Selene: A Modern Moon Mission

Goddess of the Moon

Always seen carrying a torch, the Roman Goddess Selene lit the way for those to follow [1]. As the moon lights the night sky on Earth, we hope that our revolutionary concept and design will shine a light inspiring future lunar missions.

Selene will be sent to accomplish several tasks during her mission. She will explore the moon, brave extreme temperatures, and capture images unlike those seen before.

Given the guidelines of Google Lunar X Prize, we hope to highlight a new method for lunar excursions. Our challenge was to effectively land on the surface of the moon, roam for a minimum of 500 meters, and compile a Mooncast. The Mooncast, consisting of a High Definition (HD) video, along with a 360 degree panoramic picture, and a photograph of our rover will then be sent back to Earth. We will also undertake the additional goals of collecting samples relating back to the Apollo Missions and surviving a frigid lunar night [2].

Overall, Selene will travel across the surface of the moon, utilize modern technology in order to send data back to Earth, undertake special challenges, and, most importantly, set a precedent for future rovers to follow.

Blasting from the Past and Propelling to the Future

Inspiration for Selene was drawn mainly from the past, present and future lunar rovers such as the Chinese rovers [3]. The most current Chinese rover is set to be deployed in 2012. Like other Mars rovers, this rover will also have six-wheels. Created by a team at Shanghai Aerospace System Engineering Institute, this rover is capable of moving at a reported 100 meters per hour. The most interesting part of this design is its power system, which consists of a standard solar cell array as well as a nuclear power source, allowing the rover to operate continuously during a lunar night and even in the shade.

Another source of inspiration for our rover was the Lunar Roving Vehicle (LRV) used first on July 26, 1971 for the Apollo 15 mission, and then again during the Apollo 16 and Apollo 17 missions [4]. The buggy-style rover was utilized mainly as a form of transportation for the astronauts. The chassis was made up of three parts and constructed from aluminum alloy 2219 tubing while the four wheels consisted of zinc coated steel strands that made up the tires and titanium chevrons to provide traction [5]. Unlike Selene, however, the rover was not designed to travel autonomously but, rather, to be operated by the astronauts. Therefore, Selene's arrival on the moon will mark the first unmanned lunar rover mission and open more opportunities for rover exploration.

In addition to lunar rovers, many Mars rovers also influenced Selene's design. One example of this is the rover Sojourner that touched down on Mars on July 4, 1997. The rover itself was very small in size, only about 600mm long by 480mm wide and 280mm tall [6]. This very tiny rover, however, featured a unique rocker-bogie suspension system along with aerogel insulation [7]. These elements helped to make the Sojourner a frontrunner in the investigation of Mars.

Two other more recent additions to the Mars Exploration Program were the Mars Exploration Rovers that launched on June 10 and July 7, 2003, and arrived on the Martian surface on January 3 and January 24, 2004. They were sent on a mission to collect and characterize various types of rocks and soil and look for signs of water. These robots used a variety of technology to help reach their goal. One of these instruments is the Microscopic Imager, which was used to take close up and high resolution pictures of the terrain. A material that was mandatory for this robot was the Alpha Particle X-Ray Spectrometer. This is used to analyze the elements that are in the soil and the rocks [8].

Meet Selene: Conceptualizing our Robot

In order to better facilitate movement and incorporate all of the rover's features, Selene's body will be rectangular in shape. The height will be 1.07 meters, with approximately ½ meter of clearance from the ground. Using the weight and dimensions of the Mars rover Sojourner [6] as a guide, Selene will weigh approximately 87.5 kg on Earth and 14.5 kg on the moon. Selene will have six wheels, in order to increase stability. All six of these wheels will be made out of aluminum due to its strength, light weight, and availability. For additional traction, the wheels will have cleats and treads created from stainless steel. The wheels will have a 0.30 meter diameter. In case of excessive wear or other failure, the back wheels will have a set of identical backup wheels. These will be kept inside the main frame, and will rotate with the other wheels if the need arises. In order to give Selene greater stability to maneuver the rocky surface of the moon, a rocker-bogie suspension system will be used. This system uses rotating joints that all connect from the wheels to one central point at the chassis [7]. The chassis itself will be molded from carbon fiber reinforced plastic.

