3.3.1 Marble Sorting Machine Project

Principles of Engineering Block 3

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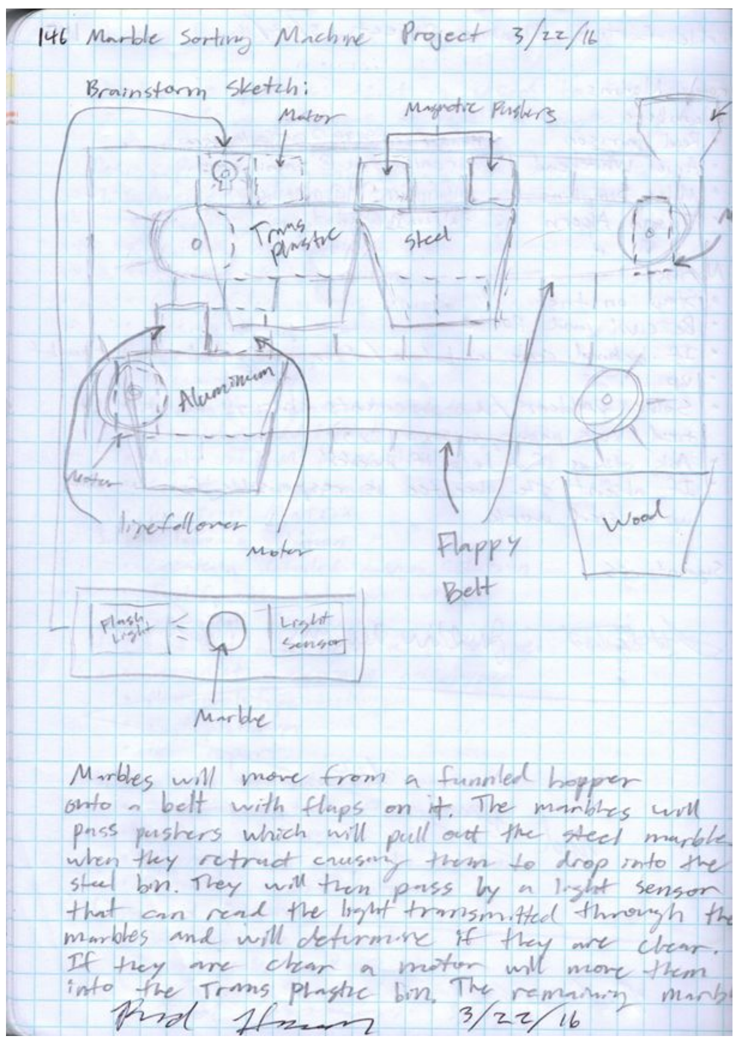
Design Problem:

Recycling is a good way to reuse materials that can be broken down and turned into something else, but sorting through these materials after they reach sorting facilities can be a problem. The design problem we are aiming to address in this project is to build a machine, using a VEX robotics kit, that can autonomously sort several marbles of different materials (each representing a recyclable material) into their own separate designated bins.

Additional constraints are that our machine must retain full control of the marbles at all times, which means no throwing, flinging, bouncing, or any similar action, our machine must successfully sort the marbles from a commingled state, it must be able to identify and separate at least four of the five materials (aluminum, steel, wood, opaque white plastic, and semi-translucent clear plastic) from one another, and it must do all of this in under two minutes.

Brainstorming:

To the right is an image of my brainstorm sketch for the marble sorting machine.



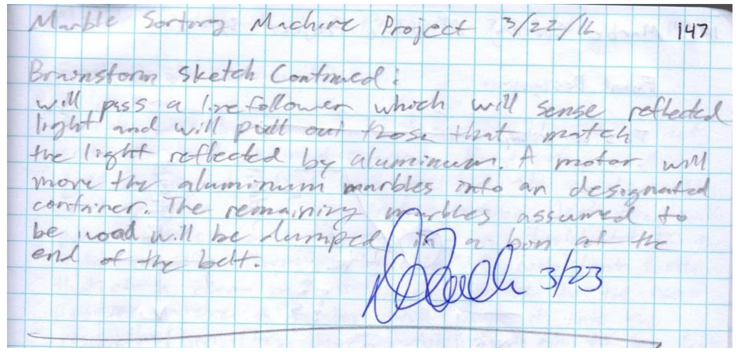
Description:

Marbles will move from a funneled hopper onto a belt with flaps on it. The marbles will pass pushers with magnets which will pull out the steel marbles and move them to a designated steel bin.

