Operations Manual

Design of a Multi-Functional Mobile Robot

Team 23- Spring 2017

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Abstract

Abstract

Each year the American Society of Mechanical Engineers (ASME) hosts a unique Student Design Competition (SDC) at its Student Professional Development Conference (SPDC). For the 2016-2017 school year teams have been tasked with the development of a multi-functional robotic platform to compete in a series of five athletic-based competitions: a sprint, tennis ball throw, stair climb, golf ball hit, and weight lift. While the components of the robot are still being finalized, our team has continued to iterate our design such that it addresses all of the imperative criteria for the competition determined by the team to be mobility, power, stability, size, durability, and safety. In the future, the team is looking forward to ordering and machining the remainder of the components and starting the assembly process so that testing with the actual unit can begin.

Acknowledgements

Team 23 would like to thank Dr. Camilo Ordonez and Mr. Keith Larson for their expert technical advice on the structure and many of the mechanisms to be employed by our robot. Additionally, team 23 would also like to thank the FAMU-FSU College of Engineering for funding this endeavor and as well as the ASME for organizing this competition.

1. Introduction and Functional Analysis

Notes from ppt:
Project Function
How will your project work?
Comments:
Seems kinda similar to what we have, obviously edit and update the sections
A lot of what is talked about in this section should be moved to section 3. This section should be mainly about the rules of the competition and a brief overview of how we're accomplishing the event.

There are strict requirements set by the competition organizers which all robots must satisfy. The first, and arguably the most limiting, is that the robot must be able to fit within a 50 cm x 50 cm x 50 cm sizing box. This includes not only the robot itself, but the controller, any spare batteries, any spare parts, and even the weight which will be used in the second event. This constraint is especially difficult. As the size of the weight increases (causing the score to improve), the robot must become smaller in order to fit all necessary components into the sizing box. The robot must use rechargeable forms of energy. Therefore, irreversible chemical reactions like gasoline or gunpowder are not permitted and rechargeable batteries of any kind are the only allowable core power source. Other conservable energy sources such as springs or compressed air are permitted so long as the energy can be restored to its initial state by the robot at the end of each event.

1.1. The Sprint Event

The first event in the competition is rather straightforward. Each robot must complete a straight-line sprint down a ten-yard long track and return. The event is scored based on the fastest time with penalties for each time the robot touches the sideline.

The robot will use its primary motors in order to turn the tracks and achieve forward motion. The robots differential drive system will allow us to correct the course and ensure that no points are lost due to collision with the sideline.

1.2. The Lift Event

Comments: This needs to be rewritten since we're no longer using a bag.

The next event of the competition requires the robot to lift a weight of the team's choosing as high as possible. This event is scored according to the product of the mass lifted and the height lifted. However, a flat 50 cm is subtracted from any measured height which the robot can lift the weight. The weight can be placed onto the robot by the participating team at the beginning of the event, and due to the starting height of 50cm, the weight must be placed on the top of the robot. The weight being lifted must be in the form of a rectangular prism with no gripping or holding features whatsoever.

placed onto the robot by the participating team at the beginning of the event, and due to the starting height of 50cm, the weight must be placed on the top of the robot. The weight being lifted must be in the form of a rectangular prism with no gripping or holding features whatsoever.

While preparing for this event, the team is taking the approach of lifting as heavy of a weight as possible a short to medium distance. In order to maximize the amount of weight the robot will be lifting, the team will be filling rectangular containers with fine, lead shot, typically used in shotgun shells. This will allow a maximization of empty space as each rectangular prism can be of arbitrary size and filled to capacity with lead such that virtually all of the unused space in the robot is filled with lead. In the event that cost constraints prevent the use of lead shot, other options, such as wet sand, are equally viable.

