Desert Robotics - Lunar Rover Design

Kelly Blasberg, Steven Blasberg, Jesse Hall, James Linnell, Alexander Nabavi-Noori, Parker Robinson - Palm Desert Middle
Leslie Barba, Mekai Ely, Rosaleen Escareno, Sonia Gonzalez, Stephanie Olivas, Giselle Quintana-Reyna - Abraham Lincoln School

DESERT ROBOTICS - LUNAR ROVER DESIGN

BASIC ROBOT DESIGN

Overall size: 3.5 ft. by 2.5 ft.

Chasis: carbon composite body

Mass: 150 Lbs

Wheel diameter: 60cm

Power: 200 w nominal
78W idle/30W hibernation

Sensors: low-power, laser-based sensors for travel during the lunar night

Obstacle avoidance system

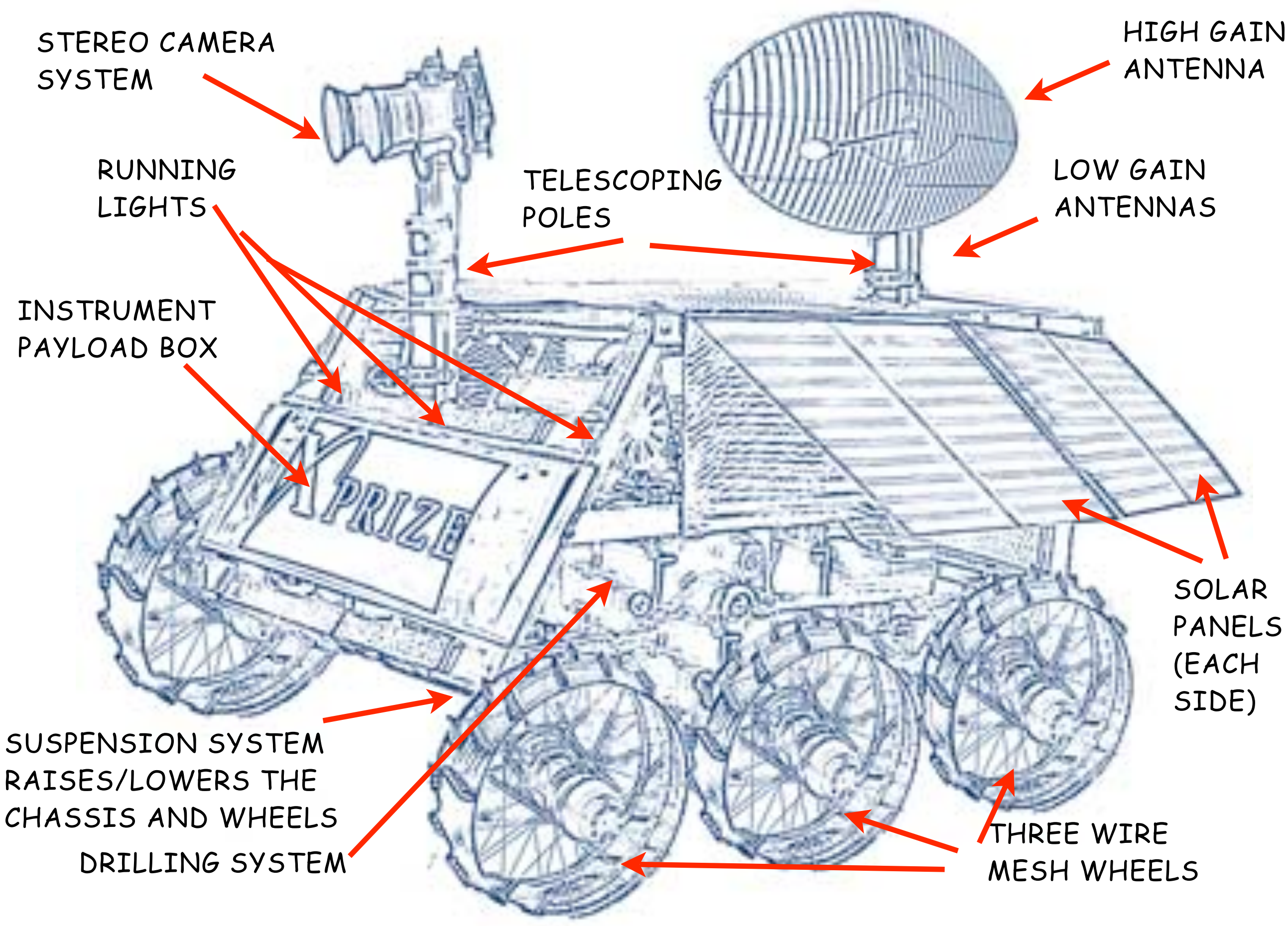