The other marbles will continue down the line, and will pass between a light sensor and a flashlight. The light sensor will read the amount of light transmitted through the marbles. If the marble is clear then it will be moved to a clear marble bin by a motor.

The remaining marbles will pass a line-follower which will measure the reflected light off of the marbles. If it senses a value consistent with that of aluminum then it will move those marbles to an aluminum marble bin.

All of the remaining marbles will be assumed as wood and dumped in a box at the end of the belt.



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Brainstorm Sketch Continued:
will pass a line follower which will sense reflected light and will pull out those that match the light reflected by aluminum. A motor will move the aluminum marbles into an designated container. The remaining marbles assumed to be wood will be dumped in a box at the end of the belt.

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Decision Matrix:

To decide on a final design we ranked each of our ideas on the design matrix as seen below.

The criteria we ranked our designs on were difficulty of programming, construction time, speed of sorting, accuracy, and requirements met. Some of the criteria such as difficulty of programming and construction time are a measure of how easily and quickly we think each design will be able to be built. Other criteria such as speed of sorting and accuracy were measures of how we though each design would perform. Lastly the criteria “requirements met” ensures that we check that each of our designs actually meet the base constraints and criteria included in the design brief.

Our ideas all ranked about the same, but Miles’ design had a slight lead over the other three designs as it already incorporated many of the parts that we considered to be the best attributes from the other designs.

Group Members	Difficulty of Programming	Construction Time	Speed of sorting	Accuracy	Requirements met	Total
Ariel	4	4	3	2	5	18
Reid	4	3	2	4	5	18
Justin	5	3	3	2	5	18
Miles	3	4	3	4	5	19