To perform the lift itself, the team decided to use a device known as an air jack. These are pneumatically-powered devices capable of exerting very large lifting forces at a very low operating psi. The particular jack that is under consideration for buying is capable of lifting 1.5 tons to a height of about 75 cm. It takes about 45 seconds to inflate completely and 5 seconds to deflate. Because the weight is initially starting at a height just under 50 cm, the team is expecting a very respectable score for this event.

1.3. The Throw Event

The robot launches a tennis ball as far as possible. Distance for this event is measured on a fixed axis and if the ball falls off center, the distance it traveled along that axis is taken as the score, not the total Euclidean distance. The distance the ball bounces and rolls after its initial landing is also included in the score.

The robot utilizes the pneumatic system to pressurize a small reservoir with compressed air and release it into the barrel.

1.4. The Climb Event

In this timed event, the robot is tasked with climbing up, and then back down, a set of three steps. Each step will be between 8 and 15 cm tall with a 50cm x 50cm landing between each step.

The design adopted by Team 23 is slightly modified from the chaos frame, developed by ASI Robotics. In order optimize our use of resources, the front legs are controlled by one motor, and rear legs are powered by another motor. Similarly, the tracks on the right side and left side of the robot are paired as well such that the robot maintains its ability to steer. The design maintains mobility throughout the rotation of the arms, due to the track maintaining constant contact with the ground throughout the full rotation of the arms.

Figure 1: The true chaos platform built by ASI Robotics

1.5. The Hit Event

The Hit requires the robot to "hit" a golf ball from the ground as far and as straight as possible. The ball is only allowed to have a small clearance above the ground, a maximum of 0.2cm. The score will be based on the distance which the ball lands from the measuring line minus the distance traveled along the measurement axis. After the first encounter the ball has with the ground, the distance traveled will no longer count.

The spinning wheel approach works by forcing a ball into contact with one or two wheels spinning at high velocity. The wheels compress the ball and impart energy onto it. The robot would utilize the chaos frame design to stand over the ball and lower the wheel assembly downwards. A structural system of drawer slides will suck the ball upwards. The ball would be driven vertically and roll up a ramp designed to add a backspin. The backspin will increase the distance traveled.

2. Project Specification

Notes from ppt:
Dimensions of the crucial part
Some important characteristics of different components (data sheet of microcontroller, motors, etc)
Comments:
Once again, seems kinda similar to what we have, obviously edit and update the sections

Comments:
Once again, seems kinda similar to what we have, obviously edit and update the sections

2.1. Control

A suitable microcontroller for our robot is the Arduino Uno with USB shield to allow us to connect a Bluetooth hub to our device for connection to a controller with Bluetooth capabilities. Two Arduino Unos were used as a result of a number of bad pins on the USB shield. The second Arduino was used as a slave board in a master-slave I2C control to send additional PWM signals. The handheld controller that is used for our device is an Xbox 360 controller since it's easier to sync with our robot due to Microsoft's built in library with all of their devices. This will alleviate many of the programming issues which would arise if Team 23 were to use a third party controller such as one from Sony or any other company.

2.2. Drivetrain

In order to drive the system, a total of four motors are be required. The two primary motors are responsible for the rotation of the tracks on each of the arms, this will provide the majority of our forward motion for events like the sprint and stair climb. The secondary motors are used to power the arms, allowing the robot to lift and angle itself. The front and rear arms operate independently from each other, as will the left and right tracks. This gives the ability to steer by driving the left and right tracks at different speeds, while reducing the number of required motors.

The primary motors are AM9015 motors with attached 27:1 planetary gearboxes from Andy Mark. These motors are able to provide a constant output torque of approximately 400 oz-in at 150 rpm and is able to drive a 50lb robot at approximately 3 m/s with an additional gear ratio of 6:1 under ideal circumstances. These have a stall torque of approximately 63 Amps. Our secondary motors are RS775 gear motors and Encoders with 188:1 planetary gearboxes also from Andy Mark. This motor is ideal for our purposes due to its torque to cost ratio and will be able to provide sufficient torque to our legs with an additional gear ratio of approximately 12.5:1. We are operating both of these motors at their nominal operating points to avoid any possibility of damaging or destroying them during our months of testing the system. These motors have a stall torque of 22 Amps.

