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Red Rover, Red Rover: Simulation of 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

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Semester Two: Simulation of 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.

Acknowledgements

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Introduction

Continuing their work from last semester on the Unpressurized Manned Rover for Use on Mars Surface topic of the Fall 2003 TSGC Design Challenge, The Trinity Tigernauts have created a 1:6 scale model of their previously designed Mars rover. The TSGC project was again integrated into ENGR 4382, a senior-level design course in Trinity University's engineering science curriculum, as many of the course's requirements overlapped with those of the Design Challenge.

This report is intended to provide an account of the completed Mars rover project. The Tigernauts and the group's collaborators are introduced, and background information regarding the topic at hand is presented. This is followed by the group's specific design objectives and the methodology followed in completing the project. Finally, design requirements and restraints of the project are discussed and a final design concept for the rover is presented.

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 International 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 aid in the exploration for water on Mars. The Tigernauts were privileged to have Dr. Mandell as a team mentor for the design challenge.

Collaborative Efforts

Weekly meetings with the team advisor, Dr. Kevin Nickels, were a great assistance in developing various aspects of the Red Rover project. Valuable feedback was also provided by other faculty and students of Trinity University's engineering science department.

The team website was constructed in the previous semester due to the collaborative efforts of Mr. Colin Meyer, an experienced webmaster. His instruction and guidance allowed the website to have a professional and streamlined appearance. The Tigernauts have again conferred with Mr. Meyer in order to keep the website updated and reflective of the new direction in which the Tigernauts have taken the project.

Making the concept into a workable prototype vehicle was one of the major design objectives for this project, so the Tigernauts consulted Al Robles from Al's Hobbies in San Antonio. His extensive experience in RC technology was invaluable in the fabrication of the frame, suspension, steering, and propulsion aspects of the prototype. His advice helped to simplify the conceptual design and made the construction of the RC rover feasible.

Team Identification / Member Profile

The TSGC manned rover project was integrated into Trinity University's ENGR 4381/4382 Engineering Design VII/VIII courses. These two consecutive courses were intended to be a capstone design experience for small groups of senior-level engineering students, in which their entire undergraduate engineering education could be applied under the supervision of a faculty advisor.

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 Kathleen Lachance, Michael Poteet, Landon Nemoto, and Roberto Aranibar. Each member has been the team leader for one quarter of the project duration. All of the team members are senior-level undergraduate students who will have soon earned 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 second semester of the RC Red Rover project were divided up into the following general categories: frame and suspension, RC technology, position estimation, and video system. Each of the team's members was primarily focused on one of the four areas listed. The roles of each group member are described in the following paragraphs.

Michael Poteet, the primary designer of the chassis and suspension of the conceptual rover, was responsible for the fabrication of the prototype's frame and suspension. His tasks included any modifications needed in applying the RC technology to the prototype and overseeing its construction. Michael has modeled the suspension utilizing the necessary calculations; he also has made sure that the prototype behaves as the conceptual rover would. His concentration in mechanical engineering and strong background and experiences in automotive-related work served him well in handling these tasks.

Landon Nemoto's primary duties were concerned with ensuring the proper motion of the model via RC technology. This technology moved the rover, allowing the Tigernauts to test the suspension and position estimation systems. Once the model was operational by means of RC technology, he designed and implemented a pan/tilt mount for the video camera as well as aided in the construction of the frame and suspension. His extensive and interdisciplinary background in both electrical and mechanical engineering served him well in carrying out these tasks. In addition, he has completed the patch design and maintains the team website.

Kathleen Lachance is handling the design of the position estimation system (PES). Her concentration in electrical engineering made her well suited to handle this system. The PES is designed to generate a two-dimensional, birds-eye view plot of the rover's path during an experimental excursion of the rover. A useful byproduct of the PES is the fact that the same data was used to analyze the efficiency of the suspension system.

Roberto Aranibar is responsible for the vehicle's video system. This involves developing a solution for remotely acquiring and controlling live video from the RC vehicle. His previous

experience in robot design and his emphasis in electrical engineering made him well suited to handle this task.

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. The group name is cited, as well as the years of loyal service the Tigernauts have provided TSGC. Lastly, the colors involved reflect Trinity's school colors of white, silver, and maroon.

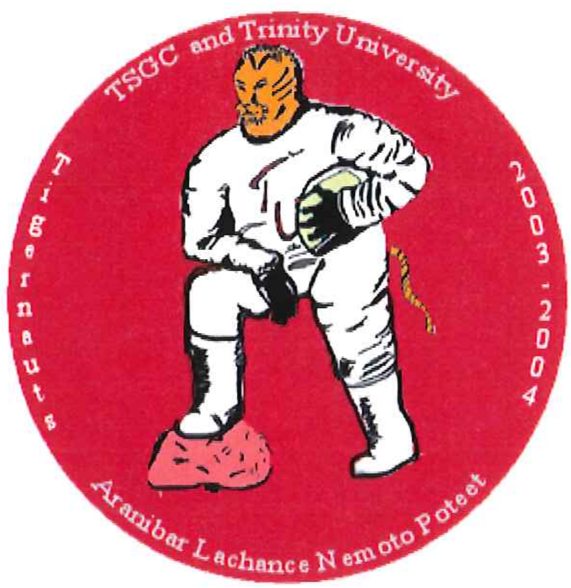

Figure 1.1 Team Patch Design

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]

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[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>.

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]

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 Tigernauts ultimate objective for the Red Rover project was to have an RC, 1:6 scale model of the rover's frame. The rover model was to be equipped with some of the onboard systems outlined in their final report of last semester's TSGC design challenge. Due to budget and time constraints, aspects of the rover model differed slightly from the original rover design. The model's frame and suspension was designed using the SolidWorks CAD drawings from the original design of Red Rover, and was expected to have a four-wheel passive independent suspension. Testing of the RC version of Red Rover over rough terrain would attempt to simulate the vehicle's response to the surface on Mars. The suspension system of the rover would be analyzed for its ability to absorb shock due to the terrain, and modified to improve the design using adjustable shocks and springs.

Having the RC rover carry extra ballast to simulate the scaled payload of the actual Mars rover was another objective of the Tigernauts. The rover was expected to have a position-processing system with data logging capabilities to record its accelerations during its journey, from which the displacement of the rover would be determined. One of the team's goals was to graphically represent the path of the rover's movement using the data logging and position-processing systems.

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[9] Experiment Operations During Apollo EVAs. Astromaterial Research and Exploration Science. 21 Sept. 2003. <http://ares.jsc.nasa.gov/HumanExplore/Exploration/EXLibrary/docs/ApolloCat/Part1/LRV.htm>.

Finally, the rover was equipped with a video system that was controllable and viewable remotely. The video system was intended to simulate the actual video system that was designed in the first semester of the team's work.

Design Plan / Methodology

The rover is propelled via RC technology. The RC electronics facilitate testing of the other subsystems present on the rover, namely the suspension and position estimation system. The RC electronics also benefit the video system by providing a change of scenery. This hardware utilizes a handheld radio transmitter to communicate to a 4-channel receiver located within the rover, allowing the user to manipulate two DC drive motors and one servo steering motor. These drive motors propel the concept vehicle; the servo serves to steer the front wheels of the vehicle, providing the vehicle maneuverability. The RC components on the model are powered through one power supply consisting of two 7.2 V batteries. This supply also powers one electronic speed controller whose purpose is to regulate the speed of the drive motors.