Running light in the front for night

Instrument Payload:

Robotic drilling arm for sample collection

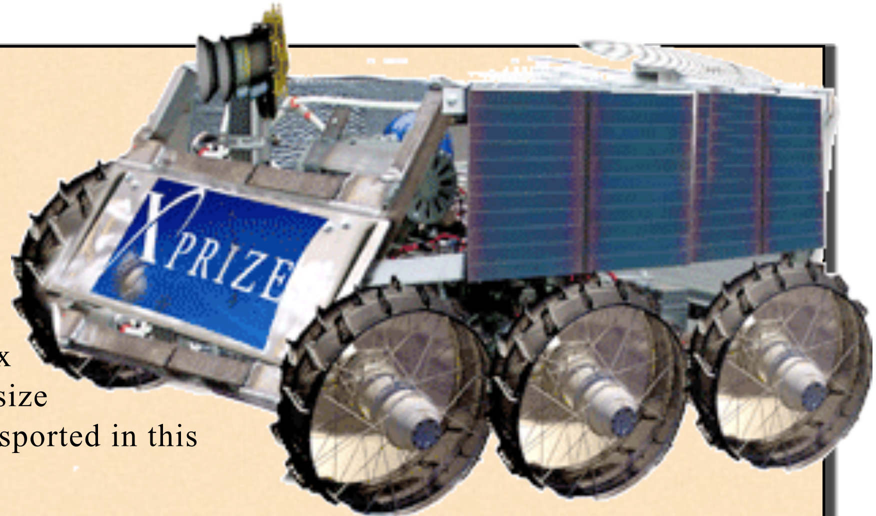
Spectrometer system for water detection

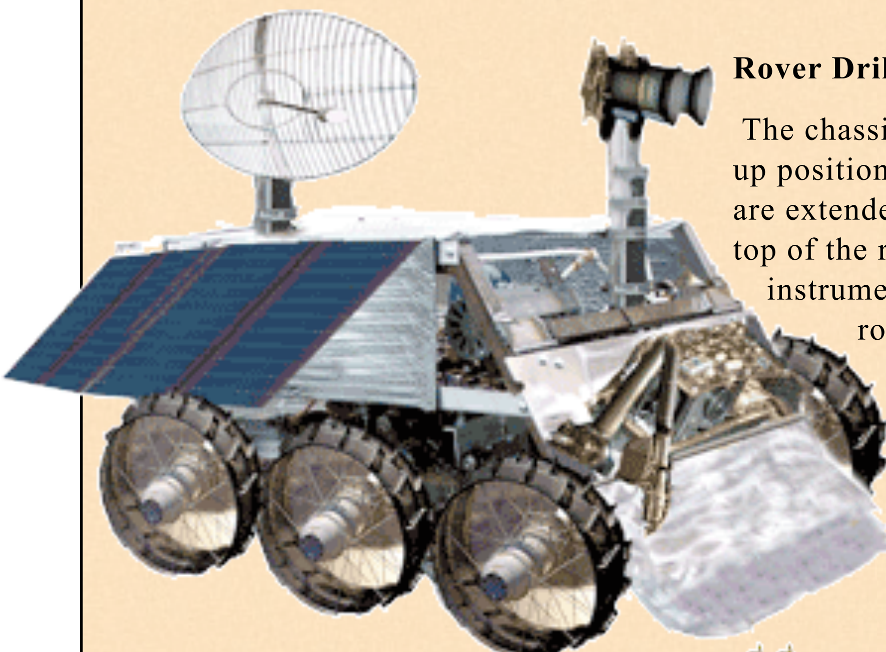
The Desert Robotics Lunar Rover is a one section carbon composite chassis with 3 wire mesh wheels on each side, front telescoping pole with rotating hi-def stereo vision system, panoramic still camera and rear communications pole with hi-gain and low-gain antennas. The robot has a hibernation mode to conserve energy during periods of the lunar day not suitable for excursions and during part of the lunar night.