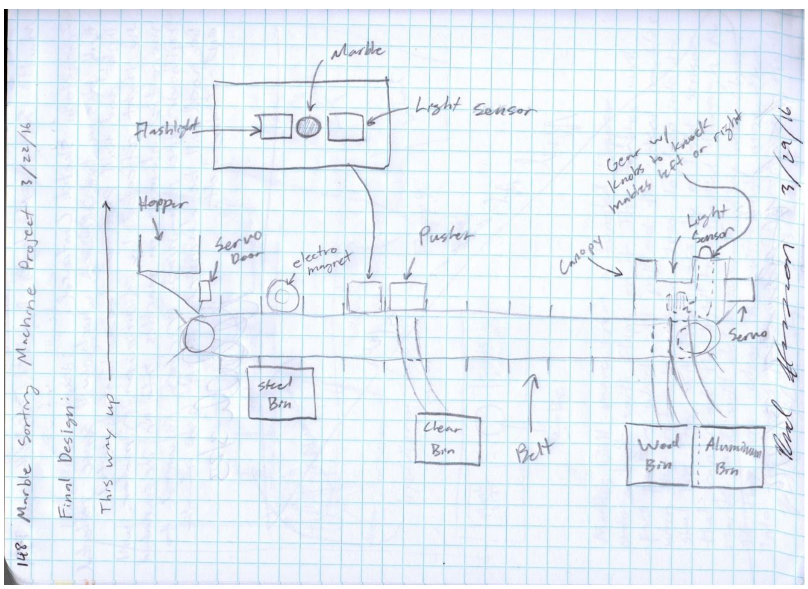
1 --------------------- 5
Worst Best

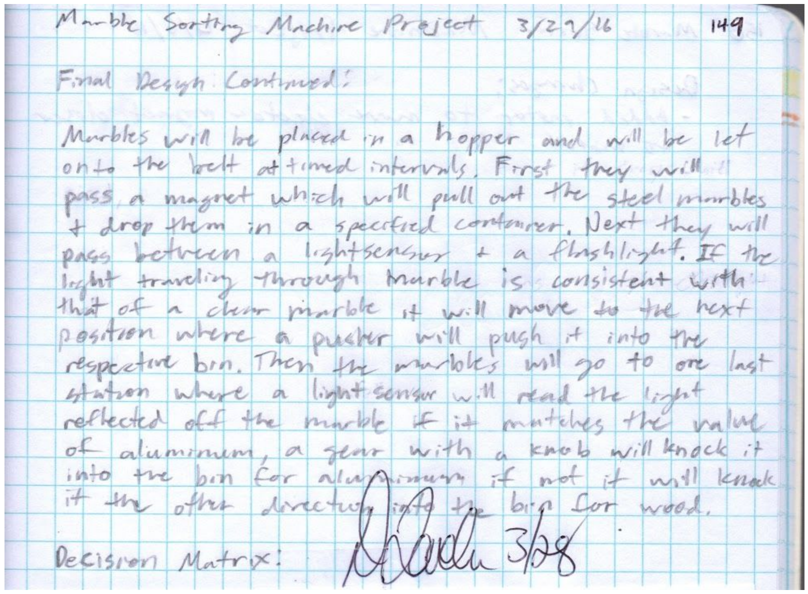
Final Proposed Design:

Below is an image of the final proposed idea for our marble sorter. The final idea is Miles' design.

Description:

Marbles will be placed in a hopper and will be let onto the belt at timed intervals. First they will pass a magnet which will pull out the steel marbles and drop them in a specified container. Next they will pass between a light sensor and a flashlight. If the light passing through the marble is consistent with that of a clear marble it will move to the next position where a pusher will push it into the respective bin. After that the marbles will go to one last station where a light sensor will read the light reflected off of each marble. If it matches the value for an aluminum marble a knob will knock the marble into the bin for aluminum.If the marble does not have the same value as aluminum it will be assumed to be the 4th type of marble and will be knocked in the other direction into its respective bin.





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Final Design Continued:

Marbles will be placed in a hopper and will be let onto the belt at timed intervals. First they will pass a magnet which will pull out the steel marbles + drop them in a specified container. Next they will pass between a lightsensor + a flashlight. If the light traveling through marble is consistent with that of a clear marble it will move to the next position where a pusher will push it into the respective bin. Then the marbles will go to one last station where a light sensor will read the light reflected off the marble if it matches the value of aluminum, a gear with a knob will knock it into the bin for aluminum if not it will knock it the other direction into the bin for wood.

Decision Matrix:

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Design Modifications:

As with every product, our machine did not function very well in its first iteration and as a result many design changes were needed. Below is a list of all of our design modifications to the original design as well as the reason the modification was made.