Another subsystem is the position estimation system (PES). The PES is designed to generate a two-dimensional, birds-eye view plot of the rover's path during a journey of fixed length. It utilizes a data logger mounted directly on the vehicle. Two accelerometers are present on the rover, with one attached to a control arm (a suspension piece located between the frame and the wheel) and the other attached to the frame itself. The data logger records data acquired through the accelerometers. This data is interpreted as the acceleration of the rover, which later allows one to compute the rover's position once it is mobile. This PES for the RC rover was created using MATLAB and the acceleration data. A useful byproduct of the PES is the fact that data taken by the PES can be used to analyze the efficiency of the suspension system. However, due to data logging restrictions, a plot of the rover's path and a study of the suspension system must be conducted on separate journeys of the rover.

The video system for the RC rover is controllable and viewable from a remote personal computer (PC). The video system incorporates a graphical user interface (GUI) that provides capabilities in varying image parameters such as frame rate and resolution. A pan/tilt mount has

been installed on the RC model to allow the camera to move, responding to control of the RC transmitter.

The above features are mounted on a brass frame utilizing 4-wheel passive suspension. The suspension istested using the aforementioned accelerometers to determine optimal spring and damping coefficients for the springs and shocks on the vehicle. This allows the rover prototype to minimize the impact caused by rough terrain.

RC Technology

I. Project Requirements and Restraints

The function of the RC technology is to provide the model of Red Rover with the ability to move. Once RC Red Rover is mobile, the Tigernauts will be able to test the springs and dampeners of the suspension system as well as test the position estimation system utilizing the accelerometers and data logger. Therefore, the paramount requirement of the RC technology is that it propels the model of Red Rover.

One requirement is that the Tigernauts must have the ability to remotely steer the rover model. The user will employ a transmitter to communicate with the rover model, piloting the model any direction desired. The transmitter sends pulse-width-modulated signals over a specific frequency to the RC model. Possible frequencies (as ruled by the FCC) include 27, 49, 72, and 75 MHz.

However, one must also take into consideration any possible time delay between the transmitter and receiver introduced through the use of pulse width modulation over this specific frequency. This delay, if any, will occur during the time spanning the command being given by the user and the response of the rover model.

The Tigernauts will require a 4-channel receiver to communicate to each component. Any receiver with a lesser amount of channels will be useless. Each "channel", or "interface of communication," is a set of three wires—one for ground, one for the signal, and one for positive voltage (approximately 5V).

The rover model must be mobile for a satisfactory amount of time that permits testing of the suspension and position estimation systems. This translates directly into the necessity for a power source sufficient to supply a satisfactory amount of power over this amount of time.

The construction of the rover model must be as inexpensive as possible so that money can be better applied towards the subsystems and their testing. Thus, the RC electronics also need to be as inexpensive as possible.

The alternatives the Tigernauts considered for the RC electronics reduced to the "build-buy" decision: build a complete rover model from scratch or purchase an existing RC vehicle to adapt to the Tigernauts' needs. After weighing the costs of each alternative, the most economic (as well as practical) solution was to purchase an existing RC vehicle possessing several necessary components to the construction of the concept vehicle. In addition to this purchase, individual parts crucial to the construction of the Tigernauts' vision were acquired to work in conjunction with the purchased vehicle.

II. Final Design Concept

The final design for the RC components of Red Rover comprises an integral part from a purchased Traxxas E-Maxx model 3906 as well as individual parts necessary for the completion of the Tigernauts' goals.

The Tigernauts wanted the RC version of Red Rover to stay as true to the design from the previous semester as possible. This meant that since the rover was originally designed with two motors as the means of propulsion, the concept vehicle also should possess two motors. The DC motors on the concept vehicle must be able to drive the rover model when complete with obligatory mass.

In this regard, the E-Maxx model provides an electronic speed control (ESC) unique to the RC industry yet perfect for the Tigernauts. This electronic speed control allows for control over the speed of two DC motors at the same time, compared to a plethora of industry-standard ESCs that control just one motor. The ESC from the E-Maxx and utilized on the concept vehicle is powered by two 7.2 V Nickel-Cadmium batteries in series, and controls two DC motors in parallel.

(This can be seen in Fig. 2.1—while not an accurate representation of the electrical wiring of the components, this figure provides a depiction of the positioning and necessary connections of all the equipment.) The ESC regulates the speed of the motors, and in turn, the speed of the vehicle.

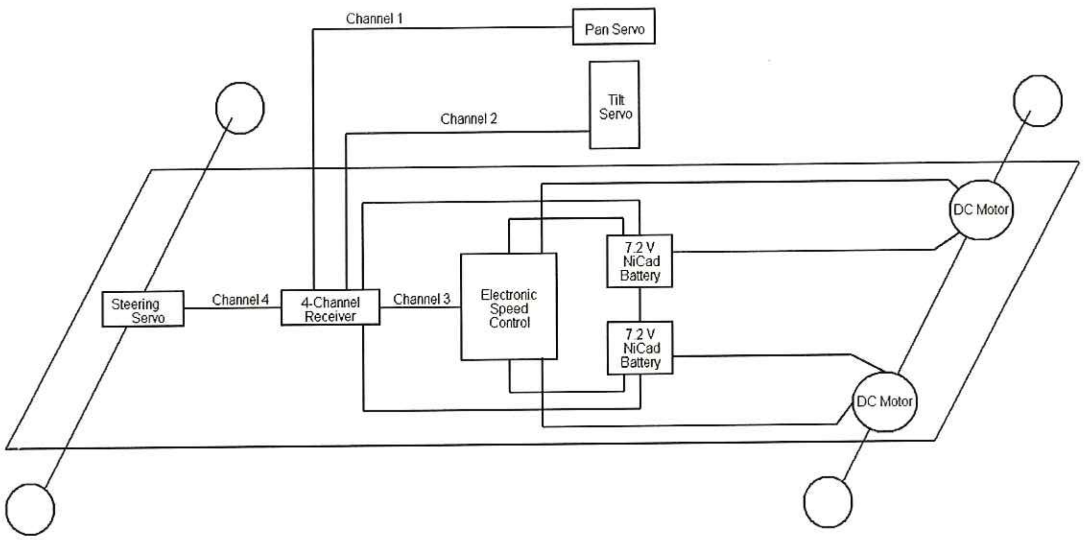

Figure 2.1 Basic Schematic of Concept Vehicle.

The E-Maxx's transmitter and receiver could not be used, since its receiver was only 3 channels. Satisfactory versions of these items are manufactured by Sanwa, as part of their Airtronics VG400 Digital Proportional Radio Control System, and were purchased by the Tigernauts. This system includes the transmitter, 4-channel receiver, and four servos. The group applied the Sanwa equipment to the concept vehicle. Channel 3 on the receiver is allocated for "throttle," or controlling the ESC. This is mapped onto the transmitter as the left joystick moving vertically—away from the user for forward, and towards the user for reverse. Channel 4 is used for a servo that will steer the vehicle—mapped to the left joystick moving horizontally, with left movement for the vehicle turning left and right movement for the vehicle turning right. Channel 2 is used for panning the mounted camera via servo motor, while tilting the camera via servo motor utilizes channel 1 of the receiver.