Additional gear reductions on the drive system take place through a series of sprockets and gears. The primary drive system consists of only sprockets with the final output shaft mated to the wheel of the arm via the use of a key and keyway. The secondary drive system first transmits power through a sprocket reduction system which drives the arm shaft, a shaft running the breadth of the robot. In this design, a small gear is affixed to the end of the shaft using a roll pin. In order to actually rotate the arms, a gear is mated to the inner face of each arm of the robot. When this gear meshes with the gear affixed to the end of the arm shaft, it causes the arm to rotate when the secondary motor is driven.

MAYBE INSERT A TABLE WITH VOLTAGE, AMPS, STALL TORQUE ETC FOR THE 3 MAIN MOTORS USED.

Figure 3: Torque curves of primary (track) motors. Calculated in MatLab
Figure 4: AM9015 gear motor from Andy Mark
Figure 5: Torque curves of secondary (arm) motors
Figure 6: RS775 gear motor from Andy Mark

Mike, you know a lot more about the pneumatic system, so I'll let you write this section. Shouldn't be too much, just update.

2.2.1 Core

At the core of the pneumatic system lies the air compressor and air tank array. The plan is to use small SCUBA tanks to store the air and power the pneumatic system. These tanks will work great for this design because of their relatively high volume capacity and exceptional psi rating. The air tanks used on the robot will be aligned in a parallel such that the air storage capacity of the robot can be increased dramatically. The current configuration is utilizing a two-tank, 0.5-gal rating. The air tanks used on the robot will be aligned in a parallel such that the air storage capacity of the robot can be increased dramatically. The current configuration is utilizing a two-tank, 0.5-gal system. However, expansion of this array into a four-tank 1.0-gal system may become possible in the future. The main limiting factor in this approach is the physical space that each tank consumes.

The air compressor being used is a model rated for 200 psi from the manufacturer VIAir. Team 23 has maintained correspondence with VIAIR for a time, and has recently obtained a sponsorship from the company. In doing so, VIAir shipped a best-in-class portable air compressor to the team at no cost. This model has the ability to fill a 2.5-gal tank to 150 psi in approximately 3 minutes. This fill time is much too long to be viable in this competition, however a significantly smaller tank will be used on the competing robot. It was calculated that this compressor would be able to fill a 0.5-gal tank to just shy of 200 psi in 58 seconds. This is perfectly suited to the competition and it is for this reason that the VIAir 480C compressor will be used on the robot.

Figure 7: 480C air compressor from VIAir Corp.

2.2.2 Air Jacks

Air jacks are relatively lightweight devices which use relatively low pressures to lift very heavy objects. They are generally used to lift overturned freight trucks and to lift a car off its axle in order to change a tire. For the lift event, air jack will be placed on the top of the robot. This particular air jack is used to lift a car in order to change a tire by inflating it through the car's exhaust pipe. It lifts 75 cm, is hard to puncture, and is designed to lift 3 tons. This will be particularly useful during the competition because it will allow the team to lift a weight a relatively high distance in comparison to the weight's heaviness. The compressor feeds air into the Air jack until the Air jack is fully extended and pressurized to roughly 200 psi. The feed line from the compressor to the Air jack has a dedicated check valve that ensures bag remains inflated and stationary for the 3 second hold required by the competition rules.

2.2.3 Air Cannon

An air cannon is the most promising design to launch the tennis ball. Essentially a glorified potato gun, this cannon will use a release of pressure from the pneumatic system in order to propel the tennis ball accurately along the target axis. It is a relatively simple and straightforward design having two easy to operate stages; Prime and Fire. During the Prime stage the compressor would function to fill the pressure vessels to a max pressure of 200 psi. Once this pressure has been achieved the first stage solenoid valve is triggered feeding the larger Firing stage. The compressor continues to run building pressure back up to a max of 200 psi then the second stage solenoid is triggered dumping the high pressured air into the barrel opening and launching the tennis ball.