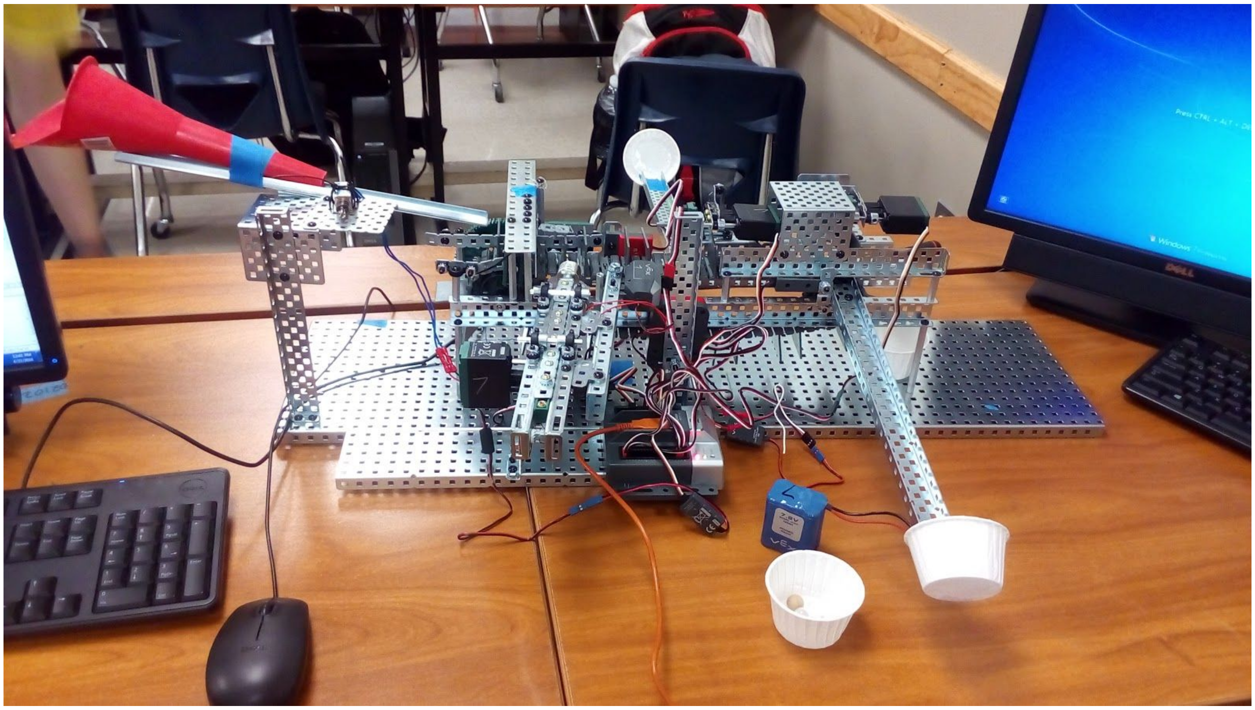
- **Magnet Motor:** We needed a way to move the magnet closer to the marbles since it was not powerful enough to grab them from the distances we originally thought it would be able to. To fix this the magnet was mounted on to the end of a pusher arm that could move in and out of the flaps on the belt via a motor.
- **Servo Door Replacement:** Originally our idea was to have a servo that moved open and closed very quickly to allow only one marble onto the belt at a time.This design was scrapped due to our limited supplies and the realization that we might need a servo elsewhere on our machine. On top of this we also needed something that could move faster than the servo. Instead of the servo we opted to use a Solenoid to control the flow of the marbles.
- **Solenoid Pusher (Clear Marble Station):** We found out that a solenoid did not have the reach to effectively knock marbles from the belt. To remedy this we replaced it with a servo mounted directly above the belt with an arm that could move across the belt to knock the marble out of the belt.
- **Backboard:** There was an issue of marbles rolling out of our feeder and over shooting the compartment that we wanted them to land in. To fix this problem we built a backboard to stop the marbles from overshooting the intended “drop zone”.

- **Flap Stop:** One problem we quickly ran into with the magnet motor pusher arm was that unless the belt was very carefully lined up, it would not enter into the compartment correctly. In order to allow for a greater margin of error we added a small prong above the belt right before the magnet station to hold the flaps open wider for the pusher arm.
- **Redesign of Last Station:** Due to time constraints we knew we couldn't make the last station as it was originally intended. To decrease its build time we simplified the design. Instead of an arm that would knock the marble one way or the other based on its reflected light signature we made it to only move one direction for one type of marble and to just let the other type of marble fall off the end of the belt into another cup.
- **Removal of Belt Flaps:** One issue we had to constantly deal with was the fact that the flaps on our belt could easily catch on wires and other parts of the machine causing it to be thrown out of alignment. To reduce the chances of this happening we removed some of the flaps that were not serving a functional purpose.
- **Gear Modification:** Belt alignment was the bane of our machine. In order to function well the belt had to be able to rotate at regular intervals. After several attempts at solve the problem, I changed the motor from powering the axle directly to powering it indirectly via a gear system. The motor was hooked up to a small gear which locked with a larger gear. The massive gear ratio made it to where the motor required more power to move the belt. This modification was made in order to reduce drift on the belt (this is caused because the motors still carry some energy after the program tells them to stop resulting in them drifting a little before coming to a complete stop).

FInal Design:

Overall, this project was a failure due to time limitations and the limitations of the VEX robotics kits. As many groups found out, the sensors and motors, while fairly accurate, are nowhere near as precise as necessary to reliably and consistently be able determine the differences between marbles and move them into the right bins.

During the official test, our machine only successfully sorted one steel marble into the right bin and one clear marble into the right bin. In addition, in the bin at the end of our belt, we did manage to catch three or four marbles of various types however since they were all mixed together they were not sorted correctly. All other marbles were not successfully separated or sorted during the official test. I am unable to provide an accurate number for the total time of completion because our machine worked too slow to process all of the marbles in the allotted time limit and was therefore unable to sort all the marbles. The official test was ended after approximately five minutes.



Above is an image of our completed machine.