The video camera is housed within and moves using a pan-tilt assembly. The assembly is constructed with two servo motors—one servo motor is oriented vertically, while the other is oriented horizontally (Fig. 2.2). The motor oriented vertically is mounted to a platform, while the servo's wheel is indirectly mounted to the horizontal servo. The camera is mounted atop the

horizontal servo's wheel. Thus, when the user transmits along channel 2 (the right joystick is manipulated vertically), the vertical servo's wheel moves as desired--with away from the user meaning "tilt down" and towards the user meaning "tilt up." This vertical servo's wheel tilts the horizontal servo as well as the camera, thus tilting the camera the desired direction. Transmitting a command by moving the right joystick horizontally left or right allows the user to pan the camera left or right using the horizontal servo's wheel (on channel 1). Panning and tilting the camera at the same time is possible, but releasing the joystick (or allowing it to return to its set point) will also cause the camera to return to its original orientation.

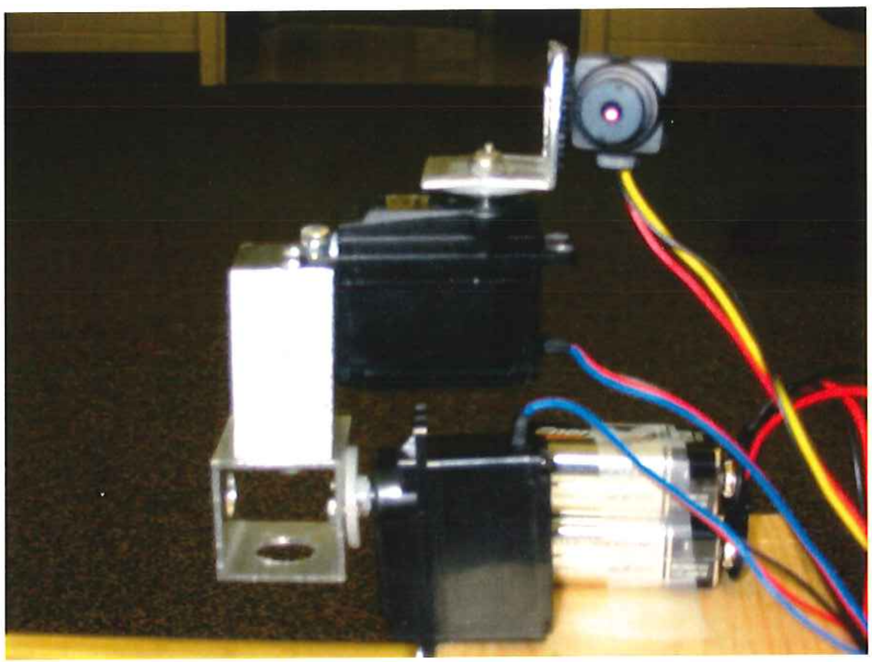

Figure 2.2 Pan-Tilt Assembly

The pan-tilt assembly allows the Tigernauts to see a multitude of objects from various angles. This is a necessary capability when testing along an obstacle course occurs—one sees through the video camera what the rover's suspension is about to experience.

The RC components the Tigernauts have utilized successfully propel and steer the concept vehicle of Red Rover. Radio transmission takes place at 78 MHz, with negligible delay between the command given by the user and the action by the vehicle. Sufficient battery power is available for the consumption of the RC components. With these requirements met, the concept vehicle of Red Rover can move in the direction of the next (or perhaps nearest) obstacle.

Frame and Suspension

I. Project Requirements and Restraints

One of the main goals of the frame and suspension of the prototype will be to resemble the concept vehicle as much as possible. Some additions and alterations are necessary and will be discussed later. The function of the prototype from the mechanical aspect will be to have a representative suspension to that of the prototype, meaning that the combination of springs and dampers should behave similarly to what the concept would have. Since the concept employed Magneto-Rheological shocks, an active dampening system, it will not be used in the prototype due to cost and size limitations. Also, the use of these special shocks would add to the complexity of modeling the suspension.

II. Final Design Concept

The first task of the prototype is to make the design easy to produce and functional considering its smaller size. One option is to have each individual component made from the CAD drawings and making an identical model of the concept vehicle. This option, although desirable, would require an enormous amount of time and money. Another alternative is to use existing pieces from a smaller vehicle and modify the design to fit these components. This idea would use parts from a radio controlled (RC) vehicle. The parts of the concept to be replaced would be the steering and drive-train systems. This option would cost considerably less and the parts mentioned could be obtained relatively easily and quickly.

Another challenge for the prototype is to choose a scaling factor for the dimensions of the concept vehicle. This value should make the rover small enough to be easily handled and make the fabrication cost less due to already existing material dimensions. If parts are used from an existing RC vehicle, the frame should be of comparable size for the parts to easily transfer to the prototype. Also, the material selection for the prototype will be another decision to be made. The material from the concept (aluminum-magnesium alloy) is very expensive and hard to machine so it will not be used. The prototype will need to be made from a metallic material that can easily be formed into the needed parts.

The dimensional scale chosen for the prototype was 1:6, which would give it a 20" x 12" footprint (10' x 6' on the concept). This size will allow the vehicle to be approximately the size of an RC truck. In addition, the diameter of the tubes used on the frame and arms will be ½", which is a readily available size for most metals. As previously mentioned, an RC truck (Traxxas E-Maxx model 3906) was bought and cannibalized to use the steering and drive-train parts. An entire vehicle was purchased due to the monetary savings over buying all of the individual parts. The mechanical components of the RC truck to be used include the wheels, tires, gears, steering arms, tie rods, U-joints, shocks, and springs. The suspension of the RC truck is ideal for this application because of the variability of both the shocks and springs, which is necessary in completing the model of the rover. Spacers can be added to the springs, changing their effective coefficient and fluid can either be added or removed from the shocks to change the damping coefficient. In Figure 3.1 below is the rover that was constructed.

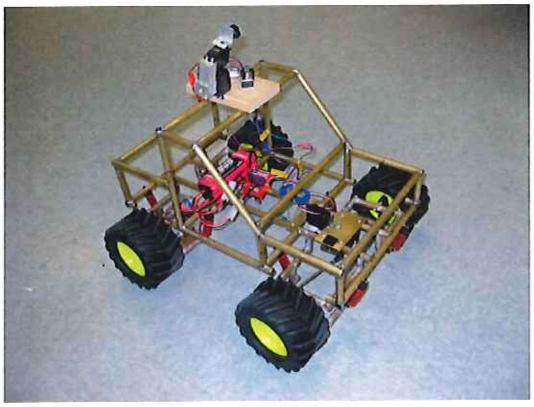

Figure 3.1 Prototype Rover

In order to use the RC parts, the control arms had to be completely redesigned. This manifestation is shown below in Figure 3.2. This control arm allows for the same design to be used at each wheel.

and

into

Figure 3.2 New Control Arm Design

The two small extrusions at the front of the control arm are where the steering arm will attach. The drive motors are still located in the rear, but simply connecting them to the wheel would not be practical for this application. In the concept rover, a planetary gear system was used inside the rear wheel itself to maximize the high rotational speed of the motor and convert it into usable torque. For the prototype, an external gear is used along with a newly designed fixture, and then mounted onto the platform of the rear arm. This is shown in Figure 3.3.

