Fall 2003

Red Rover, Red Rover: An Unpressurized Manned Rover for Use on Mars Surface

Kathleen Lachance
Trinity University

Roberto Aranibar
Trinity University

Landon Nemoto
Trinity University

Michael Poteet
Trinity University

FALL '03

Red Rover, Red Rover

An Unpressurized Manned Rover for Use on Mars Surface

The Tigernauts
Department of Engineering Science, Trinity University
One Trinity Place
San Antonio, Texas 78212

TRINITY UNIVERSITY
SAN ANTONIO • 1869

Team Members:

Kathleen Lachance, Team Leader: Senior, Engineering Science
Roberto Aranibar: Senior, Engineering Science
Landon Nemoto: Senior, Engineering Science
Michael Poteet: Senior, Engineering Science

Faculty Advisor:

Dr. Kevin Nickels, Dept. of Engineering Science, Trinity University
knickels@trinity.edu

JSC Mentor:

Dr. Humboldt Mandell, Research Fellow with UT's Center for Space Research, retired manager of JSC's Exploration Office.

Table of Contents

List of Figures

List of Tables

Introduction

The Tigernauts are a group of senior-level undergraduate engineering students at Trinity University who are participating in the Texas Space Grant Consortium's (TSGC) Design Challenge. The Design Challenge project adopted by the Tigernauts entails the design of an unpressurized manned rover for use on Mars. The rover is designed according to criteria set by the TSGC Design Challenge specifications for this particular topic, which are discussed later. Information regarding the team's members, advisors and other individuals associated with the project, background on the design topic and facts pertaining to past rover mission endeavors are also discussed. The report gives details on the team's goals and objectives for the project, as well as their approach followed to complete the project. This includes specific project requirements and evaluations of design plans and a final concept of the rover and its subsystems.

Sponsor / Research Group Identification

The Tigernauts have been assigned Dr. Humboldt Mandell as team mentor for the TSGC Design Challenge. Dr. Mandell previously served as the manager of NASA Johnson Space Center's Exploration Office. Currently, he is a Research Fellow at the University of Texas, in the Center for Space Research. He was chosen by JSC's Exploration office to be a mentor to the Tigernauts.

During his time with NASA, Dr. Mandell worked as a designer for the Space Shuttle and Space Station. Additionally, he was the program manager of the human Moon and Mars Exploration Programs. Dr. Mandell has been working on projects related to Mars for the last ten years. Presently, he is working on a project to develop a drill to explore for water on Mars. The Tigernauts are looking forward to working with Dr. Mandell on this design challenge.

Collaborative Efforts

In an effort to receive feedback regarding the team's progress, the Tigernauts visited with the assigned NASA mentor, Dr. Humboldt Mandell, and one of his colleagues, Dr. Burke Fort, at the Center for Space Research of the University of Texas in Austin. Drs. Mandell and Fort gave the team a presentation covering the various projects carried out by the Center for Space Research. The team then gave a presentation over their concept variants and possible plans of approach, during which Drs. Mandell and Fort made suggestions and provided feedback. The most important piece of advice Dr. Mandell bestowed upon the group was that limits should be imposed in areas such as weight of the rover, cost of the subsystems, and power drawn from the source so that the group does not design for an open-ended problem, constrained by nothing. Other space-related vessels should be studied (the *Magellan* or the *Cassini* for instance) so the group can formulate proper limits to impose on the group's Mars rover. Weekly meetings with the team advisor, Dr. Kevin Nickels, have also assisted in developing various aspects of the project, such as the requirements of the specific subsystems.

For designing the six K-12 activities and completing the educational K-12 outreach option area, the team consulted Kathy Becker, a fifth grade science teacher at Encino Park Elementary School in San Antonio. Ms. Becker's experience in creating effective, educational presentations to younger audiences proved to be of great assistance in pursuing these objectives.

The team website was constructed due to the collaborative efforts of Colin Meyer, an experienced webmaster. His instruction and guidance allowed the website to have a professional and streamlined appearance.

Team Identification / Member Profile

The TSGC manned rover project has been adopted by Trinity University's ENGR 4381/4382 Engineering Design VII/VIII courses. These two consecutive courses are intended to be a capstone design experience for small groups of senior-level engineering students, in which their entire undergraduate engineering education is integrated under the supervision of a faculty advisor. The design concepts emphasized in these courses include analogs, analysis, modeling, testing, safety, optimization, robustness, construction, reliability, sustainability, and economics to name a few.

Inspired by the Trinity University mascot and the team's enthusiasm for its space-related project, the group selected "The Tigernauts" as the team name. The members of The Tigernauts include the team's leader, Kathleen Lachance, and members Michael Poteet, Landon Nemoto, and Roberto Aranibar. Each member will be the team leader for one quarter of the project duration. All of the team members are senior-level undergraduate students pursuing B.S. degrees in Engineering Science. The team's faculty advisor is Dr. Kevin Nickels, an assistant professor in the Engineering Science department at Trinity University. Contact information for each of the individuals mentioned above is provided in Appendix A.

The tasks for the manned rover project have been divided up into the following five general categories: structure and mobility, power, communications, computation and imagery, and thermal control. Each of the team's members are primarily focused on one of the first four areas listed, while thermal control is being taken into consideration by each member and the group as a whole. The roles of each group member are described in the following paragraphs.

Michael Poteet is the primary designer of all the mechanical design issues concerned with the vehicle's structure and mobility, such as its suspension, drive train and chassis. His concentration in mechanical engineering and strong background and experiences in automotive-related work make him well suited to handle these tasks.

Landon Nemoto's duties are concerned with power generation, storage, consumption, distribution, and budgeting. He must ensure that the power sources selected provide adequate power for vehicle mobility as well as the power required by the vehicle's systems and tools/equipment. His extensive and interdisciplinary background in both electrical and mechanical engineering demonstrates his ability to handle these tasks.

Kathleen Lachance is handling the design of the communication system. This includes any transmissions between the vehicle, its crew (in and away from the rover), a base station, an orbiter, and Earth. Her concentration in electrical engineering makes her well suited to handle these tasks. In addition, as the current team leader, she is in charge of project management.

Roberto Aranibar is responsible for all computation and imagery requirements. These requirements include a remotely-controlled video system and automatic logging of records pertaining to the crew and vehicle status. Due to constraints imposed by the circumstances of the project (e.g. time, number of team members), Roberto's focus is primarily on the design of the rover's video system, which the team plans to prototype in the coming semester. His previous experience in robot design and his emphasis in electrical engineering ensure his ability to handle these tasks.

Team Patch Design / Description

The patch design is literally our representation of a Tigernaut. The tiger stands upon the Mars surface, as shown by the red rock. The Tigernaut's helmet is off to show maximum detail in the facial region and clarify that the being in the space suit is a tiger—not because the tiger can breathe in space. The group's names are listed, along with mentions of Trinity University and the TSGC.

Figure 1.1: Team Patch Design

Topic Background Information

Rovers first garnered mainstream attention during the Apollo missions of the 1970s. Manufactured by Boeing, these rovers assisted astronauts on three consecutive missions. During Apollo 15 (July 26, 1971 to August 7, 1971)[1], the rover was first utilized to "explore regions within 5 km of the lunar module landing site."[2] The lunar rover vehicle (LRV) covered a total of 27 km, over which the astronauts collected rock and soil samples. Apollo 16 (April 16, 1972 to April 27, 1972)[3] also showcased the LRV, as the rover traversed 27 km. Again, the primary goal was merely transportation for the astronauts to collect lunar samples and take photographs.[4] Apollo 17 (December 7, 1972 to December 19, 1972)[5], the final mission that saw astronauts on the moon, also saw the LRV cover 30 km while the astronauts again took lunar samples and photographs.[6] The distances covered were a far cry from Apollo 11, the mission that men first landed on the moon: the distance then (July 16, 1969 to July 24, 1969)[7] was a grand total of 250 meters.[8]

These rovers had a mass of 200 kg and could carry 490 kg of payload (including two astronauts). The LRVs had dimensions of 3.1m x 1.83m x 1.14m, and a 2.3 meter wheelbase. The range was 65 km at 17 km/h (or 4.72 m/s), powered by two 36V silver zinc batteries.[9]

---

[1]Williams, Dr. David R. Apollo 15. National Space Science Data Center. 21 Sept. 2003. <http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo15info.html>.

[2]Williams, Dr. David R. Apollo 15 Command and Service Module (CSM). 15 July 2002. National Space Science Data Center. 21 Sept. 2003. <http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1971-063A>.

[3]Williams, Dr. David R. Apollo 16. National Space Science Data Center. 21 Sept. 2003. <http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo16info.html>.

[4]Williams, Dr. David R. Apollo 16 Command and Service Module (CSM). 18 Sept. 2002. National Space Science Data Center. 21 Sept. 2003. <http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1972-031A>.

