×2cm) = 40cm.
- Total height of payload =height of (rover+2 sides of wall) = 46cm+ (2×2cm) = 50cm.
- Total dimension of container = L×B×H = 100×40×50 = 0.2m3.

Balaji Srinivasan, St. Joseph College of Engineering

All these robots have been fixed with local sensors, so they can only identify objects closer to them. These robots have to communicate between each other during the task.

This paper develops a control logic that will enable multipurpose robotic systems to navigate and coordinate with other robotic modules. We are currently working on various communication and navigational set up. We have also come up with an idea of Light Communication in case of multiple robotic systems. The idea behind this paper is experimented with three robotic modules. There might some abnormal conditions such as breakdown of down of the autonomous robotic modules. In that case, we have built a manually controlled robotic rescuer module which helps the other robotic systems to recover from the abnormalities.

This paper is based on five categories

- Lead robotic System(Multipurpose)
- RF Robotic Communication module
- Light chaser robot (Formation control)
- Rescuer Robot
- Mission Completion Robot

Gaddam Bhanu, V-Tech Junior College

There will be a need for different kind of vehicles, and undoubtedly large hauling vehicles, whenever they are required, will need a good power source. Whether that be fuel cell, battery, solar power, beamed power But the type of vehicle needed for a small, relatively self-sufficient group should have a number of characteristics.

- The motive source should be 100% field repairable preferably with only a few tools and simple spare parts.
- Spare parts should be such that they can be manufactured locally from small amounts of raw materials.
- The vehicle should have a fail safe criteria that it can bring the driver home under almost any circumstances in which the driver is still capable of driving.
- It must use indigenous energy supplies.

There is the issue of traction and off-road travel, which will drive the gearing ratios, axle loading, weight and balance, and wheel design.

Braking will have to be dynamic, feeding the energy back into a dynamo. Normal friction brakes are a bad idea for two reasons

1. The abrasiveness of the regolith.
2. Brake cooling is purely by radiation to the background and conduction through the frame.

Gears, chains and derailleur will have to be very robust and spares will be required. These parts would be able to withstand the rigours of large temperature swings and abrasive particles. One could seal them, but then it is more difficult to field strip. And not to mention which, without great efforts the lunar grit will get in anyway.

Use of a small motor like that in a minibike could solve a number of problems (if they don't add too much complexity on their own). The motor could be the means by which braking returns energy to storage. Energy can be recovered on downhill stretches and used to ease uphill travel. It also can reduce the heat loading on the space suit during acceleration from a standing start, or indeed any acceleration under load. The motor would, of course, need to be built such that it can be disconnected from the system entirely if it fails. The overall system would have to be able to get the lunan back home regardless.

Ganesh Kumar, Vellore Institute of Technology

Objective of the mission is to explore the moon surface terrain, find the oxygen present in the soil and to find the mystery inside the deep craters on the moon. Our focus is on to make a rover which traverses a wide variety of terrain. Its sensitive components are fully isolated from the surroundings, giving more stable operating environment. The rover will capable of performing various tasks with its own board sample collecting robotic arm and 3D viewing image cameras.

Motion of rover is vital for the mission success. Hybrid motion is suggested, having two mode of movements: rolling and walking for each leg. Each of the six legs have its own individual control mechanism and microprocessors and these are connected through a network which according to the path plan decide whether the particular leg will be in rolling mode or walking. Wheels are designed considering the proper traction mechanism on regolith. The wheels' outer vertical side is used as the bottom in the walking mode. This solve the problem of moving through regolith, craters, stones, boulders and pulling out itself when trapped in such conditions and also it come out of the Lander itself.

An attachment to the rover has designed called LUNAR HAWKER, which is a small flying, individually control unit. It acts as a pathfinder for the rover and covers the images of that region of deep craters where a rover hardly able to go. Also it brings back the sample from that region to the rover or the Lander.

Subsystem consists of sensors system, communication system, onboard computer system, thermal system, power system, driving and steering system. These are designed considering the environment constraints and solar hazards. For protection of communication system from solar and cosmic noises we are testing a technique to form an artificial magnetosphere around the concerned unit. Navigation and obstacle detection through 3D viewing system (video camera, alpha proton X-ray spectrometer etc.) using image processing technique are considered to make the rover autonomous. Main body houses soil testing and oxygen production plant from the sample along with the sophisticate electronics components. To tackle the unpredictable terrain, rover is made flexible.

Part of the design is the consideration of a rough moon map to decide where our Lander to be landed to get maximum sunlight and some instruction can be feed in the rover regarding its destination. Also simple structures of the Lander are suggested for easy and successful landing and deployment of the rover.