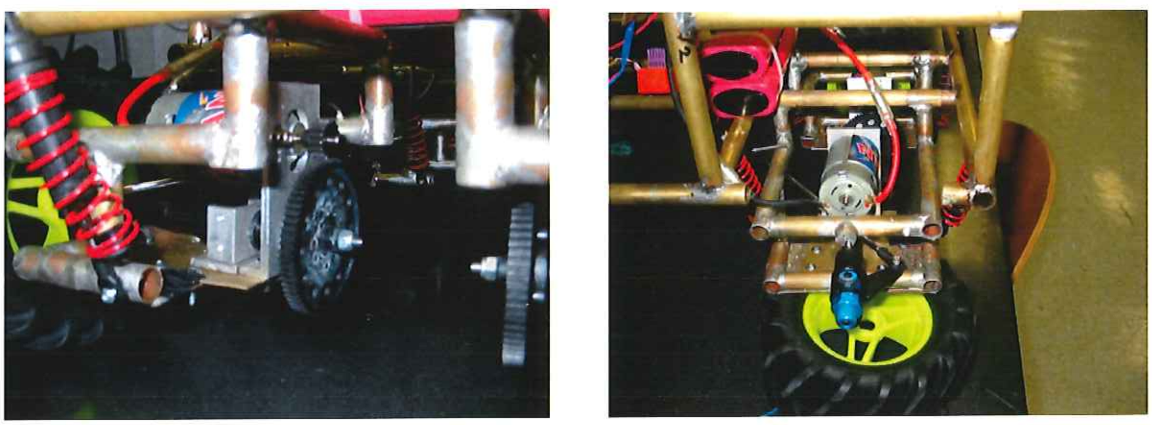

Figure 3.3 Rear Control Arm Configuration

The two front arms will not have this platform and will still be used in steering the vehicle. Having only one control arm design makes it much easier to manufacture, which was one of the primary goals of the project.

Brass was chosen as the material to fabricate the frame and control arms. This decision was made by Joel, the person who started building the rover. Brass is a relatively light material and it can be soldered rather than welded, making it easier to deal with. Also, the use of hollow, ½" tubes minimizes the weight of the rover.

In creating an effective suspension, the key element is to minimize the transmittance of the system, which is the amount of force felt by the frame and operators when compared to the impact induced by the road on the control arms. Methods in doing this will be outlined in the following section of the report.

Position Estimation & Suspension Analyzing System

I. Project Requirements and Restraints

The position estimation system (PES) is required to generate position data that tracks the rover as it travels over a given path during a finite length of time. These data are used to generate the rover's traveled path, a two-dimensional plot which presents the rover's travels along the x, y, and z axes during a fixed interval. A restraint of the PES is that with our hardware, we are currently limited to the use of LabVIEW, a computer-based data acquisition package.[10]. This implies that the rover is tethered to a computer running the data acquisition program. The testing of Red Rover is therefore limited to a ten-foot path next to the computer. The suspension analyzing system (SAS) utilizes the same data from the accelerometers to determine the efficiency of the suspension system. It compares the transmissibility of the arm-mounted accelerometer with that of the frame-mounted accelerometer.

II. Design Plan/Methodology

Two tri-axial, analog accelerometers have been selected for use in analyzing the suspension system and the PES. As demonstrated in Figure 4.1, one accelerometer is mounted to the frame of the vehicle, and the other is mounted to the arm. The accelerometers are mounted using heavy-duty Velcro. By analyzing the difference in accelerations experienced by the arm accelerometer and the frame accelerometer in the Z-direction, it is possible to study the effectiveness of the suspension system.

[10] Previously, the design included an onboard data logger as the data acquisition system, but the sampling rate of the data logger was too low to generate useful data for this project. Other data loggers were investigated, but all models encountered sampled no faster than 1 Hz, which was unacceptable for this project.

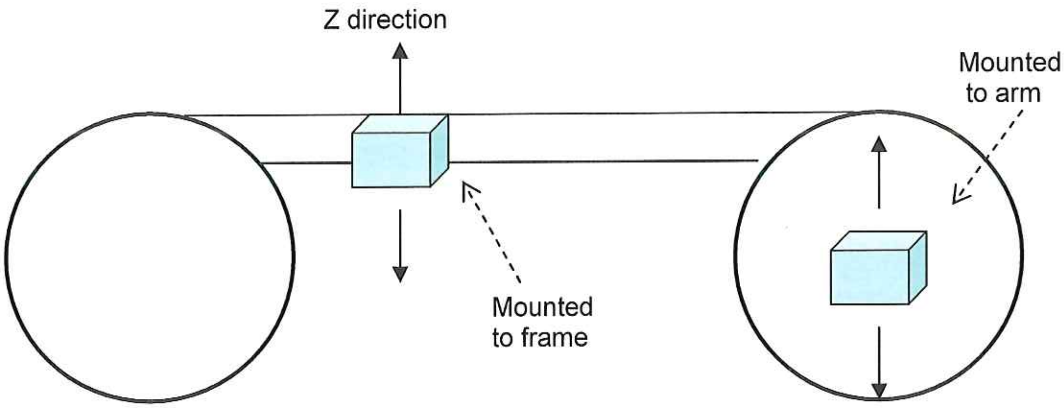

Figure 4.1 Analyzing the Suspension System

One would anticipate the frame-mounted accelerometer to experience oscillations with decreased frequency when compared to the arm-mounted accelerometer if the suspension system is working properly.

i. Suspension Analyzing System

The accelerometers are mounted to Red Rover using heavy-duty Velcro. The output of the accelerometers is connected to Labview using 10 ft. long cable, allowing the rover to run the length of the track shown in Figure 4.2. LabVIEW is utilized to acquire accelerometer data for further processing.

Experiment One: Impulse Drop Test

1. Subject the rover to a five-inch vertical drop. Sample Z-channel of accelerometers on arm and frame at 250 Hz.
2. Repeat two more times, record data.

Experiment Two: Track Test

1. Run the rover over the track in a straight line. Sample Z-channel of accelerometers on arm and frame at 250 Hz.
2. Analyze data from the first run, and adjust the suspension system as needed by adding/subtracting ballast.

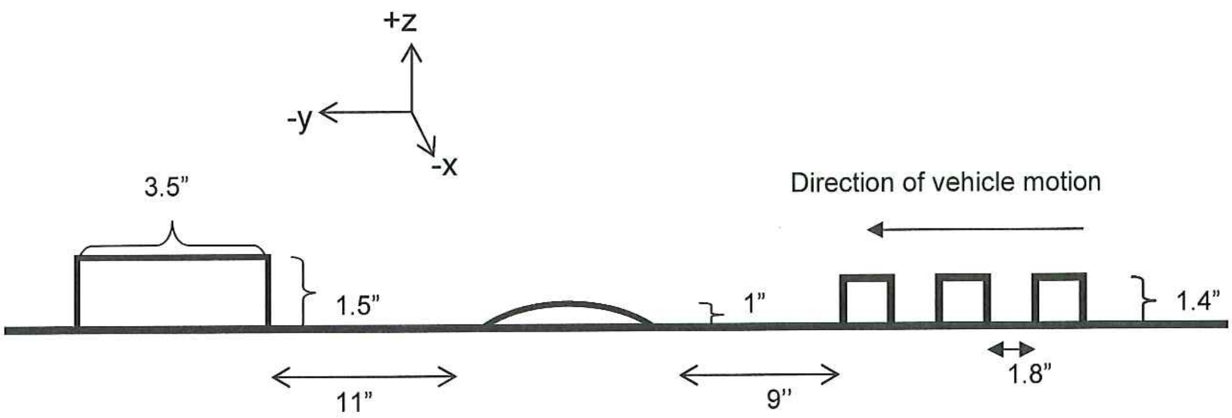

Figure 4.2 Track for testing of SAS and PES

ii. Position Estimation System

1. Run the rover on the track in a straight line at the slowest speed setting.
2. Sample X, Y, Z channels from one accelerometer at 250 Hz.
3. Generate position data from accelerometer readings using rectangular approximations.
4. Compare plot of position data with known path of rover.