Ready, Set, Go: Powering Selene

Once Selene is fully functional, she will embark on her long journey to the moon. Upon arrival, Selene will land in the Sea of Tranquility. This spot is relatively smooth and level, making it an ideal place for the rover to start its exploration. The Sea of Tranquility is also the same site where the Apollo 11 mission landed; therefore, the area is fairly well known and well documented [9]. Furthermore, the Sea of Tranquility is located on the side of the moon that will be closest to Earth when Selene lands, making communication with Earth easier. The rover will not be landing until noon on a lunar day, giving it time to travel a little distance before going into standby for the night.

When examining the challenge of powering the rover, Selene will use a combination of both solar panels and battery to successfully fuel her endeavors. Solar panels were selected due to their reliability and low weight. In addition to this source of energy, certain precautions must be taken to keep them working at a decent rate. To keep them protected, the solar panels will be placed under glass. Also, a liner- made of a varnish like material- will be used, because if too much dust is collected, it could possibly decrease the amount of energy absorbed. This method has been used with past rovers and has been found to be efficient. Ideally, solar concentrators will also be included as well because they focus the light and usually increase the amount of power collected by 5%. Solar panels are an ideal source of energy for this particular mission since the mission's longevity does not exceed more than a few weeks. The amount of power utilized from the power collected by the solar panels usually ranges from 30%-35% [10]. These solar panels, positioned like wings, also rotate according to the position of the sun- using light sensors- to ensure the amount of power being collected by the cells.

We considered several options for powering the rover. The possibility of a generator was mentioned, but the idea was vetoed because the goal was to have a light weight and relatively inexpensive rover. Besides using solar panels, the other source of power for the mission, will be a battery used during the day and powered by sunlight. During the night, the battery will be expected to fulfill power needs. The battery itself will be a lithium battery, chosen for its lesser weight. Since the rover will be relatively small and compact, other possible larger batteries would only weigh the rover down in motion and capacity. Instead, the lithium batteries are comparably lighter and have a higher voltage than their competitors [10]. Selene's lithium battery may have a shorter lifespan than alternative batteries; however, she will not be in need of one that lasts more than a few weeks. Due to a combination of weight limits and usability, the solar panels and lithium battery were chosen as fitting energy sources.

Bot on Film: Photographing, Videoing, and Communicating with Selene

The rover's camera consists of a stereo pair of high resolution cameras modeled after the Panoramic Camera found on the Mars rovers Spirit and Opportunity [11,12,13]. This camera will be primarily used for taking panoramic pictures of the lunar surface. Unlike the camera found on the Mars rovers, this camera will not be attached to a rotating mast. The camera will stay still, attached to the rover's chassis. The rover itself will rotate to obtain 360 degree photos. The rover will also use this camera to take a self portrait while on the moon. Mirrors on either side of the camera will swing in front of it in order for the robot to obtain these pictures. The camera will take both video and still pictures, documenting the rover's time on the moon. To protect the camera from moon dust, a glass sphere will cover the camera lens. A metal "eyelid" will cover the sphere when the camera is not in use. Soft brushes inside the metal shell will clean off the glass when the shell

closes and opens. In this way, the robot's camera will be able to "blink" and clean itself when it becomes dusty.

Communication is an essential key to the lunar expedition requirements. Since it is mandatory to transfer at least 1G of information back to Earth, wireless communication is critical. One instrument that will be used on the rover would be a small omniantenna, a device which allows signals to be found regardless of its position. Advantages included are its light weight and reliability. One possible disadvantage would be the slow pace at which the information would be transferred back to Earth. However, we concluded that the benefits of the omniantenna outweighed the drawbacks. This antenna will work with an ultra-high frequency (UHF) radio communications system to send and receive information in its interactions with scientists on earth [14]. During her mission Selene's communication system will prove efficient and reliable.