2.3. Electrical Systems

Specifically, power requirements, circuit design, protections against inductive kickback from the motors, etc. Is our design even possible!?

2.3.1 Motor Controller

The main motor controllers in use for the robot are a Sabertooth 2x32 and a Roboclaw 2x30. These are designed for movement and control of the large motors selected. This allows the robot to climb stairs, move in any direction, and set up the arms of the tracks to place itself in different positions for each event. The Motors operate at the full voltage of the battery. A 14.4 V Nickel-Metal Hydride battery was used in this case, but the motors are rated for 12V. Though the motors are simple inductors at their core, it is not recommended to use a power supply greater than 18V for any meaningful period of time.

2.3.2 Controller

The controller being used for the robot is an Xbox 360 controller. The Xbox button in the center of the controller are used to toggle between the different events. For each event that the controller is toggled to, an LED on the front of the controller will light up to represent which event the controller's buttons will be mapped to. This is beneficial because it allows the user to select a specific task so if there is any misclick or incorrect input command during the task, the robot doesn't act based on incorrect user input. Both the relay circuit and the controller will be designed so eliminate any possible incorrect commands that may cost the robot any additional loss of power by triggering anything that should be off during the competition or throughout the testing process of this project.

throughout the testing process of this project.

2.3.3 Microcontroller

The microcontrollers in use are two Arduino Unos that are used as the robot's brain and is helpful in commanding input. The primary microcontroller establishes the connections for the main pins and the secondary microcontroller is used to send the PWM commands that cannot be sent using the primary. The commands for the competition are fairly simple and do not require complex computing.

2.3.4 Batteries

Lithium ion/polymer batteries are the best option for powering the robot. They have small dimensions, can be recharged quickly, and have a high energy density. These batteries are typically used in robotics for controlling and require less to power the electric motors. It is in the best interest for this competition to use multiple batteries in parallel. This will allow further design manipulation regarding space and when it comes to possible task assignment. There are disadvantages to using multiple batteries: multiple batteries to recharge and multiple parts of the robot will stop working at different times. However, the way the competition is laid out, it is possible to program the robot so that everything that is not to be working during the task being performed can be turned off using the relay circuit. Everything the robot is designed to do is not going to be running simultaneously, so that eliminates the second concern mentioned for the use of multiple batteries.

3. Project Assembly

Notes from ppt:
3-D Model of the project
Crucial components and their assemblies
Comments:
Section needs a lot of work. Need lots of figures. Color coded stuff from the presentations would be kinda cool here. Maybe use cad models of assembly of legs and stuff.