III. Final Design Concept

Suspension Analyzing System -- Results

After executing the experiments outlined in the Design Plan/Methodology section, the performance of the suspension system can be seen in the following figures. Data from *Experiment One* are plotted in Figure 4.3.

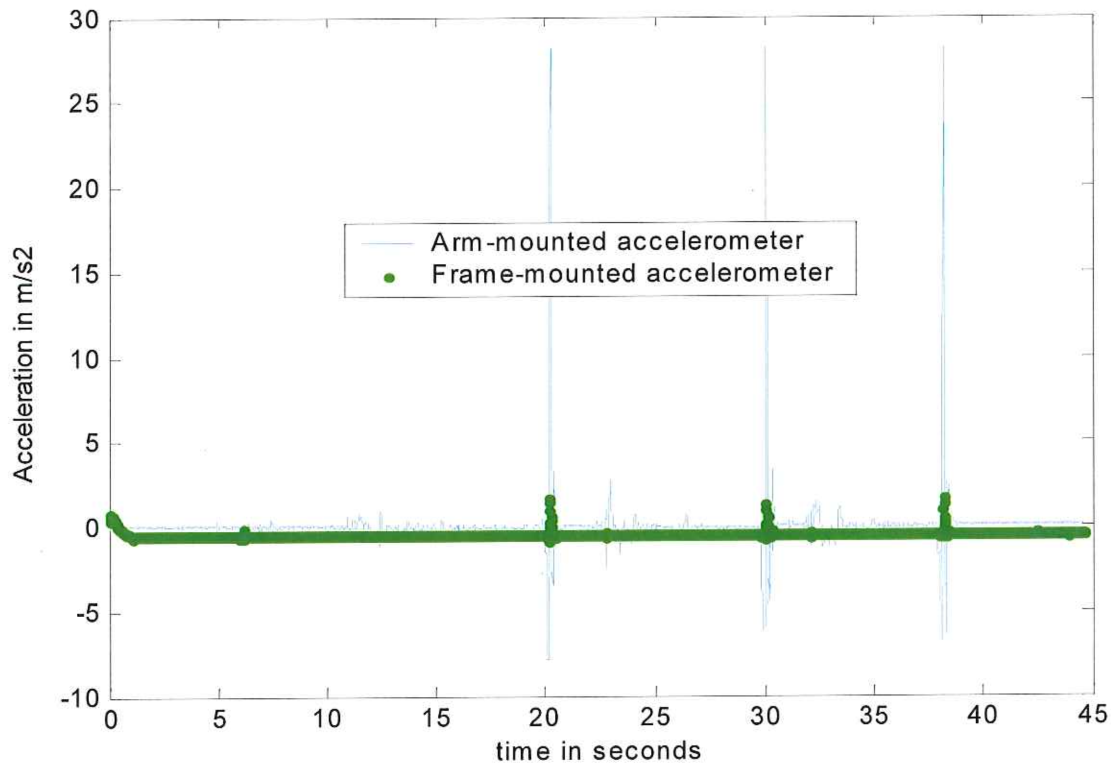

Figure 4.3 Suspension System Performance for Impulse-Drop Test

The figure demonstrates that the suspension system of Red Rover functions well during an impulse-drop test. The large accelerations experienced by the arm-mounted accelerometer are markedly reduced in the frame-mounted accelerometers. This implies that the suspension system efficiently dampens out the impulse.

Results from the Track Test are found in Figure 4.4. The frame-mounted accelerometer demonstrates accelerations with significantly smaller amplitude than the arm-mounted accelerometer. The three obstacles in the track are observed by increased accelerations at approximately time = 2 seconds, time = 7.5 seconds, and time = 11 seconds. As the rover travels over the obstacles in the track, the impact on the suspension system from the obstacles is significantly dampened so that the frame-mounted accelerometer experiences a near-smooth ride in comparison with the arm-mounted accelerometer. The data indicate that the suspension

system if functioning properly and that the transmittance mentioned earlier is being kept to a minimum.

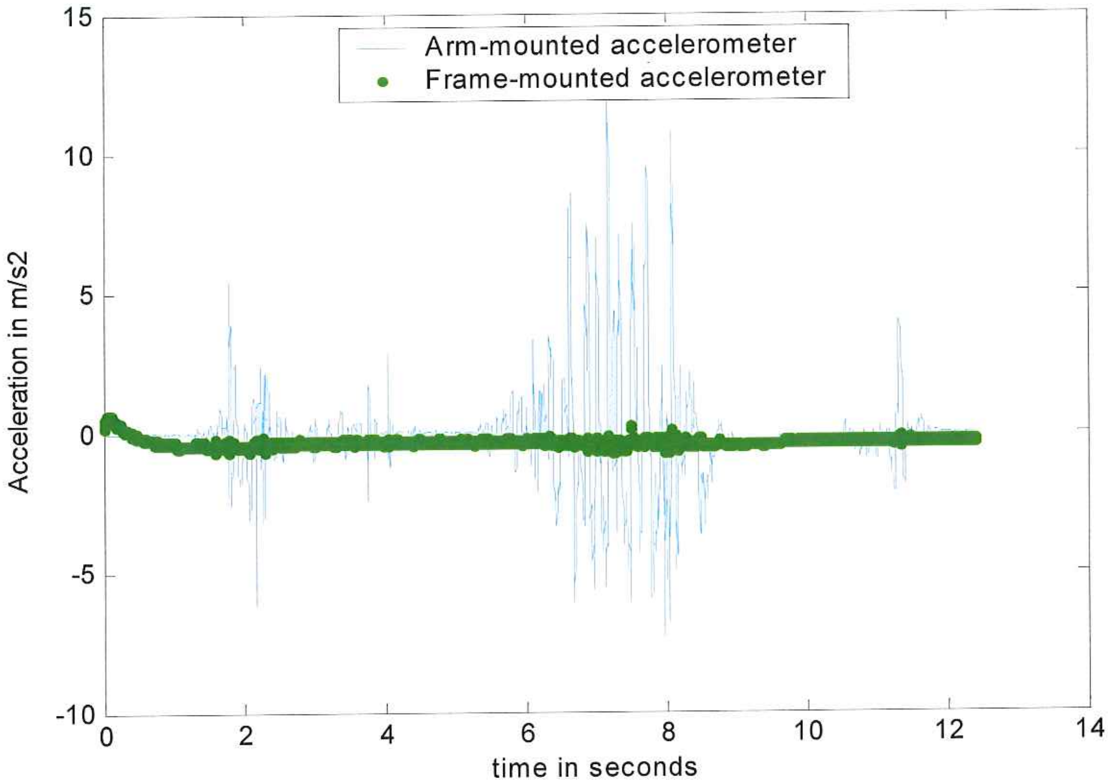

Figure 4.4 Suspension System Performance for Track Test

The data generated by the SAS are valuable information to the improvement of the rover design. They could be used repeatedly to enhance the suspension system of the rover and make it more suited to the design purpose: traversing a Martian environment while minimizing the vibrations experienced by passengers and payload of Red Rover.

