RoverSAT

The rover is a self contained package that needs to survive impact, autonomously drive, and capture images of its landing site.

Students
Nate Johnson
Ross MacGregor
Drew Johnson
Mike Steigerwald
Steve Assmus
John Rhoades

Advisor
Dr. Paul Wilbur

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1.0 Mission Statement

The 2005 DemoSat project was to design a rover to survive impact and take pictures upon landing. The rover is self contained for a protected landing. After landing wheels are unlocked and deployed from the inside lifting independent of the side of landing. Likewise, forward, reverse, and turning motions were achieved. Teamwork between interdisciplinary engineers is encouraged throughout project development.

2.0 Mission Requirements and Description

Basic requirements included the mass of no more than 1.5-kg, however our team decided to attempt to be around 80% of this mass. With tow projects underway, the budget was split in half which allowed for only $1000.00 per project. Basic constraints for this project included impact survival, capturing and storing pictures, and navigating the landing site. Other constraints were imposed deadline throughout development and a completion deadline three weeks prior to launch date for testing and refinement.

3.0 Payload Design

Mechanical Design

Note: More detailed descriptions it is available upon request.

Chassis-

Through design selection a monocoque was determined to be the most reliable way to achieve the strength desired under the mass constraint. Because the rover shifting within the landing structure has proven to be problematic in previous years, a self contained structure was preferable. A semi-triangular design was decided upon which implements only three wheels, thereby reducing the weight and the number of servos need for operation. Driving it in the direction of the side with two wheels, leaving the third as a free spinning free wheel, a gain reduced the number of servos and made the rover a tail-dragger design. This design increased the stability and decreased the chance of nose diving into the ground. With the absence of a shell the structure was designed to handle the appropriate loads during impact. The analysis was done through Pro/Mechanica using the worst case scenario of a 35 mph impact velocity equivalent to a 5-g force. See Analysis section for further detail. The basic mold was designed to contain ample room for fastening the internal components while directing the loads to the surrounding structure walls.

Figure 3: Monocoque Chassis
Wheel Arms-

The wheel arms were designed to be light weight and provide a means to mount the drive servos, yet the rear lacks a drive servo. As can be seen from the figure above, the wheel arms contain a slight taper design from the top with a .75-inch radius to the bottom with a .625-inch radius. At the top of each wheel arm a servo horn was installed. A .25-inch hole was drilled to accept the center hub. On each side of the hub one .0625-inch mounting hole was drilled to hold the horn in place.

Wheels-

The basic design for the wheels was taken from the previous year’s design because of the excellent strength to weight ratio. A three spoke design with rounded interior corners was used, while still allowing for a .375-inch hub, see Figure 5. However, a new Pro/E model was generated for a smaller diameter wheel that would recess within the designed chassis. Teeth were incorporated around the perimeter to supply additional traction. Another design feature is the holes around the perimeter which were primarily used for securing the part during manufacture.

Locking Mechanism-

The locking mechanism was designed to lock to the tether and secure all wheel arms from premature deployment. A cross design was implemented to attach all locking rods to the locking servo horn. These rods passed though .125-inch holes in the wheel arms to secure in the undeployed state. Slots were used to lock the wheel arms in their deployed state in either direction, to allow for slight inaccuracies in the pitch servos. All rods were designed to eliminate direct stress on the locking servo. The tether lock is designed to completely detach from the chassis. Two slots were placed on the tub section of the chassis for the tether lock channels to fit.
Through these slots an “N” shape rotating plate secures these channels from the inside with tabs from the locking plate. When the locking servo unlocks, the tabs slide out from the channels and releases the tether lock. Springs were added between the chassis and tether lock to ensure no interference from the tether during wheel deployment. Seen right is the locking device for tether attachment. The top is shown in the locked position while the bottom is shown in the unlocked position.

Figure 7: Tether Locking

Servo Motors-

With weight and torque the biggest concerns the GWS Micro 2BBMG servo motor was selected as the motors with the best torque to weight ratio. These motors actuate the locking of the wheel arms, the detachment from the tether, and trigger driving the wheels. These motors were also selected due to familiarity with GWS and with the electrical engineers request. The two motors implemented for driving the wheels were modified for continuous rotation. The modification will be discussed in detail within manufacturing.