PICTURE HERE OF CURRENT ROBOT

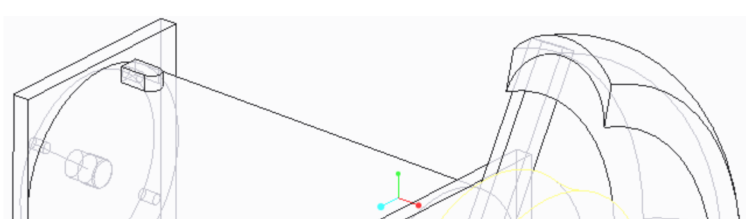
3.1. Arms

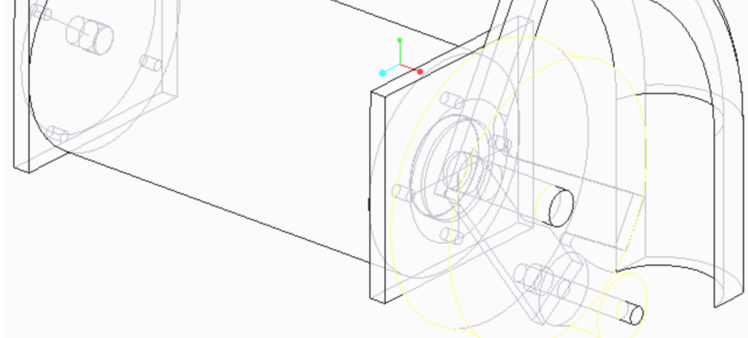
The robot was designed to mimic the highly mobile "Chaos Platform" first developed by ASI Robotics. It will have four individually tracked legs that are capable of rotating 360 degrees. This design will provide four points of constant ground contact throughout the competition. Two motors will be responsible for flipping the arms up or down (one motor for the fore arms and one for the aft arms). Two other motors will be responsible for the tracks' control (one for the right and one for the left side tracks).