Rover Closed Position:

The chassis is down with the wheels in the up position. The camera and antenna poles are retracted and the antenna in folded on the top of the rover. The door to the instruments box is closed. This is the smallest size that the rover can be. It is transported in this position.



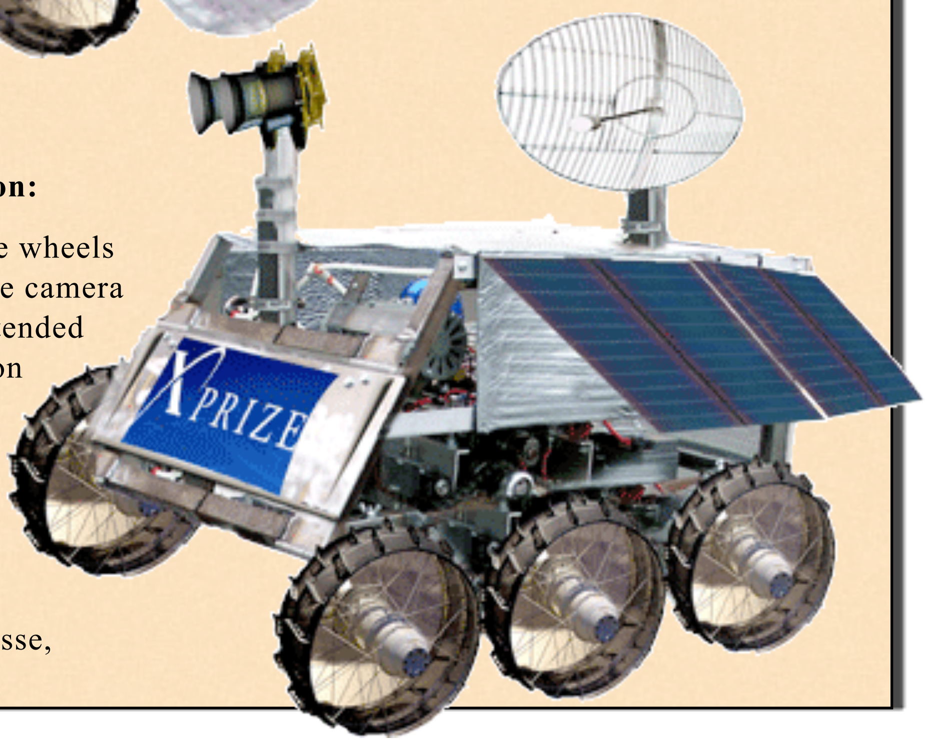


Rover Drilling and Sample Position:

The chassis is down with the wheels in the up position.   The camera and antenna poles are extended and the antenna in open on the top of the rover. The door to the instruments box is open exposing the robotic arm and spectrometer systems. The core drill is next to the arm and pushes down from the bottom of the rover to drill into the soil. The door acts as a scoop to collect samples of the top soil of the regolith

Rover Operating Position:

The chassis is up with the wheels in the down position. The camera and antenna poles are extended and the antenna in open on the top of the rover. The door to the instruments box is still closed.