IV. Position Estimation System -- Results

Using a rectangular approximation method of integration, the acceleration data collected by the accelerometers are used to compute position data. This information is used to generate a 2-dimensional plot. Figure 4.0 shows the path generated the PES which approximates the actual path taken by the rover over the track. Recall that as the rover traveled over the track, the

orientation of the accelerometers was such that the forward direction was the negative-y direction (see Figure 4.5).

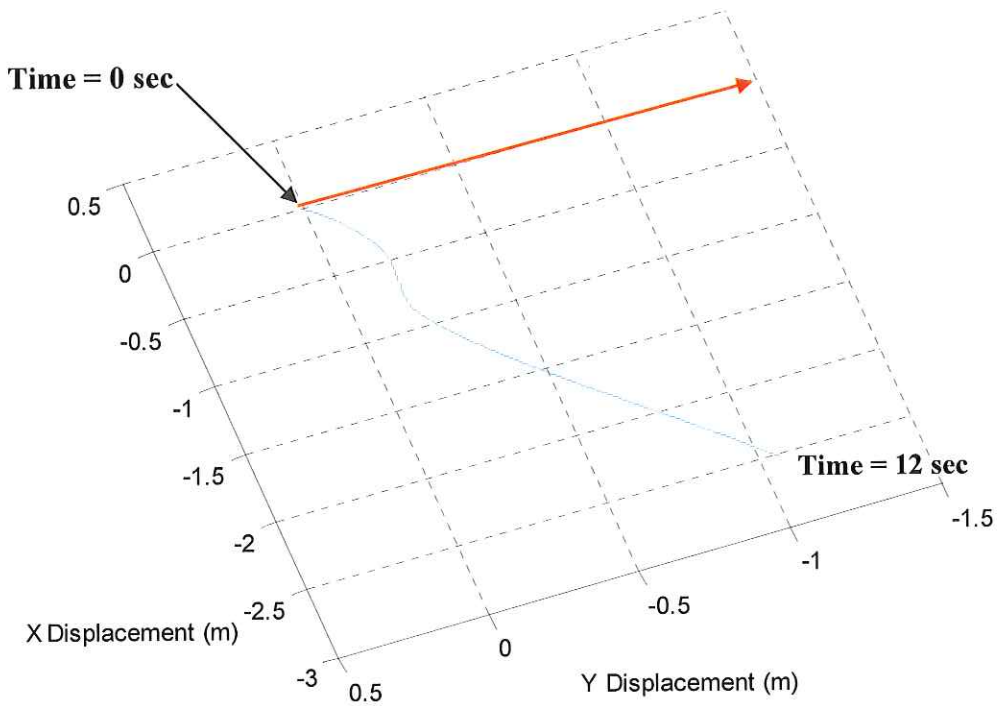

Figure 4.5 Position Estimate for Rover's Path

As one might deduce from the plot, the PES is not an error-free method of position tracking. The actual path of the rover is indicated by the red arrow in Figure 4.5. As one can observe, data indicate that the rover experienced displacement in the x-direction. This implies that there is some drift in the data, which is most likely due to the inaccuracies of the rectangular approximation method of integration used to obtain position information. Small errors can become extremely large during this integration process, and impact the end result. However, the PES approximates the path of the rover well considering the hardware and processing techniques utilized in this project. With more time and hardware resources, the PES could be greatly enhanced and fine-tuned[11].

[11] A good model for a PES is described in:

Video System

I. Project Requirements and Restraints

The overall requirement of the video system is to develop a means for remotely acquiring live image data from the RC vehicle, while easily and readily being able to modify parameters of the data being acquired. In fulfilling this requirement, there are several restraints under which a solution must be devised.

First and foremost are the size and weight of any onboard video hardware. Due to the small size of the RC vehicle, the size and weight of the video system must be minimized. Naturally, one of the goals of the video system is to maximize the system's range of transmission/reception.

As noted above in the video system objective, a quick and easy method for remotely adjusting video/image parameters such as frame rate and image resolution must be available to users of the system. Since the group is ultimately attempting to create an actual mars rover simulation, data communication with the video system must be carried out from a remote location.

The use of a PC is almost inevitable in satisfying the main requirement of the video system. Therefore, additional software restraints are created. The software used must provide capabilities for accessing live video streams. There must also be capabilities for achieving decent frame rates (i.e. 30 fps). The software/hardware combination must also allow for configuration and modification of video hardware features. Lastly, 'ease of use' hints at the development of a graphical user interface (GUI), which means that software must be compatible with a GUI programming package.

II. Final Concept

The video system is operated under the control of a video GUI. Image data are transmitted via radio frequency (RF) wireless technology. This particular technology provides the best transmission/reception capabilities under the high-interference environment in which the

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Borenstein, J., Ojeda, L. 2001, "Improved Position Estimation for Mobile Robots on Rough Terrain Using Attitude Information." *Technical Report UM-ME-01-01, The University of Michigan,* Ann Arbor, MI.

system will be tested and used. A standard NTSC video output is provided through an RF receiver, which is then streamed through a PCI video capture card and converted into a PC-compatible signal. The video signal is then available to a video GUI. This data flow process is shown below in Figure 5.1.

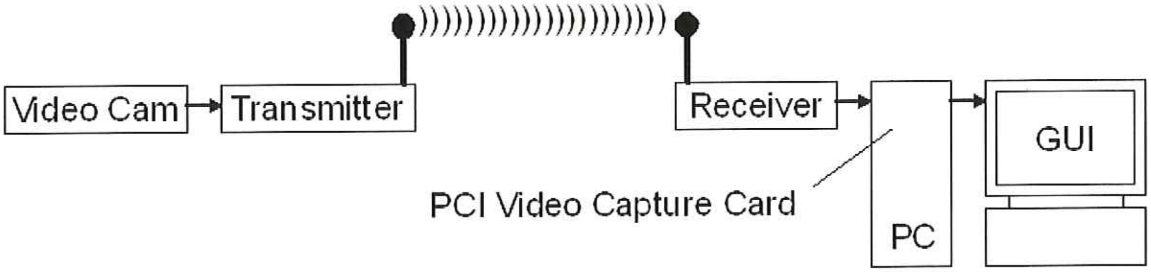
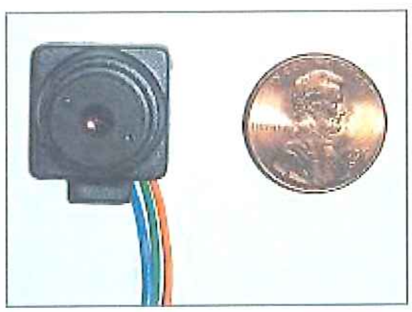


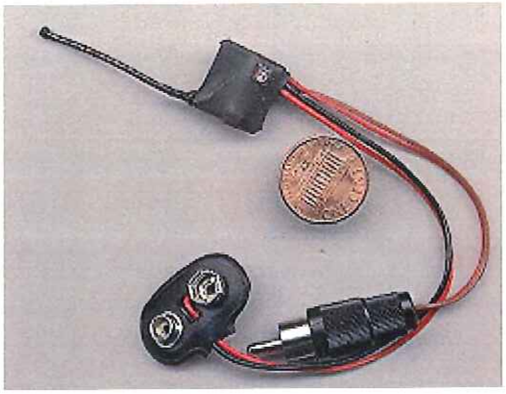
Figure 5.1 Video System Data Flow Diagram

Miniature video components are used to minimize the size and weight of the onboard video system. The onboard video system is comprised of only two hardware components[12]: a color video camera and a video transmitter, which, in total, weigh 22.723 grams. Off-board video system hardware includes a video receiver and a PCI video capture card. Onboard components are shown below in Figure 5.2.