Material Selection-

Due to weight concerns and manufacturing ease, only three materials were given consideration: PCB board, Lexan, and carbon fiber epoxy composite. PCB board and Lexan (both plastics) would provide a strong shape, however complex bends and joints would be difficult to create and severely weaken the designed structure. Because of these weak points, carbon fiber epoxy composite was chosen. Research began with previous years reports by the FSAE race team and their monocoque lay up. The final lay up method and techniques will be further discussed throughout manufacturing.

Mass and Monetary Budget-

Our projected mass was close to 1.2-kg. Just prior to completion the rover was taken apart in order to weigh individual components. These were then put into an excel file and the total mass calculated. Our mass was more than our projected value, but significantly less than the maximum allowable mass. The carbon fiber tub and lid chassis made up the majority of the total mass at 520-g, with a total project weight of 1.3-kg. Our monetary budget was $1000.00. On launch day our team had spent approximately $930.00, with the majority allotted towards electronics and carbon fiber.
Electronic Design

Board-

As in previous years, the board was designed using Eagle CAD. Some of the bigger adjustments from previous years were the addition of another voltage regulator, thickening of the traces that power the darlington drivers, and the separation of the headers for each of the servos. However as a recommendation, we suggest to make all ground traces on the board thicker, as that was the first trace to go this year.

Electrical/Software Design-

Each servo used requires a single pulse width modulation channel. The ATMEGA 32L only has 4 channels, yet our design has 6. To compensate for this, our design allowed us to turn on and shut off servos using darlington drivers. Simply put, we are able to harness every PWM channel, and only power the servos that need to be on. This also helps with power management as each servo pulls around 200 mA.

Landing detection consisted of a 3 way vote, with a majority win solution. The three voters were a pressure sensor, an accelerometer, and a timer. Both the pressure sensor and accelerometer used analog to digital conversion pins. After the voting process had determined that it was on the ground, we put another 20 minute timer in to allow for a margin of error, as well as allow the components inside the rover to heat to temperature.

One of the biggest dependencies on any project is data storage. In our case, we were able to find a module made by Rogue Robotics to communicate to an SD card using RS232 communication. Once the card is formatted, and the data transfer speed was initialized, it was just a matter of opening a file handler, writing the data to the file, and closing the file handler. This allowed 512 MB of storage space for in-flight data, as well as pictures.

The camera used was the same camera that was used last year, the Gameboy Camera. The reason we used this camera is because the camera itself is very easy to interface with. There isn’t actually a CCD in the inside of the camera. Instead, there is a device made my Mitsubishi called the artificial retina. Simply put, with a few different initializations of different registers, you were able to change capturing modes fairly easily, something that was not available on the Gameboy version, yet possible none the less.

4.0 Student Involvement

We had basic team divisions, including a mechanical team consisting of three students and an electrical team consisting of three students. The breakdown in as follows:

Mechanical Engineering Team-
Nate Johnson: Mechanical team leader. Major role included project management and general oversight through development.
Ross MacGregor: Major role included chassis fabrication.
Drew Johnson: Major role included metal fabrication

Note: General design and development was a team effort with individual visual concepts of how the ideas were going to be developed.

**Electrical Engineering Team**

Mike Steigerwald: Major role included: Hardware assembly and programming
Steve Assmus: Major role included: Board Design and Layout, Hardware assembly, and programming.
John Rhoades: Major role included: Programming of the kernel and RS232 communication.

### 5.0 Testing Results

Testing came in two areas including mechanical and electrical. The mechanical testing began CAD analysis. A solid model was generated in Pro/Engineer and load analysis was done. The results from this analysis show that the loads that are expected are well within the limits of our survival threshold. The next test, impact testing, was performed after the majority of the project was complete. This included calculating the drop height for an expected 35-mph impact and then repeatedly dropping the rover form this height in different orientations. Cold temperature tests were also carried out. The test on the servo motors and the batteries were carried over from prior projects. Our focus was on the cold temperature dependency of the carbon fiber epoxy composite, acrylic electronics mount, and aluminum metal work. This process included a cooler and liquid nitrogen in which components were suspended and then loaded.