One Small Step for Rover-kind: Documenting the Apollo Missions

In addition to the still pictures and videos that make up the Mooncast, Selene will document man-made artifacts in the Sea of Tranquility. While on the moon, she will take still photographs regularly and autonomously at pre-programmed intervals. If an object she photographs does not share characteristics with any of the typical formations of the lunar landscape programmed into her memory, she will alert the scientists on earth with a "question" signal. The photograph will be sent to earth and examined briefly, and a signal will be returned to Selene. This will either instruct Selene to continue on her programmed path or to approach the object in question and return more visual evidence to earth. This feature will be manually overridden once Selene has returned enough photographs of debris from other lunar missions. The images Selene collects in the Sea of Tranquility will show the traces left behind by the previous lunar explorers who inspired her mission.

Catching Some Z's: Selene Survives a Lunar Night

After spending a week on the moon, Selene will move onto her next task, surviving a lunar night. A lunar day consists of about 29 days--roughly a month on an Earth calendar. For about half of that time, a portion of the moon, in this case where *Selene* is located, is facing away from the sun. This is called a lunar night, and it is one of the toughest obstacles she will face. During this lunar night, temperatures on the surface of the moon drop to about - 167.7° C [15] making for a frigid, icy, and bitterly cold two weeks. To combat these conditions, *Selene* will be equipped with several special features specifically designed for lasting the lunar night. In order to keep some of the heat trapped within the carbon fiber body, the rover will be fitted with thermal blankets on her exterior. A thermal blanket is made of a thin sheet of metallic foil spaced out with insular fabrics [16]. In most of these blankets, the coating is aluminum vapor, distributed by a vacuum. The space blanket is not

only beneficial for preserving heat for the rover, but also because it is practically weightless and will not hinder the rover in any other way. Another possible heat source was radioactive materials. Some of these materials, such as plutonium-238 or plutonium- 239, have been used on certain Mars expeditions. However, they would require a generator which would add to the weight of the rover and require too much power to operate. The use of aerogels [17] on the rover was also considered, although it was dismissed because the moon's environment lacks air [10]. Therefore, through an examination of all of the heating options, thermal blankets were found to be the best fit for this mission: surviving a lunar night.

However, these materials and provisions are not sufficient on their own. In addition to thermal blankets, several aspects of *Selene*'s nocturnal activity will be used as methods to protect her from the intensity of a lunar night. The first method is rather simple: to keep the equipment that requires warmth together and only heat that portion of Selene. This will conserve more energy than trying to heat multiple parts of the rover. Furthermore, the rover will start up periodically and travel a certain distance before shutting down again. This will prevent the motor and gears from freezing or sticking due to disuse. This idea was inspired by the advice of car dealers, who tell their customers to drive their new vehicles at least once every few weeks. This method will also conserve power that will be scarce during the lunar night as the rover will be running only on battery power. These strategies will help Selene complete the near impossible task of surviving a lunar night.

Looking to the Future

In conclusion, Selene will complete the required tasks along with some of the bonus tasks specified by the Google Lunar X Prize Competition. These responsibilities include sending a Mooncast, consisting of at least 1 GB of information back to Earth; recording High Definition (HD) videos; photographing a 360 degree image of the surface of the Moon; and taking a self-portrait while on the Moon [2]. The Mooncast will be made possible through Selene's various technologies such as her stereo pairs of cameras and omniantenna. With the help of six wheels and a combination of solar and battery power, the rover will travel a minimum of 500 meters. While coping with the challenge of surviving a lunar night, a bonus requirement, Selene will employ the use of thermal blankets. She will also be taking on the challenge of imaging man-made artifacts, such as debris from the Apollo Mission, when she lands in the Sea of Tranquility.

The information Selene returns will hopefully inspire other similar missions just as prior missions have inspired us. Lunar exploration is full of possibilities and should not be ignored. As we look to the future, we hope to find more opportunities to take an active role in lunar exploration.

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