[5]Williams, Dr. David R. Apollo 17. National Space Science Data Center. 21 Sept. 2003. <http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo17info.html>.

[6]Williams, Dr. David R. Apollo 17 Command and Service Module (CSM). 15 July 2002. National Space Science Data Center. 21 Sept. 2003. <http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1972-096A>.

[7]Williams, Dr. David R. Apollo 11. National Space Science Data Center. 21 Sept. 2003. <http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo11info.html>.

[8]Williams, Dr. David R. Apollo 11 Command and Service Module (CSM). 15 July 2002. National Space Science Data Center. 21 Sept. 2003. <http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1969-059A>.

[9]Experiment Operations During Apollo EVAs. Astromaterial Research and Exploration Science. 21 Sept. 2003.

It is the goal of this team to design a rover that can assist astronauts on Mars in much the same way the LRVs of Apollo assisted the astronauts on the Moon. This Mars rover must meet certain criteria, set forth and further explained in the "Design Objective" section of this report.

Design Objective

The team's objective is to provide plans for a manned, unpressurized rover suitable for the Mars atmosphere which supports a crew of two astronauts. The rover must be able to travel at least 10 km at a minimum speed of 10 km/h. It must have enough power to endure a 12-hour mission. Due to the rocky surface of Mars, the rover will need a strong frame and suspension able to withstand any obstacles the terrain may possess. The power supply/generation of the vehicle needs to support the vehicle itself, along with the onboard systems and tools.

Several of the rover's onboard systems are designed. The communications system for the rover includes audio and video data feeds between the vehicle, its crew (in and away from the rover), a base station, an orbiter, and Earth. The paths of communication are determined as a part of the design. This feed does not only carry collected data (photographs, videos, and astronaut's verbal communications), but also information concerning the condition of the rover (power level and diagnostics) and its crew (health status of astronauts). Also, with these transmissions comes an accurate method of tracking the position of the rover. This enables the astronauts in the rover and at the base station to know the precise location of the rover at any time.

The proposed video system has the capability to follow the movement of an astronaut out in the field while keeping them centered in the frame. This involves a rotational camera base with adjustable height, and two video cameras.

The final design includes CAD drawings portraying the physical structure of the rover and the subsystems mentioned above. A final CAD drawing assembly will be sent out to a rapid prototyping company so that a small-scaled model can be produced. Detailed descriptions of the subsystems are also included to complete the design.

<http://ares.jsc.nasa.gov/HumanExplore/Exploration/EXLibrary/docs/ApolloCat/Part1/LRV.htm>.

Design Plan / Methodology

A number of steps will be needed in completing the task at hand. A sound understanding of the problem is vital, as well as a knowledge of the resources available. Thorough research is necessary to develop an understanding of these two areas. Avenues explored during this process include similar past and present endeavors and other general information concerning the different components of the rover.

Dr. Mandell provided valuable advice as to how to begin a design of the rover. He suggested developing a work breakdown structure for Red Rover and its subsystems, to include:

1. Structures and suspension
2. Motors and propulsive subsystems
3. Power generation, distribution, and management
4. Thermal control systems
5. Drive assemblies and transmission
6. Seats and human accommodations
7. Communications
8. Guidance and control functions
9. Instrumentation
10. Spare parts
11. Management planning

By considering the elements of this list and matching possible areas of research with the capabilities and specialties of the individual group members, the Tigernauts are able to determine which systems the group members can design given the time constraints of the project.

The group's individual members are focused on different subsystems of the rover. These designs are then incorporated into a final product that satisfies the design objective. Since the team is integrating the TSGC Design Challenge into the course requirements of Trinity University's ENGR 4381/4382 Engineering Design VII/VIII courses, the team will continue to work on Red Rover after the TSGC Design Challenge Showcase. After all the TSGC deliverables have been completed, the team plans to create functional descriptions of the mobility and video systems. During the spring semester, the Tigernauts will prototype these systems.

To approach the design problem, design constraints imposed by practical power sources and launcher vehicle cargo capabilities are investigated. To maximize efficiency, the plan is to start out with the intent of using the smallest existing launcher to transport the vehicle to Mars, moving up to a larger launcher only if necessary. This will dictate a maximum size, weight, and power consumption for the rover, making it possible to distribute these limits to its individual subsystems. The rover and its subsystems can then be designed according to specifications which meet these requirements.

Structure & Mobility

I. Design Requirements

The suspension and drive-train are crucial elements in the design of the rover. This area's main function is to house all of the power and communication components of the vehicle, along with maintaining stability while the rover is in motion. The chassis needs to be able to handle the rocky terrain of the Mars surface while minimizing its overall weight. This strength to weight ratio is important not only to cut down on needed power for propulsion, but for keeping the launch cost to a minimum as well. The expense associated with putting the rover into space is well over ten thousand dollars per pound.

Another design consideration involves the shock absorption capabilities of the suspension. Due to the sensitive equipment on board the rover, the forces due to impact while driving will be kept to a minimum. The suspension needs to incorporate some sort of spring-mass-damper configuration in order to tame the Martian terrain. Another hazard of Mars is the large amount of fine dust particles located in the atmosphere. Careful consideration is being taken when designing the joints of the suspension, as well as any other moving parts where the presence of dust could pose as a problem. Also, the temperature on Mars is considerably less than it is on Earth, so the materials chosen need to be able to handle the colder environment. Finally, in addition to satisfying the design criteria set forth by TSGC, the rover needs to be relatively simple and easy to repair or replace any parts that may become damaged during the mission.

II. Final Design

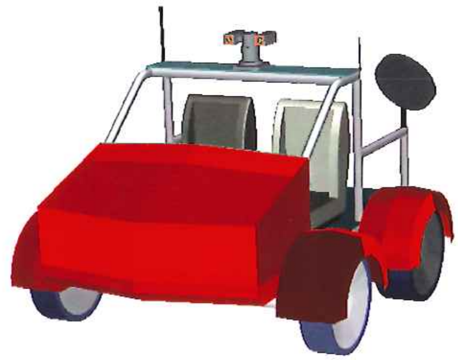

Figure 2.1: Final Design of Red Rover

Above in Figure 2.1 is the final design of Red Rover. The chassis and most of the suspension of the rover are made of an Aluminum-Magnesium alloy. This material is being used more in modern day automotive frames due to its light weight and high strength and was chosen for these reasons. The basic frame of the rover (shown below in Figure 2.2) is a ten foot by six foot rectangle and consists of 3" diameter hollow cylinders. Horizontal cross members and supports accompany the two 10' long main

Figure 2.2: The Structural Frame of the Red Rover

members, as well as the pivoting surfaces for the control arms. There is also a roll cage made of the same cylindrical material in order to protect the power source, communication equipment, and passengers aboard the rover. A half inch thick composite material is placed directly on top of the frame and serves as a floor board for the vehicle.

The suspension was a major focal point of the design, mainly due to the importance of the contents carried onboard the rover. Many of the electrical components are extremely sensitive to vibration, so keeping them stable will be of key importance in the design. The suspension consists of four control arms somewhat similar to those used in automobiles. The front control arms are of a different design than the rear ones due to their function. This is further illustrated in Figure 2.3 below. The rear half of the vehicle serves as the driving force while the

Figure 2.3: View of Front and Rear Control Arms

front half directs the rover. Each of the four wheels has a control arm, along with a spring/damper configuration located between the control arm and the frame. This apparatus is shown below in Figure 2.4. The springs are made of a titanium alloy called Beta-C[10]. The use of

[10] Broge, Jean L. TIMET's Titanium Alloy for Springs.. Society of Automotive Engineers. March 2001. <http://www.sae.org/automag/material/03-2001/>

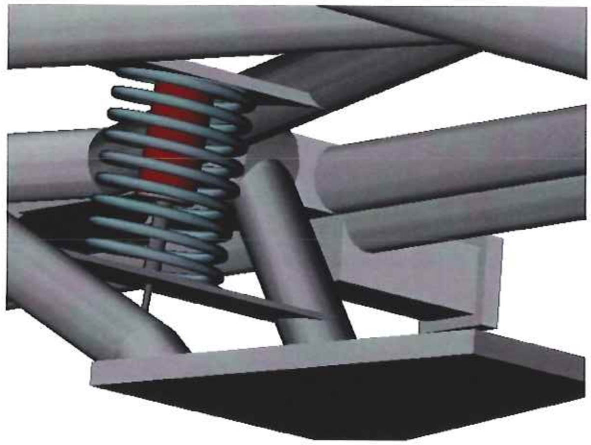

Figure 2.4: Spring and Damper Apparatus

this material is ideal for a suspension application due to Titanium's high strength to weight ratio. This product is now starting to be used in modern automotive applications. The dampening system incorporates a Magneto-Rheological[11] silicon fluid shock at each of the wheels. This technology utilizes magnetizable particles in a fluid similar to that used in conventional automotive shocks. When a magnetic field is applied to the composition, the viscosity is changed, the magnitude of which depending on the applied field. This allows the ride of the rover to be as rigid or as fluid as is needed.