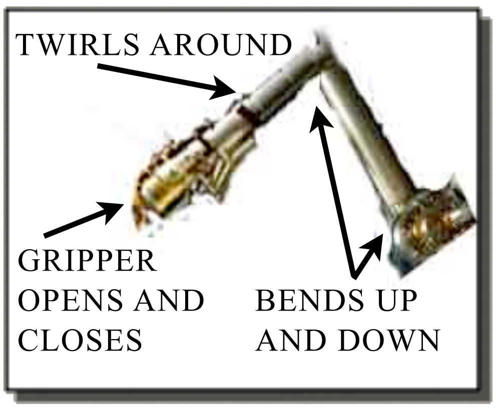
Photoshop Drawings by Jesse, Alexander, and James

COMPUTER CONTROL SUBSYSTEM

A microprocessor, or CPU, is like the 'brain' of a computer. It is mounted on a circuit board along with memory and other chips. There is usually a heat sink and fan to keep it from over heating. Our rover robot is using a system that has been tried and proven reliable. Each subsystem on the rover has at least one embedded control microprocessor, the 80K85 Intel processor developed by NASA. To insure reliability each processor has a built in test program called Smalley3. This system gives extra reliability in the software programming. [1] There is also redundant control over each of the rover's systems. The onboard computer has a dual processor and 2G Ram.

Computer programming controls all functions of the robot. Its software also completes commands sent via the tele-operator on earth. The wheel and front cams aid in navigation and the vision system, and along with the other sub-systems are controlled by the computer.

ROBOTIC ARM MANIPULATOR



The robotic arm, a manipulator attached to the front of the rover, is housed inside the instrument panel behind a door which opens when the arm is in use. The end of the arm has grippers that can move and pick up different objects. It can reach out and move in several different ways with four degrees of freedom. It's jointed to reach into the scoop on the front of the rover. Our arm is patterned after the Phoenix robotic arm built by Jet Propulsion Laboratory for the NASA Phoenix Mars mission. [2]

INSTRUMENT PAYLOAD

Our rover has a suite of instruments for both science and navigation.

Spectrometer System: Inside the instrument panel on the front of the rover is the very compact spectrometer system made of an alpha particle X-ray spectrometer (APXS), a Mossbauer spectrometer (MB). and a microscopic imager (MI). On the top of the panel box there are three running lights for night travel and for sample analysis. [3]

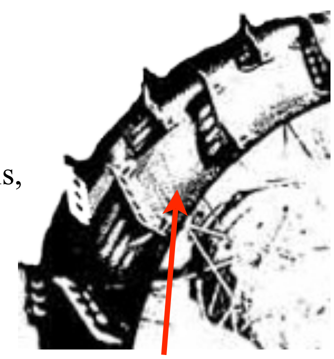
Instrument Box: The robotic arm is also inside the instrument panel. Next to it is a drill that pushes down through the bottom of the rover and into the lunar regolith. The robot sits lower when the drill is working. This gives more stability and lets the drill push harder into the soil. The drill takes .5 meter long geological samples. The spectrometer system can analyze the samples to look for water/ice. [4]

Vision System: A three CCD Panoramic imaging system produces hi resolution 360 degree multispectoral images which can be stitched into panoramic or mosaic pictures. The system has stereo lenses, 250g each, with 3W power for CCDs, and 3.5W power supply for startup warming, The field of vision is 17 x 17. The cameras operate within the temperature range: -55°C to 0°C and have a survival temperature range: -110°C to +50°C. The two camera lenses are mounted on a telescoping mast. The highest point is 1.5m above the surface. The system also has a set of 5 filters for the lenses which can focus from 1.5 meter to infinity, rotate 360 degrees, and tilt 90 degree. A live video system takes movies of the rover's journey with a miniaturized high-def resolution camera. This camera is positioned right under and between the two cameras on the pole. It also rotates 360º to see where the rover is going and where it has been. Video of the rover moving will be shot by a second video camera mounted on the lander. Whenever the rover comes into the area near the lander this camera will document it. [5]

Sensors: Angle sensors are attached to the front wheel base to detect slippage. The wheels can pivot to control slippage. Temperature sensors are used to monitor the electronics box, payload instruments, and sensitive equipment. Low power laser based sensors are used to help navigate during the lunar night when the light is lower.