Kotla Vaibhav, Hyderabad

The rover is a robot, which can take high-resolution images and videos of the lunar surface and find new minerals that have not yet been found on the surface of the moon. The rover will be designed to move on wheels and fitted with sensors, high-resolution cameras, capable of recording information and images using laser beams. The wheels on the rover will be made of wire mesh to reduce the weight of the vehicle. The rover will be able to move around and pick up samples of lunar soil, do their chemical analysis and transmit the data back to the ground. The rover will run mainly on solar power.

The rover's essentials, such as the batteries, electronics, and computer, which are basically the rover's heart and brains, stay safe inside a Warm Electronics Box (WEB). With the solar filter in place, the panoramic camera will be pointed at the Sun and therefore will be used as an absolute heading sensor. Like a sophisticated compass, the direction of the Sun combined with the time of day tells us exactly which way the rover is facing. Hazard avoidance cameras will be mounted as they safeguard against the rover getting lost or inadvertently crashing into unexpected obstacles. An Alpha Proton X-ray Spectrometer mounted on the rover which can analyse rock samples and determine the age of rocks will be used to find young rocks which reflect impact events. We will be able to find substantial water near the Polar Regions, which is highly required for manned lunar bases.

Nishant Rave, Vellore Institute of Technology

The moon rover design module consists of three rovers and a ground station which acts as a container for these rovers. The first rover uses a wide field camera to image the surface around it. The second rover uses an infrared camera to detect the change in temperatures on the surface. It also has a mini soil analyser to detect the different minerals present in the lunar regolith. Whereas the third rover uses a mini seismograph to detect the moon quakes. All the three rovers use a video camera to take live videos of the lunar surface. Power sticks are used as power source for these rovers charged by solar panels. Nano wires are used as serial buses inside the PCB.

The collected data is transmitted through a high bandwidth CDMA technology to earth station. The obtained data is processed in earth station using advanced computing facilities. These rovers are placed in a container in the shape of rectangular prism. The inner walls serve as the solar arrays which can be extended. The whole module is confined to 20 kgs.

S. K. Parthasarathy, Hyderabad

The lunar rover will have high suspension wheels, telescope, microscopic cameras and wide angle camera and it functions on power from Solar panels. It also has a lithium ion power supply batteries and radio active heat sensors. It has lunar soil testers and an on board memory and computing power for the rover to move around and function properly.

Sasi Prabhakaran, Government College of Engineering, Coimbatore

According to the allocated allowable dimensions the Automated Multi-Conditional Exploration Rover (AMCER) is designed. The rover is enclosed in a container of volume 0.1945 m^3 and the total mass is 20kg. After proper docking from the space craft, the container is landed in the lunar surface. The rover is then driven out from the container in an automated way. The container serves as the base and makes a communication loop (AMCER ↔ container ↔ earth station). The moon rover is made to survive at all condition, i.e., varying temperature range (-233°C to +123°C), hazardous radiation prone area, etc. AMCER's main chassis frame and the links are made of titanium alloy (Ti-6Al-4V). The remaining body is made of a special type of plastic, PVDF CN-F, thermally stable to 335° F. The main reason for using this is the light weight of the material. The wheels are made of TEMPALUX CN-F and driven by 4 DC series brushless motors.

AMCER is designed into 3 pair of 6 wheel segment. All the main components including micro controller, communication device, scientific pay load, data storage etc. are placed on the middle segment. Batteries, material samples are fixed at the rear wheel segment. The manipulated robotic hand along with the high resolution camera and imager are at the front wheel segment. The special feature of AMCER is its segmented wheel arrangement. With this, AMCER can climb up to a height of 0.5meters, at an elevation of 50 degrees. Steep landing is also possible. There is no directional constraint in the AMCER locomotion, having all degrees of freedom. The power source is made available in two ways, radio isotope power (which also keep the warm during long lunar night) and rechargeable battery. The rover is capable of traversing a distance of 17 mile in a single EVA and the power will last for long lunar night. The power is distributed by electronic controls, which leads to power consumption.

The robotic manipulator of AMCER has 4 sensors and a image recording camera. They are mainly used to detect and locate the presence of helium-3. The rover is provided with an obstacle detection and avoidance control. The scientific pay load include search for organic evidences and sample collection. The astrophotometer is attached to measure light levels. With all these peripherals AMCER can maintain its stability and maintain a 3.9 km/h speed through the duration of an eight hour traverse, sustain a 15 km/h sprint for one hour.

V. Sakthi Balan, Park College of Engineering and Technology

In this project, the rover is designed to transform itself partially to move at considerable speed and to shift itself to do chemical analysis on the lunar regolith. Future construction on the moon may require such data in order to use or to refine the raw material for construction purposes. It will be able to move itself in craters, and in plain lands. It may also possess a drilling tool which can drill up to several inches and to use the lunar soil which is covered by meteor debris. It will possess a mobile mechanism, chemical analyzing equipments, and a video camera. It will be designed to operate by itself at some situations and also is teleoperated by the ground station. It will be powered by electricity using rechargeable batteries which can be charged from the rover compartment.