ROBOTC Program:

```
#pragma config(Sensor, in1,    lineFollower,   sensorLineFollower)
#pragma config(Sensor, in2,    lightSensor,    sensorReflection)
#pragma config(Sensor, dgtl11, encoder,        sensorQuadEncoder)
#pragma config(Motor,  port1,           flashlight,    tmotorVexFlashlight, openLoop, reversed)
#pragma config(Motor,  port2,           ConveyorMotor, tmotorVex393_MC29, openLoop, reversed)
#pragma config(Motor,  port3,           MagnetMotor,   tmotorVex393_MC29, openLoop)
#pragma config(Motor,  port4,           solenoidDoor,  tmotorVex393_MC29, openLoop)
#pragma config(Motor,  port5,           electroMagnet, tmotorVex393_MC29, openLoop)
#pragma config(Motor,  port7,           servoMotorClear, tmotorServoStandard, openLoop)
#pragma config(Motor,  port8,           servo2,        tmotorServoStandard, openLoop)
//*!!Code automatically generated by 'ROBOTC' configuration wizard               !!*//

/*
  Project Title: Marble Sorter
  Team Members: Miles Simpkins, Ariel Whitehead, Reid Harrison, Justin Alpern
  Date: 3/24/16
  Section:


  Task Description: This sorter sorts steel, clear, white, and aluminum marbles. They begin by being fed one by one
  onto the conveyor belt to run through all stations. The station is an electromagnet and sorts the steel marble.
  The second station is an LED light sensor station which sorts the clear marble. The third and final staion is a
  line follwer which sorts the aluminum marble. The last marble, white opaque, drops into a final bin.

*/
```

```
int motorSpeed = -20;                                              //Global Variables
int conveyorWait = 4;
int servoDoorWait = 0.2;
int servoDoorValue = 20;
int lightBrightness = 80;
int ClearMarbleLightValue = 95;
int selenoidWait = 2;
int EmMotorSpeed = -5;
int EmMotoDuration = 0.5;

void moveConveyor  (int motorSpeed)                                // Method to advance conveyor belt
{
  nMotorEncoder[encoder] = 0;                                      // Resets encoder to 0 before each movement
  startMotor(ConveyorMotor, motorSpeed);                           // Belt moves
  untilEncoderCounts(-42 , encoder);                               // Moves to next station then stops
  stopMotor(ConveyorMotor);                                        // Stops belt
}

void moveConveryorBackwards(int motorSpeed)                        // Method to move belt backwards
{
                                                                   // Resests encoder value
  nMotorEncoder[encoder] = 0;
  startMotor(ConveyorMotor, -motorSpeed);                          // Motor starts in reverse
  untilEncoderCounts(42 , encoder);                                // Moves until previous station
  stopMotor(ConveyorMotor);                                        // Stops belt

}