MOBILITY SUBSYSTEM

BASIC COMPONENTS


Wire Mesh Between Plates

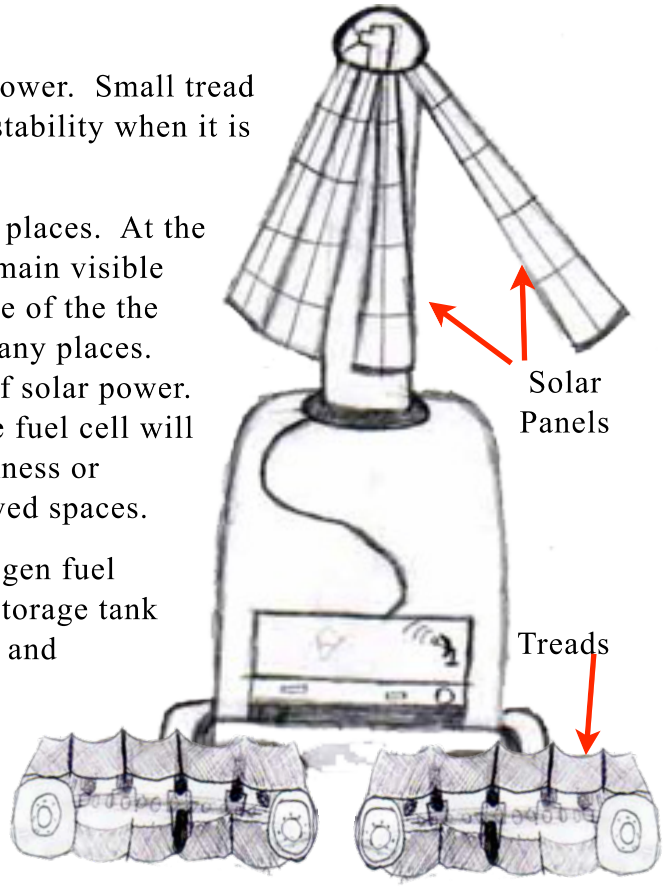
The mobility system has six independently motored Wire Mesh wheels, 3 on each side of the basic chassis box. Wire mesh is used to prevent compacting the regolith. Along the mesh are thin metal plates that help with traction. We patterned our wheel design after the lunar Lunokhod robots sent by Russia during the 1970's. [6] There is individual suspension for front wheels and dual suspension for the back two wheels.

The body can be lowered or raised from the wheel axles to allow for obstacle avoidance. In the lower position the robot is very stable and low to the ground. The drill can be operated in this position to give stability and enough pressure to drill into the soil and recover core samples. The front wheels pivot from right to left to allow for slippage correction when driving up or down slopes. This lets the robot climb a 35 degree slope without sliding sideways. The degree of the wheel pivot needed is determined by sensors attached to wheel base. This is under automated computer control. The wheel cams send data to the navigation system.

POWER SUBSYSTEM

Our rover system will use solar as the main source of power. A solar collector unit will be placed in an area that has 90% sunlight permanence. This area is on one of the rims of the de Gerlache crater. Both Clementine and LRS has documented the existence of this permanently sunlit area. [7]

The solar panels will open like the petals on a flower. Small tread feet will let the power station move and give it stability when it is in position. (See Illustration)



The lunar night can be 300+ hours long in some places. At the South Pole the sun doesn't rise high but does remain visible from several places. The problem is that because of the the low rise, mountains and hills block the sun in many places. This means some periods of darkness and lack of solar power. To solve this problem a closed loop regenerative fuel cell will be used to store electricity for times during darkness or travel into the basin area of permanently shadowed spaces.