Vineet Agrawal, Vellore Institute of Technology

The rover design presented in this paper is composed of two major parts. Each part will have support of two (or three) wheels and the support of other part. The two parts are connected by a hollow cylinder which will contain the communication and power channels. The cylinder will also provide the mechanical support of one part to the other part and will help in the rotation of one part with respect to the other part. This will help the rover to acquire the instances which will help it to come out of virtually any unstable position and to resume working. The design of the rover will require less number of motors with respect to a legged rover. The rover will be able to come out of many difficult situations such as getting inverted, falling sideways, falling in a pit of high slope etc. The non uniform mass distribution of the rover will enable rover to take help of the gravity to reset its position. The design of the carrier box will be such that it will be able to open completely by the help of rover inside so as to get the maximum area for sunlight. The box will be able to open remotely. It will serve as a station to transmit and receive signals from the earth and the rover.

Manjunath T. G., Sathyabama University

The design is a rectangular prism of height of .75m, base length of .60m and breadth .44m, The volume of the above dimensions comes to 0.198 m^3. The container will open on its own by using sensors present in it. the inside walls of the container will have solar panels for the base station only, the antenna and other instruments are placed inside as the top of the container will remain attached to the base with help of thin columns. The rover itself is designed to be so compact that we can have more than one rover in the container. The rover is single .35m long cylinder, equipped with a camera and other instruments. Powered by two motor on either end, the mechanical system used in turning is differential drive. The rovers power source are not rechargeable as the container can be stacked with more than one rover we can use each one for each separate sub mission.

Angarayan Sundarakaltharan, Infant Jesus College of Engineering and Technology

Two solar-powered rovers, a treaded rover which can pass sandy terrain effortlessly and a six-wheeled rover which can pass over a bumpy terrain, are to be used for exploring the lunar surface. Both the rovers are capable of moving in all directions i.e. Left, right, front, back by employing different mechanisms. This gives higher mobility and agility to the rovers and help in conserving the precious energy. In order to pass a higher plane both the rovers can dock to each other so, that one can help or even lift the other from the lower level to upper level. Once a rover reaches the higher plane it can tow the other. By this way they can even negotiate a height up to 1.5 times the size of the rovers, i.e., .75m. The rods used for docking one with another can also help in making them upright in case of an accidental slip or a flip over. There is a robotic arm in the rover, which requires only a minimum sweep angle as the rovers itself is very agile. Rovers are equipped with an Ultrasonic scanner apart from the 360º camera. These sensors can scan underneath the surface of the moon to map the area and check for the presence of water and other materials. Rovers are made either by Aluminium alloys or titanium alloys. The container itself consists of solar panels which can act as a recharge post for the rovers.

Prabhu Hari, Infant Jesus College of Engineering and Technology

Most of the previously designed moon rovers possess a single locomotion system which limits lunar surveillance to a solitary location at a particular instance of time. The failure or malfunctioning of the locomotion system stalls the entire process of exploration. Furthermore, the uncertainties of the surface to be explored pose the threat of entrapping the rover in the lunar terrain which might result in aborting the exploration. The following design proposes a Reconfigurable Moon Exploration system (REMEX) which could be adapted according to the operational demands. The system consists of two individual Moon rovers which are capable of independent as well as inter-networked exploration. The scientific equipments required to perform other experiments form a separate unit which is mounted on the rovers. In this mode, the rovers function as locomotive units to transport the payload. This design attempts parallel exploration of the lunar surface, provides a standby rover, which can also be used as a 'pilot rover'.

III. Next Steps

At the time of submission of this paper to IAC, the judging of moon rover competition results was not completed due to the coincidence of SEDSIC and IAC paper submission deadlines. A description of the top five papers selected for presentations and the scholarship-winning presentation will be discussed at IAC.

Following IAC, the top papers will be summarized in an article in Space Times, the journal of the American Astronautical Society. Paper submissions will be given to the California Space Authority (CSA) for further consideration. CSA administers the Lunar Regolith Excavation Centennial Challenge for NASA and will incorporate aspects from submissions (based on permission from students) into future programs, especially for outreach.

The 2008 SEDSIC will feature the next installment of the design competition. The topic of the 2008 competition is the design of a CubeSat that can operate in Martian orbit. Preliminary rules state that the design must incorporate a communications system that is compatible with the network that is common to Mars satellites and a mission that returns viable scientific data. Firmer details will be made available in January 2008 and can be received by contacting the author.