One of the design complications due to the Martian environment is from the combination of cold temperatures and a dusty atmosphere on the pivoting surfaces. The fine dust particles will get in between normal bearings or bushings and the cold weather would weaken any rubber used for general shock absorption or cushioning. Therefore, Teflon bearings are used at interfaces such as where the control arms meet the frame. This material utilizes its naturally lubricated surface in combination with its durability[12] to produce favorable results, even in conditions as harsh as Mars.

The rover also makes use of rack and pinion steering in the front end of the vehicle, which is illustrated below in Figure 2.5. When the pinion gear is turned, it forces the rack to move either to the left or to the right. This action pivots the rover's wheel via the steering arm and tie

[11] Magneto-Rheological (MR) Fluids. Lord Corporation. ©2003. <http://www.mrfluid.com/fluid_begin.htm>

[12] BOStonE F-1 Glass Filled Teflon Bearings. Boston Gear. ©2003 <http://bostongear.com/pdf/bearing_catalog_sections/bearings_28-46.pdf>

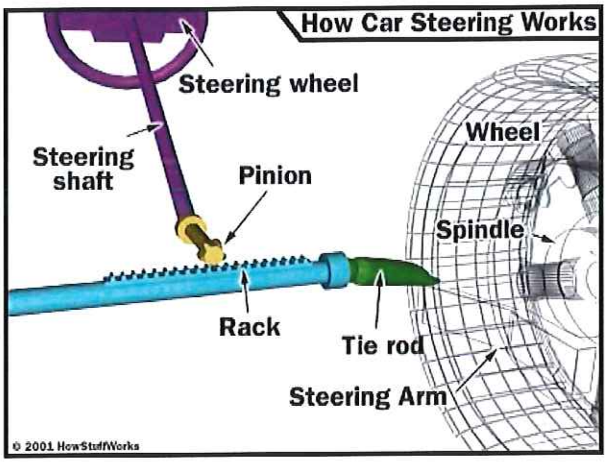

Figure 2.5: Illustration of Rack and Pinion Steering[13]

rod configuration. The steering assembly has a covering made of a composite material and Teflon bearings/seals will be placed on the outputs of the rack.

While the front wheels are used to direct the rover, the rear wheels are doing the moving. Both the right rear and left rear control arms have a ¾ hp DC motor bolted onto it that will propel the vehicle. This is illustrated below in Figure 2.6. Assuming a reasonable motor efficiency of 80%, the two motors consume a maximum of about 1400 W. The decision to have the rover be

Figure 2.6: Motor Mounted to Rear Control Arm

rear wheel drive was made due to the towing operations that were mentioned in the design specifications.

Although easing up on the throttle helps to slowly reduce the rover's speed, sometimes it may need to stop abruptly. Regenerative breaking, which is the act of placing a reverse load on

[13] Nice, Karim. How Car Steering Works. How Stuff Works. ©2001 <http://auto.howstuffworks.com/steering2.htm>

the motors to slow them down, is used to stop the rover. In this process the motor actually becomes a generator and recharges the power source. The output shaft of the motor has a gear on it, which drives a planetary gear box with a ratio of 36:1. An illustration on what a planetary gear box looks like is included below as Figure 2.7. This ratio gives the wheels enough torque to climb a 35° incline while fully loaded (estimated mass with cargo and samples at 1000 kg) while

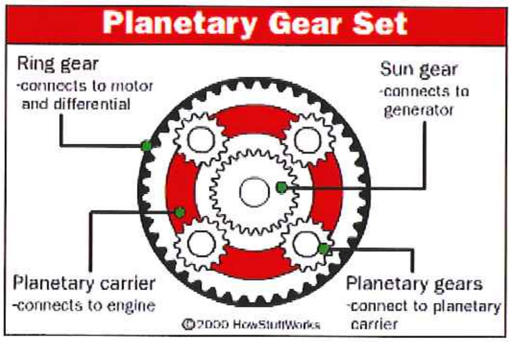

Figure 2.7: Example of Planetary Gear System[14]

still allowing for a top speed of over the aforementioned requirement of 10 km\h. The motor itself has a thin covering to keep the dust out but still allow heat to escape. The gear box is located in the wheel itself and is sealed with a composite casing accompanied by Teflon seals for the motor shaft. Cryogenic temperature rated grease is used to lubricate the moving parts. The front wheels also run on Teflon bearings.

The wheels themselves are 28" in diameter, 9" wide on the front and 12" wide on the rear. They are made of the same aluminum-magnesium alloy as the chassis. The difference in width is due the function of each of the wheels. The front wheels are primarily for steering, and a smaller width requires less force from the steering system. The rear wheels need to be wide to increase the contact surface of the wheel and the terrain. The wheel is basically empty and has a light weight composite shield on the outside to protect the moving parts from any kind of debris. Around the rim is a 2" thick zinc weaving along with titanium chevrons to aid in traction[15]. This "tire" is identical to the one used in the Apollo 15 rover. Also, to keep out any debris that the wheels might kick up, fenders are used in covering each of the four wheels. To protect the power

[14] Nice, Karim. How Hybrid Cars Work. How Stuff Works. ©2000. <http://auto.howstuffworks.com/hybrid-car9.htm>

[15] Williams, Dr. David R. The Apollo Lunar Rover Vehicle. 6 Aug. 2001. <http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo_lrv.html>

source located in the front compartment of the rover, a hood made of a composite material has been added. The hood and both front fenders can pivot about the front of the frame, allowing access to the power source.

The "cab" of the rover has two seats and a control panel that displays the speed of the vehicle and in which direction it is traveling in relation to Martian north. On the console of the vehicle (shown below in Figure 2.8) is an onboard screen that displays all diagnostic information concerning the rover. The seats have an aluminum frame with nylon coverings[16]

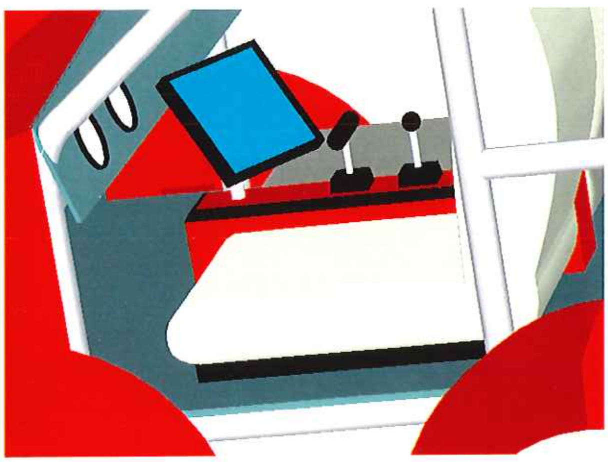

Figure 2.8: View of Cab of Rover

and accommodate an astronaut's suit and the life support system carried on their back. A simple Velcro lap belt is used in securing the astronauts while the vehicle is in motion.

The movement of the rover is controlled by a motion controller similar in appearance to a manual transmission shifter. This is located between the two seats and is apparent in Figure 2.8. Pushing the lever forward directs more power to the motors and causes the rover to accelerate, while pulling back reverses the polarity of the motors, causing the rover to go into reverse. When the joystick is moved to the side, it actuates a servo motor that acts as the pinion gear on the steering system illustrated in Figure 2.5. The "T" shaped lever located in front of the motion controller actuates a pin in the planetary gear to hold the vehicle in park when pulled back.

[16] Williams, Dr. David R. The Apollo Lunar Rover Vehicle. 6 Aug. 2001. <http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo_lrv.html>

The electrical components are located in the front half of the rover, mostly in the console between the seats. The entire rear half of the rover is used for any samples that may be collected or for tools needed on Mars. A trailer hitch is also located at the rear of the frame and different types of attachment media can be used.

Included below is Table 2.1, which gives mass and power estimates for each of the components that fall under the *Structure & Mobility* category. Every part of the rover was designed with mass requirements in mind, and, as is shown below, this was kept to a minimum.