A regenerative fuel cell is the reverse of a hydrogen fuel cell. The hydrogen cell takes hydrogen from a storage tank and oxygen from the outside air, combines them and produces electricity. The by products are water and heat. The regenerative fuel cell uses electricity to make hydrogen and oxygen from water and then puts them back in to make more electricity. The system is closed and has no by products. The water, hydrogen and oxygen are used over and over. How does this work on the moon? You start with a tank of water and use electricity from a solar panel to divide the water into hydrogen and oxygen. The hydrogen and oxygen are used to create the electricity during the lunar dark periods. The system should just continue to work without needing to be refueled. Six times more energy can be stored over rechargeable batteries of the same weight. The system will be insulated and enclosed to make it rugged for lunar environment. Glenn David Bents is working for NASA developing the regenerative fuel cell for lunar exploration. [8]

The rover will also have solar panels that will be used to supplement the batteries. Power from these will generate up to 140 W of power under the full sun conditions. There will be two rechargeable batteries to store this power. This will allow the robot to travel farther away from the fuel cell and stay away for longer times. These will not be able to be used when the robot goes into the permanently shadowed areas. It will depend upon its charged batteries during these missions.

Illustrations by Jesse and Parker

THERMAL SUBSYSTEM

CONDITIONS AT LANDING SITE

The South Pole offers a very different thermal environment than most of the rest of the moon. The weather is milder and has a lower temperature range. Temperature at the equator can vary from 123 to 373 K, but close to the pole it is approximately 223 - 10 K. This is a great advantage for a rover. But a lunar rover still needs to maintain a suitable temperature for operation. Thermal considerations are important.

THERMAL FABRIC: 3M™Nextel™ Continuous Filament Ceramic Oxide Fibers 312 and 440 are made into textiles that can operate in extreme temperatures. Many different fabrics can be made from them for use in aerospace applications, like fabric, tape, paper, and sleevings. These can be used for heat shields, coverings, linings, insulation, and seals. These products are light weight, have low thermal conductivity, high shock resistance, and low elongation and shrinkage in extreme temperatures.

Our rover has fabric made from Nextel fibers 312 lining the electronics box for insulation. The fabric is adhered to the outside of the box to protect from the cold and keep the heat from the electronics inside. All of the wires within the electronic system are wrapped in Nextel fiber braided sleeving for thermal protection. The braid supports insulation up to 1000ºC, 1832ºF. [9]

FLEXIBLE HEATER UNITS: Small 3.5 W power units are for warming the camera lenses during startup procedures and after hibernation or idle time. Larger flexible heating units are attached to inside walls of electrical box unit to keep constant temperature. The electrical box houses the computer, batteries, and other electronic components.

OTHER THERMAL SYSTEMS: The thermal subsystem also contains the thermostats and radiators to control temperature. The outside of the robot is covered with gold paint and a reflecting surface. Places where parts come together on the chassis are filled with aerogel to protect and seal it.

COMMUNICATION SUBSYSTEM

TESTED TECHNOLOGY OVER CUTTING EDGE

Our systems on the rover uses tested technology, not cutting edge. Systems that have already proved reliable are necessary for a project that involves sending equipment to an environment like the moon where there will be no onsite tech support. The communication system is capable of transmitting at a high data rate. This is important to send the video and pictures back during the two mooncasts. The system is able to receive commands from earth at all times through orbital satellite or direct line of sight communication with earth. The lander communicates with an orbital satellite. The rover communicates with the lander. The rover also sends data to the orbital satellite with an UHF antenna. To make sure that our mooncasts get back to earth, the rover can also send transmissions to earth when it is in line of sight. These systems are redundant but they back each other up in this important task. Our rover can last through the entire planned mission (and beyond). It has enough power for communication over a long period of time due to the ability to recharge at the charging station. The communications with the earth are in X-band and use a high gain directional dish and a low gain omni-directional antenna.