```

```
void SolenoidDoor (int servoDoorWait, int  servoDoorValue)      // Method to release one marble at a time
{
  startMotor(solenoidDoor,120);                                 // Powers on solenoid (default position)
  wait(0.1);                                                    //
  stopMotor(solenoidDoor);                                      // Power off solenoid
  wait(0.12);                                                   // One marble rolls through
  startMotor(solenoidDoor,120);                                 // Powers on solenoid


}
void Magnet (int EmMotorSpeed)                                  // Method to sort steel marble with electromagent
{
  startMotor(electroMagnet, 120);                               // Electromagnet powered on
  startMotor(MagnetMotor, 20);                                  // Motor arm advances elctromagnet
  wait(0.8);                                                    // For .8 seconds
  stopMotor(MagnetMotor);                                       // Motor Stops
  wait(0.1);                                                    // Wait to reverse
  startMotor(MagnetMotor, -20);                                 // Arm returns with steel marble if there
  wait(0.8);                                                    // for .8 seconds
  stopMotor(MagnetMotor);                                       // Arm stops
  stopMotor(electroMagnet);                                     // Magnet off drops marble into the cup
}

void LedStation (int ClearMarbleLightValue)                     // Method for LED station to sort clear marble
{
  turnFlashlightOn(flashlight,-100);                            // Flashlight turned on
  wait(1);                                                      // Wait 1 second
  if (SensorValue(lightSensor) <= ClearMarbleLightValue)        // If clear mrable is detected...
  {
    turnFlashlightOff(flashlight);                              // Flashligh off
    moveConveyor(motorSpeed);                                   // Advances belt 3 slots
    wait(1);
    moveConveyor(motorSpeed);
    wait(1);
    moveConveyor(motorSpeed);
    wait(1);

    setServo(servoMotorClear, -127);                            // Servo arm hits clear marble
    wait(1);                                                    // Waits 1 sec
    setServo(servoMotorClear,127);                              // Servo returns to default position
  }
  turnFlashlightOff(flashlight);                                // Otherwise flashlight is turned off
}

void LineFollowerStation()                                      // Line Follower Method to detect Alumimum
  {
      if (SensorValue(lineFollower) <= 2935)                    // If Aluminum is detected by line follwer
      {
        moveConveyor(motorSpeed);                               // Advances belt to servo arm station
        wait(1);
        moveConveyor(motorSpeed);
        wait(1);
        setServo(servo2,127);                                   // Servo moves to hit marble
        wait(1);
        setServo(servo2,-127);                                  // Servo returns to default position
      }
  }
```

```
task main()                                         // Main program
{
  while (true)                                      // Following tasks repeat
  {
    setServo(servoMotorClear,127);                  // Sets servos to default postions
    setServo(servo2,-127);
    startMotor(solenoidDoor,120);                   // Arms solenoid door to default postion to hold marbles back
    wait(3);                                        // Marbles fed in
    SolenoidDoor (servoDoorWait,servoDoorValue);    // One marble released
    wait(2);                                        // Marble rolls into slot
    moveConveyor(motorSpeed);                       // Conveyor advances to next station
    wait(1);
    moveConveyor(motorSpeed);
    wait(1);
    moveConveyor(motorSpeed);
    wait(1);
    Magnet(EmMotorSpeed);                           // Electromaget station to sort steel
    wait(1);
    moveConveyor(motorSpeed);                       // Conveyor advances to next station
    wait(1);
    moveConveyor(motorSpeed);
    wait(1);
    moveConveyor(motorSpeed);
    wait(1);
    LedStation(ClearMarbleLightValue);              // LED Station to sort clear marlbe
    wait(1);
    moveConveyor(motorSpeed);                       // Conveyor advances to next station
    wait(1);
    moveConveyor(motorSpeed);

    wait(1);
    moveConveyor(motorSpeed);
    wait(1);
    LineFollowerStation();                          // Line follower station sorts aluminum, white White opaque marbles
    wait(1);
    moveConveyor(motorSpeed);                       // Conveyor advances
    wait(1);
    moveConveyor(motorSpeed);
    wait(1);
    moveConveyor(motorSpeed);                       // Drops white opaque in last bin
    wait(1);
```

Design Process:

- **Define Problem:** During this stage we looked over the design brief and background information. We read the requirements for the final product and got some hands on time to study the different types of marbles.
- **Generate Concepts:** We each created brainstorm sketches and then came together as a group to discuss them. Using a decision matrix, we narrowed down the designs until we found one we thought was best.
- **Develop a Solution:** After the design matrix we each drew a final design in preparation for the build stage.
- **Construct and Test a Prototype:** We built the hardware and software and did several debugging and test sessions.
- **Evaluate the Solution:** We evaluated what needed to be done to fix issues after every debugging and test session.
- **Present Solution:** We made our informal presentation of our solution to the class.

Reflection:

a. If we could do the whole project over, I think that I might have gone with a simpler design with fewer moving parts since coordinating all the parts on our machine became the primary issue with our group.
b. The most challenging aspect of this design problem in my opinion the time frame. Many of the designs were not terrible, but a lack of better time investment resulted in many having buggy software that often didn't work as intended.
c. I learned a lot about what not to do when you are on a tight time schedule (for example, don't save programming for later). I also learned how to work with some different personalities from what I usually work with and while getting along may have been a tiny bit rougher, overall I think it was a good learning experience (because you can't always work with people you get along with well).
d. Some of the major challenges of working in a design team are scheduling and being able to put aside differences to accomplish a goal. There were some clashing personalities in our group, but we still managed to pull our act together for this project. To me my biggest issue was trying to find mornings when I could meet with my group when my group members didn't have lacrosse practice, or band, or any other sort of time consuming activity. Despite these issues, what makes a group great is their ability to work around these issues, and I think we managed them about as well as we could.