Table 2.1: Structure & Mobility mass and power estimates

System	Component	Quantity	Total Mass (kg)	Avg Power (W)
Chassis	**-**	**-**	**220.55**	**0**
	Frame	1	177.13	0
	Front Control Arm	2	18.84	0
	Rear Control Arm	2	24.58	0
Suspension	-	-	**29.91**	**10**
	Titanium Spring	4	5.36	0
	Dampener	4	11.08	10
	Tie Rod	2	2.78	0
	Rack	1	7.25	0
	Steering Arm	2	3.44	0
Motor	-	**2**	**~30.0**	**1440**
Interior	**Chairs (2), Floorboard, Firewall, Console**	-	**~50.0**	**0**
Body	**Fenders (4), Hood**	-	**~30.0**	**0**
		Totals	**360.46**	**1450**

Computation & Imagery

I. Design Requirements

As mentioned earlier, computation and imagery tasks are areas or systems that require data processing, with the exception of the communications subsystem, which is being handled as a separate design entity. The main goal of the computation and imagery area is to provide a means for the following:

1. User Interfaces
2. Instrumentation: measurement devices including those for
    a. crew health monitoring
        i. astronaut health
    b. vehicle and vehicle systems status and diagnostics
        i. speed, direction, attitude, altitude, distance traveled
        ii. vehicle and vehicle systems temperatures
        iii. proper operation of all systems
    c. ambient conditions
        i. temperature, pressure
3. Data logging: analogous to black boxes on airplanes
    a. Record keeping of all pertinent data in (2) throughout a rover exploration mission
4. Onboard Display: must be able to display all in (2) as well as images being transmitted
5. Video system

Due to the circumstances of this project (time frame, number of people working on the project), the only one of these four areas that will be addressed in detail is the video system. Therefore, the requirements and restraints specific to the video system must be examined. Below is an overview of these requirements and restraints.

1. Transmit color video that captures important mission footage to a base station (and earth, if permitted by the communications subsystem) in near real-time
2. Support of scientific imagery operations
3. Operation within the capabilities of the communications subsystem

4. Operation within the limits of power available for computation and imagery purposes
5. Maximize the area around the rover at which images can be acquired
6. Controllable remotely
7. Reliable
8. Efficient in mass, power consumption, and cost

The purpose of the first requirement is to ensure that quality imagery of important mission footage is available to mission controllers, and to fulfill one of the design criteria specified for this project by the TSGC design challenge, which states that the video system must be capable of transmitting scenes to a base. Providing quality mission footage is the primary goal of the video system. The second requirement is established to allow for scientific uses of the video system. This is important since the main purpose of most planetary exploration missions is to collect scientific information. The third and fourth requirements are for ensuring that the video system operates properly in conjunction with the rest of the rover and its components. The maximum allowable data transmission rate specified by the communications link is 7.5 Mb/s, where 6 Mb/s are allotted to video transmission. The purpose of the fifth requirement is to ensure that the video system and its placement on the rover be specified in a manner that allows the camera(s) to capture images at as many locations around the rover as possible. Requirement 7 serves the purpose of making sure that all possibilities of failure are considered and accounted for when designing. All equipment must be able to operate properly under the harsh conditions of Mars' surface including low temperature, dust interference, and vibration and shock due to rough terrain. Finally, the last requirement, which is necessary for all components and subsystems of the rover, sets a goal for maximizing efficiency by minimizing cost, mass, and power consumption of the video system.

II. Final Design

A top-down design approach is taken to begin developing a design for the video system. That is, the most general functional block diagram that accounts for the tasks that the system must carry out to fulfill the data transmission requirements is created. The block diagram is then broken down further into more detail as the design progresses. Such a diagram is shown in Figure 3.1.

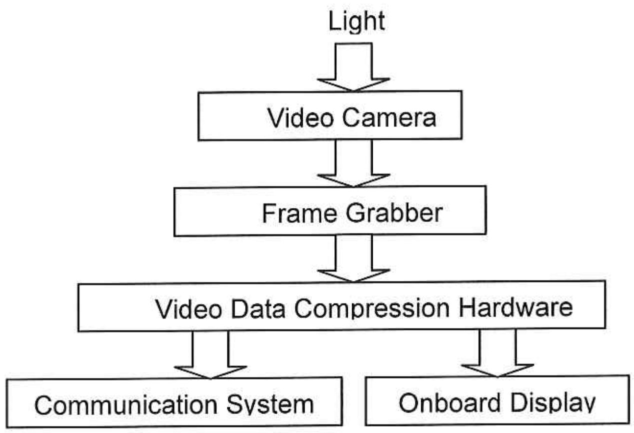

Figure 3.1: General data flow diagram of the video system

Since the primary goal of the video system is to provide general mission footage, a mono camera configuration is the primary camera configuration used. However, since most planetary exploration missions are geared towards collecting scientific information, the use of a stereo camera configuration is also supported. This configuration provides a means for measuring depth in images for scientific purposes.

As mentioned in the requirements and restraints section, equipment specifications will have to be selected so that the video system operates within the capabilities of the communications subsystem and the limits of power available for computation and imagery purposes. Keep in mind that the power required by other computation and imagery components must also be estimated and accounted for. In order to make appropriate design decisions to satisfy these requirements while providing the best quality video possible, Figure X must be broken down into further detail, as shown in Figure 3.2.

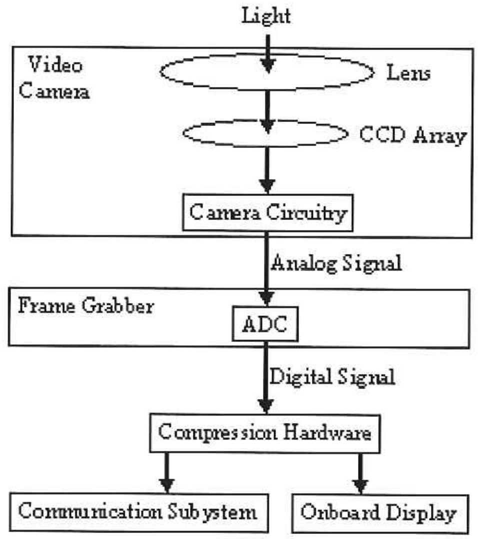

Figure 3.2: Detailed block diagram of the data path taken in the video system

From Figure 3.2 it can be seen that light passes through a lens and is converted into electrical signals by an array of CCDs (Charge-Coupled Devices). Consider one of these electrical signals. If using an analog output camera, the electrical signal passes through the camera circuitry (which is not of interest right now), and is then output as an NTSC, or standard television format, analog signal. An ADC converter in a frame grabber then takes this analog signal and quantizes it into a digital signal represented by some number of bits. Finally, video data compression hardware takes signals and uses algorithms to compress the data by taking advantage of the limits of the human visual system. Thus the amount of data needed to be transmitted is reduced by some compression ratio.

From Figure 10 and the discussion in the preceding paragraph, it can be seen that the design variables that determine the video data transmission rate are the following:

1. number of cameras used
2. image resolution (or size of the CCD array)
3. frame sampling frequency
4. pixel resolution (digital bit representation)
5. compression ratio produced by the video data compression hardware

In order to provide the best video quality while staying within the limits of the 6 Mb/s communications link available for video data transmission, the following values are used for each of the above parameters: Either one or two cameras are used at a time to support the mono or stereo configurations mentioned earlier. The number of cameras being used is a user-controlled option, which can be controlled locally or remotely. The max image resolution is 1024 x 1024 pixels. The frame frequency is also a user-controlled option that can be selected to be between 15 and 30 Hz in increments of 5 Hz. Faster sampling frequencies are required when the images collected by the camera are changing at a fast rate. This could occur when the vehicle is in motion or when the camera's direction is quickly being changed. In contrast, a lower sampling frequency could be used to conserve space on the communications link when the camera and vehicle sit still and the characteristics of the images being acquired are changing at a slow rate. A 12-bit digital representation is created by the ADC converter, allowing for a pixel resolution of 4096, that is, 4096 color levels. Lastly, the MPEG compression method is used to compress the data by at least 150:1. Therefore, the only two parameters which are varied are the number of cameras used and the frame sampling frequency. The rest of the parameters are held constant. The result is a maximum video data transmission rate of approximately 5.0 Mb/s, which satisfies the 6 Mb/s limit allotted to video data transmission, and leaves a sufficient 2.5 Mb/s communications link available for transmitting audio data.

Recall that one of the requirements of the video system is that it maximizes the area around the rover at which images can be acquired. To achieve this goal, the cameras incorporate lens systems with focusing capabilities and are placed in a location on the rover that has the fewest visual obstructions, and mounted on a platform that easily allows for gimballing movements. Figure 3.3 shows the video system mounted on the rover.