(a) Miniature Color Video Camera

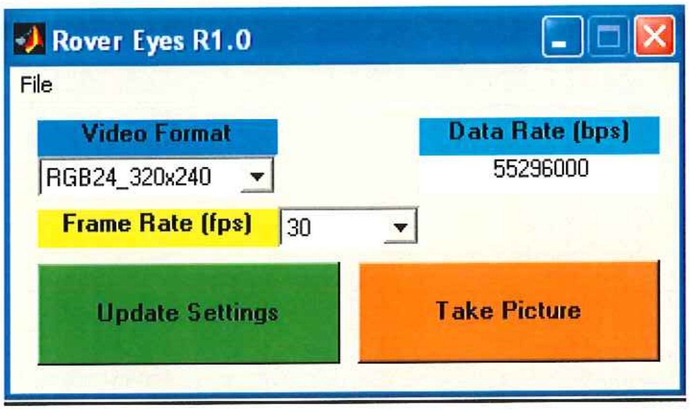
[12] this excludes the video system's power supplies and pan-tilt mount



(b) 900 MHz Miniature Video Transmitter

Figure 5.2 Video System Hardware

Mathworks' MATLAB with its image acquisition toolbox and GUI developer kit, GUIDE, are used to develop the video system GUI. The video GUI makes the ultimate goal of the video system possible, as it provides an interface through which image data can be acquired and modified. The final video GUI is shown below in Figure 5.3. The GUI comprises two windows: a control window (Figure 5.3.a) and a video preview window (Figure 5.3.b).



(a) Video Control Window

(b) Video Preview Window

Figure 5.3 Video GUI

The control window provides a user with controls which allow the user to configure video/image parameters. It is only after a user selects the desired video settings and clicks on the 'Update Settings' pushbutton that the video/image settings are configured and then reflected in the image preview window. A user can choose between eighteen different video formats and eight different frame rates using the appropriate pull-down menus. Available image resolutions range from 320-by-240 to 768-by-576 pixels. Frame rate can be varied between 1 and 30 fps. The control window also gives a user the ability to acquire snapshots using the 'Take Picture' pushbutton.

The control window also displays the rate at which image data is being displayed in the image preview window. This value simulates the rate at which image data would be transferred from the actual video system designed in the first semester of the Red Rover project. The data rate value that is displayed does not consider the compression ratio of 150:1 specified in the first semester video system design. That is, the rate at which image data would be transferred from the actual video system using the compression method specified in the rover design would be reduced by a factor of 150. The rate at which image data is being displayed in the image preview

window ranges from approximately 0.7 to 318.5 Mbps. With the compression of the actual video system, this translates to approximately 0.005 to 2.1 Mbps. Recall that the maximum allowable data transmission rate specified in the rover design was 6 Mbps.

Conclusion

The Tigernauts have created a scaled RC version of the rover that they designed in their previous semester of participation in the TSGC Design Challenge. The rover is equipped with control, telemetry, and data logging capabilities.

All of the TSGC Design Challenge option areas have been completed. The meeting presentation option area has been fulfilled thanks to an IEEE/ASME professional level meeting presentation on February 19, 2004 at Trinity University. An outreach activity was conducted on April 1, 2004. The Tigernauts spoke to an introductory engineering class at the University of Texas – San Antonio to fulfill this option area (see Appendix E for details). The team has updated their website (Appendix F) and participated in the spring 2004 TSGC Design Challenge Showcase to fulfill the website and team travel option areas.

The team collaborated with individuals skilled in areas related to the tasks that had to be carried out to complete the project. The team's collaboration efforts included seeking guidance from electronics technician Ernest Romo, machine shop specialist Manuel Garza, and Al Robles, an experienced RC Hobbyist. Advice was also sought out from the team's faculty advisor, Dr. Kevin Nickels, as well as their mentor, Dr. Humboldt Mandell, a research fellow with UT's Center for Space Research and retired manager of JSC's Exploration Office.

The Tigernauts have been successful in accomplishing their objectives for the Red Rover project. The group is grateful to have had the opportunity to work on such a project and gain the valuable experience that they did. As intended, the project surely has been a capstone undergraduate engineering experience.

The Tigernauts will be graduating from college in the spring of 2004. After graduation, Michael Poteet will be entering industry, hopefully to do some automotive engineering work. Kathleen Lachance will begin graduate studies in biomedical engineering at UCLA. Landon

Nemoto will pursue graduate study in Dynamic Systems and Controls from the University of Texas at Austin beginning in the fall. Roberto Aranibar will begin graduate study in Electrical Engineering in the fall of 2004.

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
3/12	Level II
3/25	Educational outreach option area, UTSA
3/27	Trinity University Family Weekend – poster presentation
4/8	Draft of Level III/Final report
4/9	RC rover complete and working
4/13	Draft of Showcase/Final presentation
4/15	Level III/Final Report
4/16	Website development completed
4/18-19	Showcase
4/22	Trinity University Final Presentation

Appendix C: Project Budget Report

Transactions as of 4-23-2004:

9/26/2003	Fall Level I Completion	$ 125.00
10/6/2003	Fall Option Area I	$ 125.00
10/10/2003	Fall Option Area II	$ 125.00
10/13/2003	SolidWorks	$ (47.00)
10/17/2003	Fall Level II Completion	$ 125.00
11/7/2003	Team Dinner	$ (57.43)
11/7/2003	Team Dinner	$ (12.76)
11/7/2003	Team Dinner	$ (10.77)
11/7/2003	Team Dinner	$ (12.29)
11/7/2003	Team Dinner	$ (23.91)
11/10/2003	Hotel balance	$ (361.92)
11/14/2003	Fall Level III Completion	$ 125.00
11/14/2003	Fall Option Area III	$ 125.00
11/16/2003	Fall Option Area IV	$ 500.00
11/20/2003	Travel Reimbursement, KN	$ (69.03)
11/20/2003	Kinko's Publishing of Report	$ (76.85)
12/17/2003	Travel Reimbursement, Roberto	$ (98.57)
1/27/2004	Spy Stuff, Roberto	$ (552.45)
1/27/2004	Crossbow, Kathleen	$ (394.00)
2/13/2004	TSGC bonus	$ 400.00
2/13/2004	Spring Level I Completion	$ 125.00
2/23/2004	MATLAB, Kathleen	$ (116.80)
3/4/2004	Traxxas Truck/parts	$ (465.14)
3/9/2004	imAQ Matlab Toolbox	$ (200.00)
3/11/2004	Receiver/Transmitter combo	$ (149.99)
3/12/2004	Spring Level II Completion	$ 125.00
3/12/2004	Option Area II	$ 125.00
4/6/2004	RC batteries	$ 39.98
4/13/2004	RC parts (Brass, Welding)	$ (146.17)
4/19/2004	Showcase Travel Expenses	$ (578.57)
4/19/2004	Concept Vehicle Supplies	$ (126.75)
	Remainder:	$(1,435.42)