Other Features include: Surface area of antenna limited to one m2; Power 100 w limit; Mass 15 KG limit; Thermal protection during lunar night (low temp.) and lunar day (high temp.); Protection from lunar dust and micro-meteorites; Compact storage for travel to the moon; Use of high gain phased array antenna using X band, 10MHz, to transmit to earth at high data rate (7.5 Mbps or better); Antenna size - .5 m with over 700 transmitter elements; and Use of omnidirectional antenna (VHF/UHF) to receive commands from earth.

NAVIGATION SUBSYSTEM

Teleoperation and Autonomous Features

The rover robot can be both remotely operated and has autonomous functions for navigation.   To cover the area and travel the 5000 m planned, our robot needs to be speedy. This causes some navigation problems. There is a time delay between the earth and the moon (approximately 3.4 seconds). This makes it difficult teleoperate a lunar rover from earth. From studying the tele-operated Lunokhods, lunar rovers sent by Russia during the 1970s, we learn a lot. They traveled less than one kilometer per day and they had high driver fatique, They could only drive for about 2 hours.

The tele-operation of our robot makes use of new research on visual aides for remote control. New studies are being done to develop better software for the operators on earth to use.   Operators need to be able to tell the rover what to do and when to do it. They also need to be able to predict where the robot went during the time delay while the message was being transmitted to the moon and then data sent back to earth.   The robot needs to know when to turn not to crash into things, obstacle avoidance. During the delay the operators won't know what the effects of the move are. This is where the new driver interface is helpful.   It is a visual interface that lets the driver see where the rover is at all times. The software predicts the movements and creates a visual for the driver. It is shown on big screens. Simulations show the system helps the driver and makes it easier to control the robot. [10]

The navigation subsystem also consists of wheel and front cams under computer control. Data ia sent back to earth using the high gain antenna to provide tele-operators with current location and terrain pictures. There are two avoidance hazard cameras, back and front to help the robot avoid obstacles. The terrain is very rough at the South Pole. The robot has to travel in and out of craters to accomplish its task of finding water/ice.

We need to travel 5000 meters to win the extra $5 million. We are traveling at 60 cm per sec. or 3600 cm per minute. We figured out that every 2 hours 20 minutes we can travel 5 kilometers. This means that we can accomplish the task of driving 5000m easily during the mission. We are staying through the lunar night so we have plenty of time.

BIBLIOGRAPHY

[1] Back to the Moon; A Verification of a Small Microprocessor's Logic Design, Hugh Blair Smith, Nasa Office of Logic

[2] <http://www.nasa.gov/mission_pages/phoenix/multimedia/pia09207.html>

[3] <http://athena.cornell.edu/the_mission/ins_minites.html>

[4] <http://www.frc.ri.cmu.edu/project/lri/>

[5] <http://pancam.astro.cornell.edu/pancam_instrument/about.html>

[6] Lunar Roving Vehicle Operations Handbook, LS006-002-2H, NASA, April 19, 1971

[7] The Shackleton Crater Expedition: A Lunar Commerce Mission in the Spirit of Lewis and Clark William C. Stone, Ph.D., P.E. Stone AeroSPACE / PSC, Inc.3511 Caldwell Lane Del Valle, TX 78617-3006 Email: stoneaerospace@verizon.net November 17, 2003

[8]< http://www.moontoday.net/news/viewpr.html?pid=24257>

[9] 3M Nextel Ceramic Textiles Technical Notebook, 3m Nextel™ Textiles/Composites

[10] VISUAL AIDS FOR LUNAR ROVER TELE-OPERATION, David P. Miller1 and Kyle Machulis2 1 University of Oklahoma, 865 Asp Ave, Rm 212, Norman OK 73019, USA; dpmiller@ou.edu, 2 KISS Institute for Practical Robotics, 1818 W Lindsey, Bld D-100, Norman OK 73069, USA; kyle@kipr.org