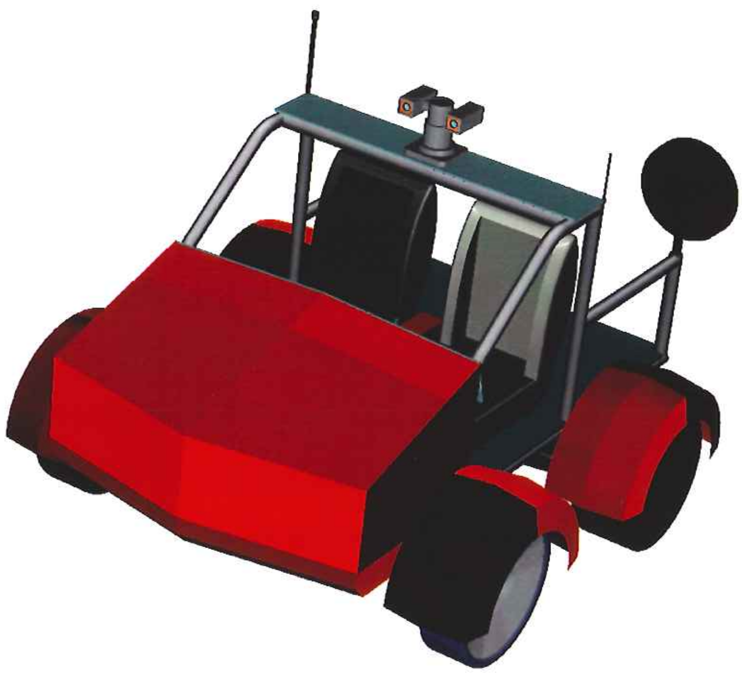

Figure 3.3: Video System location on Red Rover

The camera platform is mounted at the top of the rover, directly above the crew members. A 20° x 20° square field of view from each camera and 28.4 cm horizontal separation between the two camera lenses' centers acquires adequate views of the surroundings. The camera platform allows ±180° azimuthal rotation, ±90° range of direction from the vertical, and pan, tilt, rotation, and elevation movements. A commercial camera platform with such capabilities is the Metrica Biclops Pan/Tilt/Vergence Camera Mount (PTVM). The PTVM is a three-axis motion control platform for aiming stereo cameras. Its axes are under closed-loop computer control, with motion commanded through a standard RS232 port. The camera mast and platform are modeled after the PTVM, which will be used in the second semester prototyping of the system.

Another issue of concern is the method of controlling the camera platform's movement. Two modes of control are used; that is, a manual and automatic control mode. The manual mode enables a rover crew member or base station operator at a remote location to control the cameras' movement. In contrast, an automatic mode of control is implemented through the use of algorithms which work to keep an astronaut in center frame. This mode of control can be accomplished by using image processing techniques or by tracking a specific color of an astronaut's space suit, and is useful for keeping watch on an astronaut that leaves the rover for purposes such as collecting geological samples.

One of the most important requirements of the video system is that of reliability. As mentioned earlier, the video system must be able to operate properly under the harsh conditions of Mars' surface including low temperature, dust interference, and any shock and vibration imposed by rough terrain. Therefore, backup methods of operation must be devised. The fact that the video system is composed of two cameras and that each of the cameras' data is processed through two independent hardware systems accounts for the backup method of operation. Namely, if one of the cameras fails, another camera is still operational and the worst consequence is that stereo imaging is not supported.

To account for the low temperatures that the video system may be exposed to, all of the system's electronics, excluding the cameras, are kept in a thermally controlled electronics box in the vehicle console. This is where the majority of the vehicle's electronics are stored. Since this does not prevent the cameras from being directly exposed to the atmosphere, each of the cameras is enclosed in a material through which heat taken from the thermally controlled electronics box can flow and be exchanged with the cameras to maintain proper operating temperatures. This material for thermal casing is visible in Figure 3.4.

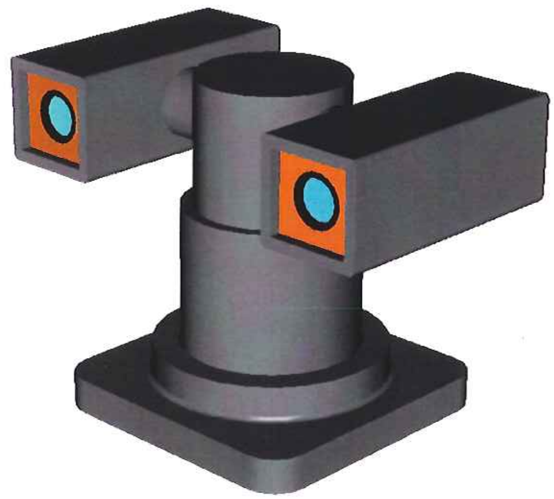

Figure 3.4: Video System – The thermal casing around the cameras is visible

When the video system power is shut down, the front of the camera boxes are closed. This serves useful in protecting the cameras during severe dust storms.

Another consideration for maintaining good reliability is shock and vibration dampening. Shock and vibration dampening rely on the vehicle's suspension system, which is designed to prevent any damage or difficulties to all of the vehicle's electronic systems.

Finally, the last issues of concern are those of mass, and power efficiency. The summary of maximum estimates of the mass and power budget for the video system as well as the major computation and imagery components are given in Table 3.1.

Table 3.1: Maximum estimates of computation and imagery mass and power

System	Component	Quantity	Total Mass (kg)	Avg Power (W)
Instrumentation	-	-	6.0	15
Onboard display	Monitor	1	9.6	90
Data Logging	Black Box	1	2.4	10
Video	Cameras	2	2.4	15
	Mast / Platform	1	2.4	10
	Compression Boards	2	1.2	20
	Frame Grabbers	2	0.6	20
	Illumination equipment	-	3.6	10
	Thermal Casing	1	6.0	10
		Total Estimates	34.2	200

Communications & Navigation

I. Design Requirements

One of the most important design requirements for the communications system of Red Rover is that there can be no single point failure in the system. This is to say that individual failures in the system must not cause the entire communications system to cease proper operation. There must be back up designs for transmitting and receiving data should one of the antennas malfunction. Additionally, the design must be able to incorporate receiving commands (from Earth or base station) at all times, even during the transmission of data from the rover.

In addition, the communications from the rover to the base station, earth, and/or orbiter are limited to the maximum data transfer rate of which the rover's technology is capable. This maximum data transfer rate is, in turn, limited mainly by bandwidth allocation for the transmissions. Red Rover will be transmitting data using the X-band frequencies (8450-8500 MHz), which are designated for deep space research.

Requirements for the navigation system are that the location of the rover at any given time is known by the scientists on Earth and the astronauts in the rover and at the base station. Also, the astronauts operating the rover need a way of determining which direction they are heading with respect to some fixed point.

II. Design Options

The path of communications for the rover will determine the type of hardware used in the design. There are multiple options for the path of communications. First, the rover could transmit data to the base station, which could then forward the transmission to Earth. Second, the rover could store information and transmit to a Mars orbiter in small bursts.

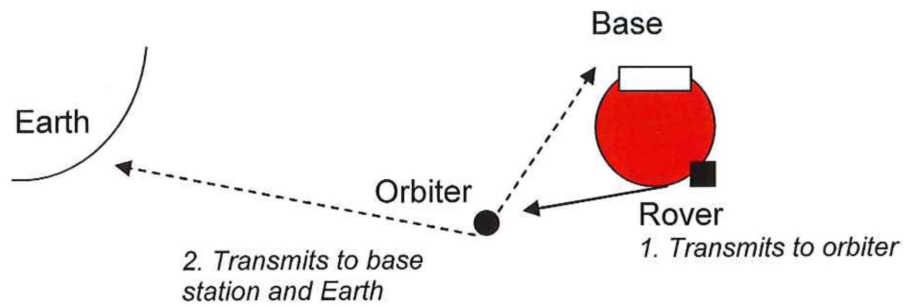

Figure 4.1: Example Path of Communication

The orbiter would then forward the transmission to the base station and to Earth. This path is shown in Figure 4.1. Third, the rover could transmit directly to Earth, and the control station on Earth could relay the information to the base station on Mars, if required.

There are four main options for antennas in the rover design. These are omni-directional antennas, parabolic dish antennas, phased array antennas, and optical communication antennas. These options differ greatly in their operation, power consumption, and applicability to the rover design.

Omni-directional antennas have been used in several NASA spacecraft designs, such as the unmanned rover Sojourner used on the Mars Pathfinder Mission in 1997[17]. However, they have very high power requirements to transmit data, therefore using these as the primary link for the Mars Rover is in all likelihood not a feasible option. The next option is a parabolic dish antenna. Parabolic dish antennas are widely used in space communications. The technology is mature. They provide high gains, which enables high bandwidth communications without

[17] Williams, Dr. David R. Mars Pathfinder Rover. National Space Science Data Center. 1997. < http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=MESURPR>.

consuming too much power. However, they perform best on stationary or very slow moving platforms. They must also be mechanically pointed with great precision to function properly.

Another option is the phased array antenna. These have several advantages. They are "electronically" pointed by adjusting the phases of the transmitters, which allows for fast and precise steering. This would be a great advantage as the rover will not necessarily be an agile vehicle capable of fine-tuning and strategic positioning. Phased array antennas are also more efficient than parabolic dish antennas.