Testing of the electrical side consisted of virtual testing as well as hardware testing. The board was tested for electrical design (common grounds, power sources, etc) with Eagle CAD. There was also hardware testing on the board itself to verify correct traces. This testing was accomplished via continuity tests with a multimeter. The code of the project was also virtual tested with AVR studio. With this software we were able to monitor the contents of each register inside the ATMEGA 32 as each line of code was executed.

### 6.0 Mission Results

As far as mechanical results the basic structure withstood the impact. Upon locating the rover at its landing site, the chassis was in one piece with no cracks or apparent damage of any sort. However, superficial damage to the foam and scuff marks on the underside were seen indicating the direction of impact concentrated on one of the legs. Once the rover was opened the locking mechanism and locking rods were examined and found to be in good working order. The tether lock was still attached to the locking mechanism,
which was also undamaged upon landing. The plate that covered the rear wheel arm hole was still attached, not bent, and fully functional. Overall the chassis and its components were undamaged and in full working order.

7.0 Conclusions

The biggest issue we had pre-launch was the integration of the code used to demonstrate at the launch readiness review and the overall kernel that was to be used in flight. Upon landing, the rover never deployed. It was determined that the source of the problem could have stemmed from two different areas. The first possible cause of the problem was the pressure sensor. The flash card itself contains data, meaning that the acquisition of in-flight data aspects of the code executed. However, if the pressure sensor failed, the progressing of the code would never have happened. The second possible cause of the failure to deploy is the unreliability of the A/D on the chip. During testing, we had several unreliable moments with the A/D pins of the ATMEGA 32. Previous years yielded similar results on such pins. Such a failure would also cause a lack of progression in our flight code.

8.0 Potential Follow-on Work

This project was a good learning experience and should be available for future DemoSat teams. A detailed report for this project will be available for reference on our type of development, analysis, research, and manufacturing methods. The potential for follow-on work on this project is slight but the experience gained would benefit future DemoSat teams and their efforts.

9.0 Benefits to NASA and Scientific Community

This mission was to encourage future design considerations for NASA. The basic design was to incorporate a shell with the actual chassis, making a solid monocoque. This is done to decrease the cost and the payload mass. Current Mars rovers deployed on Mars include separate rover and base structures. With our all-in-one design risk of separation does not come into play. However, the payloads are very different and our mission does not require us to incorporate the mass NASA needs for communication and other purposes.

10.0 Lessons Learned

One major aspect the mechanical team noticed was the wheel arm deployment method. The method that was decided on in the beginning was to remove the mechanical stop from the servo’s to deploy the wheel arms from the outside. By doing this it would increase the amount of torque that could be applied by an individual servo. This idea was good in theory, but the application and the control proved to be harder than expected. With the mechanical stop removed the servo position relies solely on time. This made it extremely difficult to position accurately with any consistency. I believe next time the
incorporation of these servo motors should be designed for their original movement pattern, unless absolutely necessary for continuous rotation.

After 3 consecutive years of the electrical teams dependency on the ATMEGA 32L microprocessor, we’ve come to the conclusion that it should not be the microprocessor of choice in the upcoming years. Though the ATMEGA theoretically is able to do everything that we want, with such a robust design and with such high aspirations as CSU has had in recent years, the microprocessor is ill-equipped to accomplish them all. Another huge lesson to be learned, yet more on the lines of advice to be given, is the amount of time required to accomplish every goal. This project itself should be a senior design project in our opinion, and as such, the 2.5 month time slot in the summer is a very ambitious goal, especially if one were to redesign everything every year. We would recommend in future attempts at RoverSAT that you choose a different microprocessor (preferable one that is much greater than 8 MHz clock speed) and that you get the board design, layout, and manufacturing done before the summer even begins.