Projected Payment:

4/23/2004	Spring Level III Completion	$ 125.00
4/23/2004	Option Area I	$ 125.00
4/23/2004	Option Area III	$ 125.00
4/23/2004	Option Area IV	$ 500.00
	Total Payment Due:	$ 875.00
	With Trinity's contribution:	$ 1,000.00
	Remainder:	**$ 439.58**

Appendix D: Project Time Report

System	Time Spent This Semester (Hours)
Video	162.25
Position Estimation	144.5
Frame and Suspension	157.5
RC vehicle design	156.75

Total Hours Spent on Red Rover	**621**

Appendix E: Outreach Option Area Report

The Trinity Tigernauts completed Option Area I by speaking to a class at the University of Texas at San Antonio. Although Option Area I is normally intended for outreach activities toward groups in grades K-12, an exception was made by the TSGC Design Challenge Program Coordinator for the Tigernauts to present to first-year engineering students.

The class was an introductory engineering course primarily composed of first-year undergraduate engineering students under the instruction of Dr. Fred Hudson, a professor of electrical engineering at UTSA. The Tigernauts prepared and presented an overview of their TSGC Design Challenge topic, with an emphasis on how the skills that the group acquired throughout their course of education in engineering were applied to the tasks involved in the project.

The activity was very enjoyable for the Tigernauts. The Tigernauts were very impressed by the degree of interest of the students and their good questions. The presentation that was used in conducting the outreach activity is attached, and a photograph of the team with the Dr. Fred Hudson after the activity is shown below.

To verify the Tigernauts completion of this option area, one can contact Dr. Fred Hudson at 210-458-5519 or fhudson@utsa.edu.

Figure E.1. Tigernauts at UTSA Outreach.

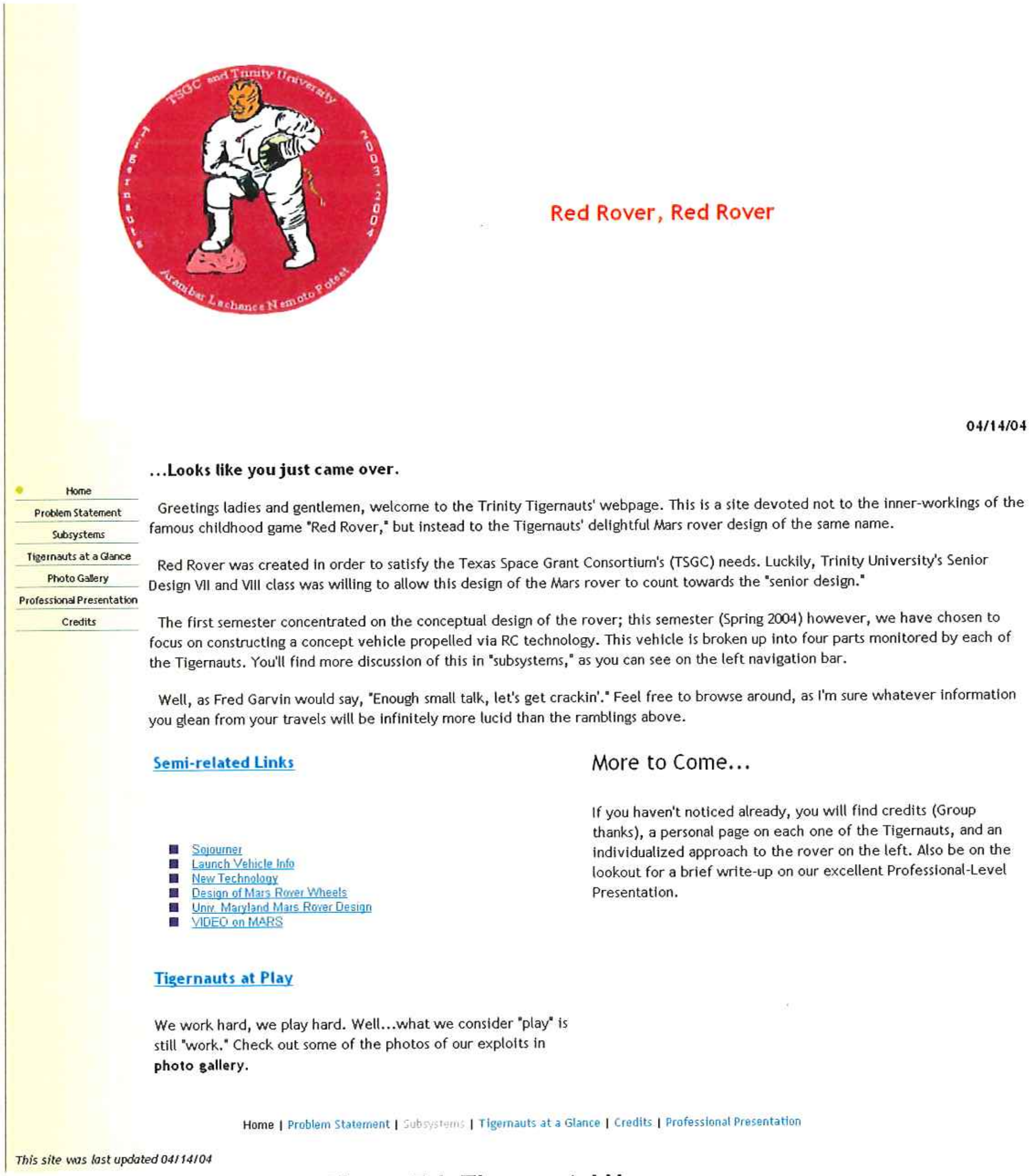
Appendix F: Website Report

Attached is a reproduction of the opening page of the Tigernauts' website. The URL of the website is http://www.engr.trinity.edu/~lnemoto.

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: RC technology as well as a "pan and tilt" design for the video system, Frame and Suspension, Video System, and Position Estimation. "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 previous semester's K-12 activity and a group dinner. "Professional Presentation" is a page for a report regarding the outreach activity in which the Tigernauts participated—a professional-level presentation given to a joint ASME and IEEE meeting. 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

04/14/04

Home
Problem Statement
Subsystems
Tigernauts at a Glance
Photo Gallery
Professional Presentation
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."

The first semester concentrated on the conceptual design of the rover; this semester (Spring 2004) however, we have chosen to focus on constructing a concept vehicle propelled via RC technology. This vehicle is broken up into four parts monitored by each of the Tigernauts. You'll find more discussion of this in "subsystems," as you can see on the left navigation bar.

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 an individualized approach to the rover on the left. Also be on the lookout for a brief write-up on our excellent Professional-Level Presentation.

Tigernauts at Play

We work hard, we play hard. Well...what we consider "play" is still "work." Check out some of the photos of our exploits in **photo gallery**.

Home | Problem Statement | Subsystems | Tigernauts at a Glance | Credits | Professional Presentation

This site was last updated 04/14/04

Figure F.1. Tigernauts' Homepage.