The last option for communication design on the rover is optical communication. This is a relatively new technology, so there are many unsolved problems in the area. The hardware isn't widely available, and would have to be custom designed and built. This makes optical communication an unfavorable option for use in the design of Red Rover.

III. Final Design

Communications

The primary path of communication will relay all video and voice data to a Mars - geosynchronous orbiter. This will be accomplished using a phased-array antenna, which will operate in the X –band (Space Research frequency band). The phased array antenna will consist of 683 transmitter elements, shown in Figure 4.2. The data requirements are estimated to be 7.5 Mbps, and all communications will be made in a bandwidth of 10 MHz.

As mentioned previously, the phase of the transmitters can be shifted to electronically "point" the antenna. This feature of the antenna will compensate for instability in rover vehicle motion during transmission. The phased array will have scan capability of +/- 60 degrees to account for this motion. Details of the link budget are provided in Table 4.1.

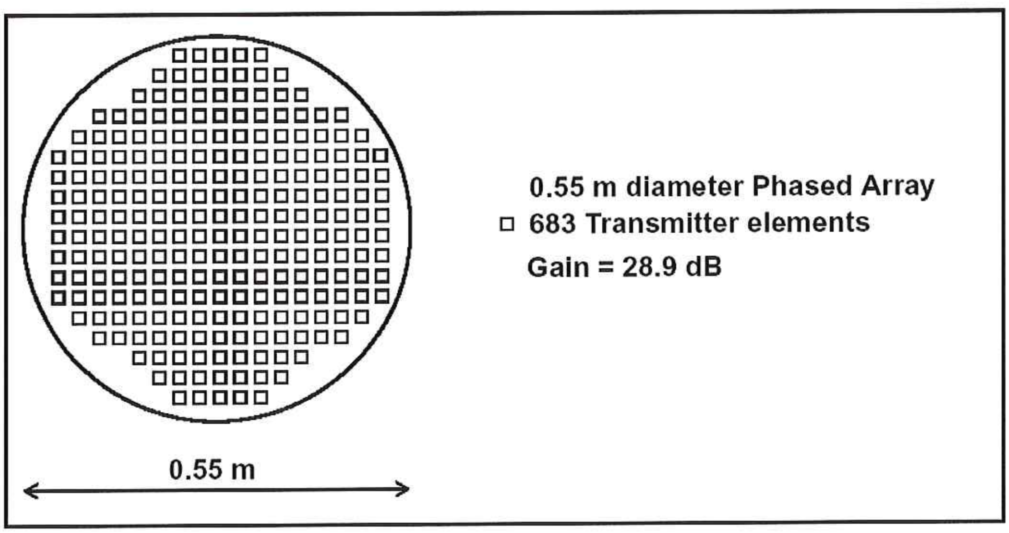

Figure 4.2: Phased array antenna[18]

[18] Deepak, B., Martin, M. Whitaker, W.. *Earth-Moon Communication from a Moving Lunar Rover,* The Robotics Institute, Carnegie Mellon University. 1996.
< http://www.ri.cmu.edu/pub_files/pub1/bapna_deepak_1996_1/bapna_deepak_1996_1.pdf>

Table 4.1: Link budget for phased array antenna[19]

Parameter	Value	Comments
Frequency	8.495 GHz	X-Band for Space Research
Data Rate	7.5 Mbps	Possible in 10 MHz Bandwidth
Transmitter Diameter	0.55 m	
Number of Elements	683	
Transmitter Gain	28.9	
Transmitter Power	12 W	
Beam Width	3.6 deg	

The orbiter traveling around Mars will be equipped with Electra, a UHF telecommunications package that relays data to and from the rover[20]. By using the forwarding and return-link relay services of the orbiter, the mass and radio power requirements for the communications system of the rover are significantly reduced. The orbiter will use its own power resources to forward the transmission to Earth and the base station. By transmitting data to a Mars-geosynchronous orbiter, Red Rover is ensured a constant communication link to the base station and Earth.

For direct communications between the rover and the base station, Red Rover will utilize an omni-directional, low gain, UHF monopole whip antenna. This link will serve as a back-up path of communications for use in emergencies. Low gain antennas do no require accurate pointing because they transmit data with a very broad beam width[21]. Therefore, should an emergency arise in which the rover is inoperable, the antenna would not need to be mechanically pointed in order to transmit successfully. However, this feature comes with a price: low gain antennas require high power levels to transmit. In order for the rover to use a low gain antenna, the data transfer rate must be quite low. The maximum data rate using the low gain antenna for

---

[19] Deepak, B. et al.

[20] *Mars Reconnaissance Orbiter: Spacecraft Parts, Electra.* 21 September 2003. < http://mars.jpl.nasa.gov/mro/mission/sc_instru_electra.html>

[21] *Mars Reconnaissance Orbiter: Spacecraft Parts, Antennas.* 21 September 2003. <http://mars.jpl.nasa.gov/mro/mission/sc_antennas.html>

communications is 600 bps, so transmission of video data is not possible. However, since this link will be utilized in emergencies, a simple "SOS" signal is the only necessary transmission.

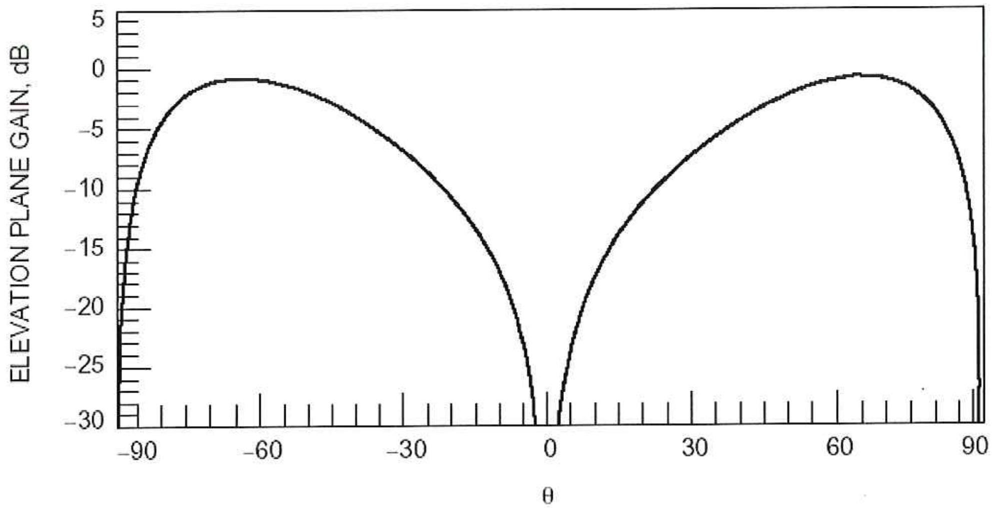

Figure 4.3: Pattern of the monopole whip antenna mounted close to the Martian surface[22].

The UHF monopole whip antenna is compact with a height of 25 cm and a mass of 0.25 kg. When the antenna is vertically positioned, it will radiate a vertically polarized field with a broad null in the axial direction. By mounting the monopole close to the Martian surface, the null is formed in the horizontal direction. This is due to its field reaction with the particles on the Martian surface at a small incident angle, as seen in Figure 4.3. This null behavior can be ignored for short distance communication between the rover and the base station.

Red Rover will have an omni-directional antenna to receive commands from Earth and the base station. Furthermore, this antenna can be used to transmit in the event that both the phased array and the monopole whip antenna cease to function. Should this happen, the transmission would go directly to the Mars-geosynchronous orbiter, which would forward the signal to Earth and the base station. This antenna does not need to be pointed mechanically, so

[22] Huang, J. *Mars Rover Antenna for Solar Array Integration.* TMO Progress Report 42-136, 15 February 1999.
<http://tmo.jpl.nasa.gov/tmo/progress_report/42-136/136C.pdf>

the rover will not need to alter its position in any way to be able to receive/send transmissions from/to Earth[23].

Additionally, the rover will carry two identical transponders; one will be used as back-up in case the first malfunctions. The purpose of the transponder is to translate digital signals into radio signals that can be sent to the orbiter. Similarly, the transponder translates the received radio signals into digital signals that the rover computer can interpret[24].

Table 4.2: Mass and Power summary for communications system

Component	#	Mass (Kg)	Average Power (W)
UHF Monopole Whip Antenna	1	0.25	12
Phased Array Antenna	1	12	90
Transponder[a]	2	0.75 each	5.0 each
Omnidirectional receiver	1	1	10[b]
	TOTAL :	14 kg	107 W

[a] Only one in use

[b] No power required unless phased array fails

A summary of the mass and power requirements for the communications system is presented in Table 4.2. Different failure modes for the communication system and their responses are presented in Table 4.3. As shown in the table, there is no single point failure of the communication system.

[23] Deepak, B. et al.
[24] *Mars Reconnaissance Orbiter: Spacecraft Parts, Antennas.* 21 September 2003. <http://mars.jpl.nasa.gov/mro/mission/sc_antennas.html>

Table 4.3: Failure modes of the communications system

Component	Failure Mode	Effect	Response	Criticality
Phased Array Antenna	Single / Multiple Transmitter	Insignificant	none	Minor
	All transmitters	Inability to transmit video data	Can still communicate via monopole or omnidirectional receiver	Moderate
UHF Monopole Whip Antenna	Single failure	None, but loss of first back-up if phased array fails	Use omnidirectional receiver as second back-up link	Minor
Omnidirectional receiver	Transponder failure	None	Use back up transponder	Minor

Navigation

Since the rover will be traveling out of sight of the astronauts inside the base station, it is important to know the relative position of the rover at all times. This is accomplished by using the Electra package on the Mars-geosynchronous orbiter. Besides functioning as a communications relay, Electra can provide specific information regarding the position of the rover. To achieve this, there must be a second orbiter circling Mars. By combining the second orbiter's position information and the Mars-geosynchronous orbiter's information, Electra can provide precise Doppler data which determines the location of Red Rover on the surface of Mars[25]. This information is relayed the base station as well as to Earth, so that the position of Red Rover is known. Furthermore, it is important that the astronauts operating Red Rover have a way to know which direction they are heading. This is achieved by a directional gyro unit which would provide a stable reference for Red Rover's heading with respect to Martian north.

[25] *Mars Reconnaissance Orbiter: Spacecraft Parts, Electra*. 21 September 2003. < http://mars.jpl.nasa.gov/mro/mission/sc_instru_electra.html>

Power

I. Design Requirements

The penultimate requirement for the power subsystem is that enough power is supplied to satisfy performance of Red Rover's other subsystems. Communications and navigation, computation and imagery, and propulsion must also constrain power consumption as much as possible in order to obtain the proper balance of power supplied and power consumed.

There are two main concerns regarding power: how much power should be supplied, and what type of power supply will be most efficient (personified by a power-to-weight ratio). To determine efficiency of the power supply, the team weighs each characteristic of the supply against how much power the supply can give to the rover. One criterion here is power-to-weight ratio, but the team is also aware of cost, surface area, and mass being other constraining factors.

II. Final Design

The group began observing the lunar roving vehicles of the Apollo 15-17 missions. These LRVs were powered using two 36-Volt silver zinc batteries.[26] However, since the group wishes to produce power without the concern of charging or re-charging batteries, alternatives to the batteries mentioned above were necessary. Krypton-85 and Alkali Metal Thermal to Electric Converters (AMTEC), solar power, and radioisotope thermal generators (RTGs) were considered.

Solar power requires 12 m^2 of photovoltaic cell area to produce 1 kW.[27] The tremendous amount of surface area required would ruin any hopes of building a compact (and efficient) rover.

After deliberating the use of a Radioisotope Thermal Generator compared to the Alkali Metal Thermal to Electric Converter cells, the group has concluded that the AMTEC technology is the optimal alternative for Red Rover's design. In terms of power conversion ratio (power generated versus power consumed), the ratio of the RTG is 6%. The AMTEC cells each have a ratio of 15%, considerably better than the RTG. In addition, the process of obtaining power through AMTEC technology ejects waste heat as a side effect of producing power satisfactory for the design. This waste heat can be harnessed and utilized in the form of thermal energy to maintain other subsystems at a proper working temperature.

A Carnegie Mellon lunar rover employs this method of power. Much of the following data regarding the AMTEC cells can be directly attributed to Carnegie Mellon's previous research. This data will be tailored to suit the specific needs of the Tigernauts' Mars rover.

Three pressurized vessels of Krypton-85 gas "rest in an aerogel and MLI insulation block. AMTEC cells are directly mounted to conductive spacers on the curved surface of the pressure vessels. An aerogel insulation block is lowered onto the AMTEC cells to allow unidirectional heat flow. Finally the power system's radiator is directly mounted to the cold side of the conversion cells to complete the assembly of the power system…The krypton vessels are not pressurized

---

[26] Wright, Mike and Jaques, Bob. A Brief History of the Lunar Roving Vehicle. 3 April 2002. NASA Marshall Space Flight Center. 7 Oct. 2003. < http://history.msfc.nasa.gov/LRV.pdf>.

[27] VanderWyst, Anton. Power Generation Analysis. 18 March 2002. University of Michigan Mars Rover Project. 21 Sept. 2003.

until shortly before launch for safety and performance needs."[28] Consult Figure 5.1 for a schematic of the basic assembled design.

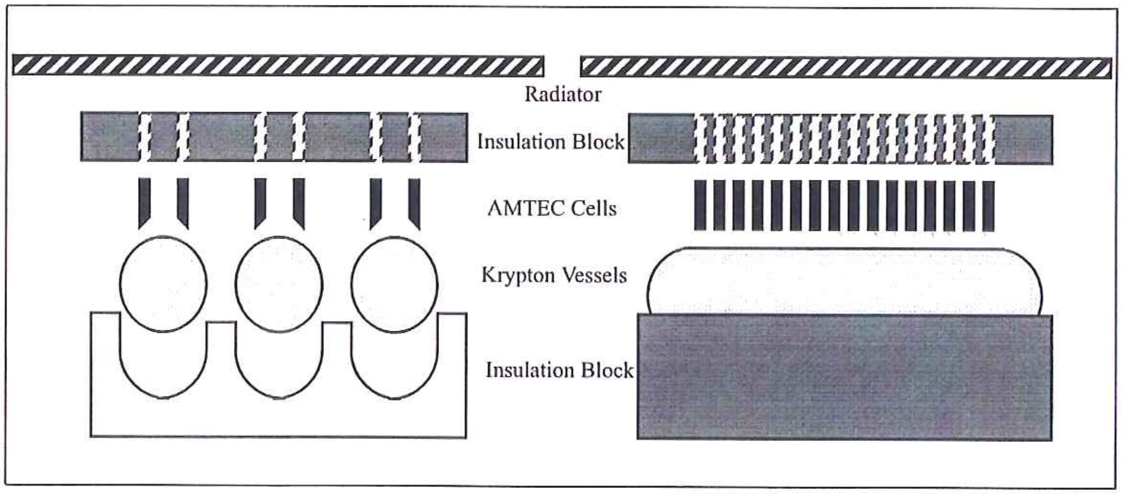

Figure 5.1: Schematic of One Basic Assembled Design

(Source: Design of a Day/Night Lunar Rover. Dr. P. Berkelman, Carnegie Mellon University.)

Three vessels made of Astroloy contain Krypton-85 gas (with a half-life of 10.7 years) at a temperature of 1000K and a pressure of 100 atmospheres. This Krypton-85 gas emits beta particles, which is converted to heat in each vessel. Each vessel is cylindrical with a hemispherical end cap on each end. The length of the cylinder is 50 cm, the diameter is 23 cm, and the thickness of the vessel is 1.3 cm, including an overall factor of safety of three. These dimensions are chosen to not only absorb a majority of the energy of the beta particles, but to negate effects of radiation as well. The vessels are designed to maintain the Krypton-85 gas at a temperature of 1000K for a lifespan of two years.

The AMTEC cells partially convert electric energy from the heat that has been emitted from the vessels. "The AMTEC cell is a thermally regenerative concentration cell utilizing sodium as the working fluid and sodium beta-alumina solid electrolyte (BASE) as the ion selective membrane through which a nearly isothermal expansion of sodium can generate high current flow/low voltage power at high efficiency…The conversion of thermal to electric energy occurs by

[28]Berkelman, Peter. Design of a Day/Night Lunar Rover. June 1995. The Robotics Institute, Carnegie Mellon University. 7 Oct. 2003.
<http://www.ri.cmu.edu/pub_files/pub1/berkelman_peter_1995_1/berkelman_peter_1995_1.pdf>.

using heat to produce and maintain a sodium concentration gradient across a BASE membrane...The liquid sodium in the heat pipe evaporator, evaporates and flows as a vapor to the heat pipe condenser inside the BASE. The vapor condenses and deposits its latent heat, picked up in the evaporator, inside the BASE tube. Then the sodium liquid returns to the heat pipe evaporator through the heat pipe wick. In the power loop, sodium liquid fills the wicks on the condenser, in the artery, on the outside of the heat pipe condenser and the inside of the BASE tube. The heat delivered by the heat pipe loop keeps the entire BASE tube region hot and raises the vapor pressure of the sodium inside the BASE...The condenser is kept at a low temperature. The sodium vapor pressure (and concentration) in the region of the condenser and the outside of the BASE tube is therefore much lower than inside the BASE tube. This pressure, or concentration gradient produces an electrochemical potential difference across the BASE tube wall...When current is drawn through the electrodes and current collectors on both sides of the BASE, energy is extracted from the cell in the form of electrical power."[29] The electrical power is then channeled to the subsystems via 65 AMTEC cells, while the thermal heat is released through the radiator.

The Tigernauts have budgeted 1700 Watts for Red Rover. 1400W will be used for propulsion (two-wheel drive), 100W for communications, and 200W for onboard computing. The power output for the Carnegie-Mellon assembled design is 520 Watts of electric power. However, since the AMTEC cells are only 15% efficient, 3466W of thermal power is necessary. It is the judgment of the Tigernauts that the design of Carnegie-Mellon be utilized as four independent assemblies for a total of 2080W. One assembly will power the onboard systems and communication while the other three assemblies power the two-wheel drive propulsion system. The maximum power output will still be 520W and the thermal power still 3466W on each assembly. Thus, for Red Rover, 260 AMTEC cells and twelve Astroloy vessels of Krypton-85 gas will be necessary. The total mass for the Krypton-85 gas necessary is approximately 4.0625 kg and the volume is approximately .2788m^3.

---

[29] Ivanenok, Joseph F. III, and Sievers, Robert K. "Radioisotope Powered AMTEC Systems." IEEE AES Systems Magazine p. 29-35, November 1994.

Each assembly discharges 2946W of thermal power into an apparatus built over the radiators. A Peltier device will harness the sum of 11784W and control working temperatures of each subsystem. Peltier devices "are small solid-state devices that function as heat pumps. A "typical" unit is a few millimeters thick by a few millimeters to a few centimeters square. It is a sandwich formed by two ceramic plates with an array of small Bismuth Telluride cubes ("couples") in between. When a DC current is applied heat is moved from one side of the device to the other - where it must be removed with a heatsink… If the current is reversed the device makes an excellent heater."[30] The Peltier device in question would have the ability to maintain a control temperature (the temperature of the particular subsystem) by controlling the current in the device to heat and cool according to the present temperature.

---

[30] General Information on Peltier Devices. 2003. Thermoelectric Peltier Device Information Directory. 31 Oct. 2003. <http://www.peltier-info.com/info.html>.

Conclusion

The Tigernauts have created a general design of a manned, unpressurized rover for use on Mars. The rover carries two crew members, and complies with the specifications set by the TSGC Design Challenge. Specific deadlines set forth by TSGC are outlined in Appendix B. The team has created CAD drawings and schematics of the rover and selected subsystems, related to communications, computation, imagery, power, structure, and mobility.

By the end of the fall semester, TheTigernauts will have completed three of the four option areas set forth by TSGC. Fulfilled option areas have included an outreach activity with a group of Boy Scouts and the design of a team webpage. The "Team Travel" option area will also be completed by participating in the TSGC Design Challenge Showcase on November 16th and 17th of 2003. All budget considerations for the team travel option and other expense considerations are outlined in Appendix C. A presentation of the design project at a professional level meeting is anticipated to take place during the spring semester, wherein the audience will be comprised of professional engineers from both the mechanical and electrical arenas, such as ASME and IEEE. The Tigernauts have accomplished the task of designing an unpressurized manned rover for use on Mars' surface through hard work and collaboration with the faculty mentor, NASA mentor, and outside resources.

Appendix A: Contact Information

Group Leader	
Name:	Kathleen Lachance
Local Address:	109 W. French #E-307 San Antonio, TX 78212
Telephone:	210-737-0979
Email:	kathleen.lachance@trinity.edu
Group Member	
Name:	Landon Nemoto
Local Address:	One Trinity Pl #1208, San Antonio, TX 78212
Permanent Address:	P.O. Box 691769, Houston, TX 77269-1769
Telephone:	713-805-4246
Email:	landon.nemoto@trinity.edu
Group Member	
Name:	Michael Stone Poteet
Local Address:	10362 Sahara Rd # 612 San Antonio, TX 78216
Permanent Address:	8012 NW 101 Oklahoma City, OK 73162
Telephone:	405-205-1819
Email:	mpoteet@trinity.edu
Group Member	
Name:	Roberto Aranibar
Local Address:	336 E Rosewood Avenue #4 San Antonio, TX 78212
Telephone:	210-733-1225
Email:	roberto.aranibar@trinity.edu
Faculty Advisor	
Name:	Dr. Kevin Nickels
University Address:	Department of Engineering Science One Trinity Place San Antonio, TX 78212
Telephone:	210-999-7543
Email:	knickels@trinity.edu

Appendix B: Timetable of Tasks

Due Date	Tasks
9/26/03	Level one deliverables due.
10/3/03	Design of team patch, resumes, K-12 activities.
10/6/03	Option Area I -- Outreach
10/10/03	Team travels to visit with TSGC Mentor. Finish K-12 activities for Level two deliverables.
10/17/03	Level two deliverables due.
10/24/03	Option Area III – Website, team deadline.
11/12/03	Option Area II – professional level meeting, team deadline.
11/14/03	Level III deliverables due, all option areas (except team travel) due.
11/16/03	TSGC Design Challenge Showcase, Option Area IV – Team Travel.
11/24/03	Begin writing functional description for prototypes.
12/5/03	Order necessary materials for prototypes.

Appendix C: Project Budget Report

Description	Cost	Source
Travel Expenses to JSC	$550	
Formal Reports/Presentations	$100	
Software: SolidWorks	$50.00	
Team Incentives	$141.40	
TOTAL	$841.40	TSGC & Trinity University

Appendix D: Project Time Report

System	Time Spent (Hours)
Structures & Mobility	41
Computation & Imagery	70
Communications & Navigation	67
Power	56
TSGC Deliverables	260

Total Hours Spent on Red Rover	494

Appendix E: Website Report

Attached is a rendition of the opening page of the Tigernauts' website. The URL of the website is http://www.engr.trinity.edu/~lnemoto, which can be found at the lower left of the printout.

Upon reaching the website, readers will find the patch design submitted with Level II to be the most prominent object on the page. Accompanying the patch design is the title to the website, "Red Rover, Red Rover."

Below the patch and title is a quick synopsis of the purpose of the website and the Tigernauts' Mars rover. The section entitled "Semi-related Links" lists several of the links that the Tigernauts found useful in their research, while "More to Come" is an understated description of the buttons to the page's left. "Tigernauts at play" alerts the reader that there is a photo gallery of the Tigernauts' exploits.

To the left are buttons that lead to different areas of the Tigernauts' web. "Problem Statement" is a button leading to a list of TSGC requirements, along with the Tigernauts' Design Objective. "Subsystems" leads to four specific areas that each Tigernaut tackled: Power, Structure and Mobility, Computation and Imagery, and Communication. "Tigernauts at a Glance" is a page with a brief paragraph on each member of the group, what they bring to the table, and the tasks they expect to complete. "Photo Gallery" is the same link as alluded to with the "Tigernauts at Play" section, leading to photos of the K-12 activity and a group dinner. "K-12 Activity" is a page for a report regarding the outreach activity in which the Tigernauts participated. Lastly, "Credits" is a page leading to links of the people that have helped the Tigernauts in their quest to complete the Red Rover design.

Red Rover, Red Rover

11/11/03

- Home
- Problem Statement
- Subsystems
- Tigernauts at a Glance
- Photo Gallery
- K-12 Activity
- Credits

...Looks like you just came over.

Greetings ladies and gentlemen, welcome to the Trinity Tigernauts' webpage. This is a site devoted not to the inner-workings of the famous childhood game "Red Rover," but instead to the Tigernauts' delightful Mars rover design of the same name.

Red Rover was created in order to satisfy the Texas Space Grant Consortium's (TSGC) needs. Luckily, Trinity University's Senior Design VII and VIII class was willing to allow this design of the Mars rover to count towards the "senior design."

Well, as Fred Garvin would say, "Enough small talk, let's get crackin'." Feel free to browse around, as I'm sure whatever information you glean from your travels will be infinitely more lucid than the ramblings above.

Semi-related Links

- Sojourner
- Launch Vehicle Info
- New Technology
- Design of Mars Rover Wheels
- Univ. Maryland Mars Rover Design
- VIDEO on MARS

More to Come...

If you haven't noticed already, you will find credits (Group thanks), a personal page on each one of the Tigernauts, and a more specific approach to the rover somewhere in this site.

Tigernauts at Play

Even when we're playing, the Tigernauts are still meeting some requirement set forth by *some*one. Check out some of the photos in **photo gallery.**

Home | Problem Statement | Subsystems | Tigernauts at a Glance | Photo Gallery | K-12 Activity | Credits

This site was last updated 11/11/03