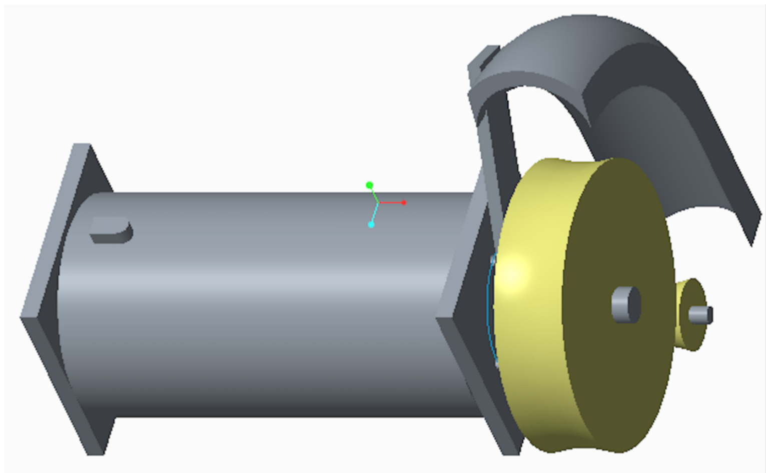
INSERT PICTURE OF THE ARMS HERE

3.2. Hit System

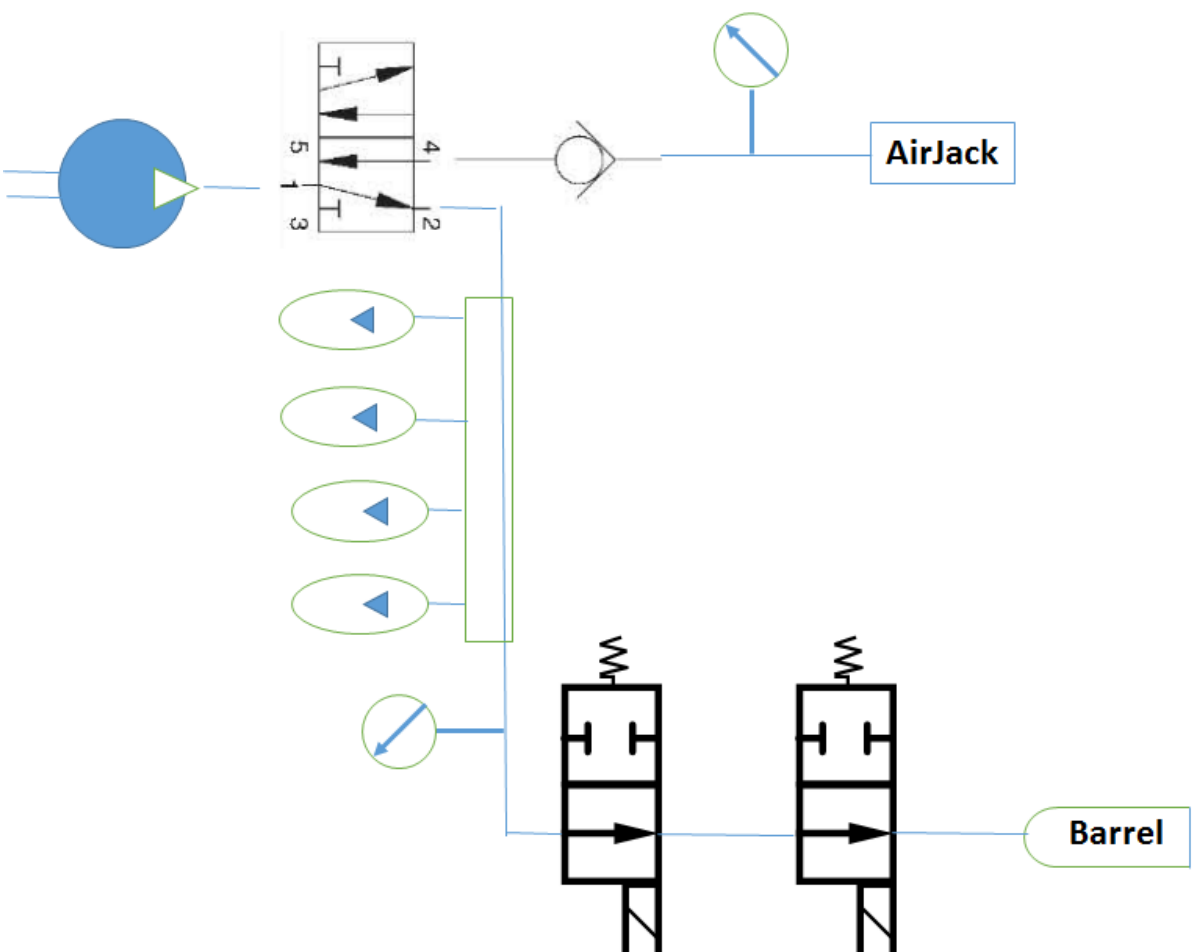
The design for the hit event is modeled after a single pitching wheel. Drawer slides are the structure that keeps the mechanism stable while it is lowered using a worm gear system. A small wheel wedges the ball against the wall while the ball is still perched on the tee. A small second wheel rotates freely on a shaft, and a rubber belt turns the wheels into pulleys. A textured surface on the wheels give better grip onto the ball, which imparts more energy into the ball, and increases distance. The second wheel lifts the ball along the chute and into the main wheel, which imparts the majority of the energy into the ball. Powerful DC motors spin the wheels upwards of 5000rpm and the exit velocity is calculated to be greater than 15m/s.







3.2. Pneumatic System



4. Operational Instruction

Xbox 360 Input Commands:

- Arm Motion
  - L2 activates the fore arms
  - R2 activates the aft arms
  - Clicking L3 activates “stand” mode
  - Speed and direction of motion is controlled by moving the right stick about its Y-axis
    - During “stand” mode, moving the stick downwards executes the standing motion; moving the stick upwards executes the returning motion
- Track Motion
  - Pressing the A button activates/deactivates primary motor control
    - Moving the left stick along its Y-axis corresponds to linear forward and backwards command
    - Moving the left stick along its X-axis corresponds to a rotation command
- Pitching Wheel
  - Pressing the B Button sends an ON/OFF command to the pitching wheel motor

Notes from ppt:
Procedure to operate
Notification during the operation (No clue what he means by this)
Comments:
Section needs to be completely written, maybe write stuff about the xbox controller we’re using, and the keybindings for each event. Talk about all of the functions that will be controlled by the controller and how they’re controlled.

5. Troubleshooting

- Track Motion
  - Tracks tend to slip off of the wheels during high-speed or prolonged operation.
  - Caused by:
    - Left/Right tensioners on each arm applying different degrees of force
    - Misalignment of the belt

In many cases it can be difficult to correct this manually when the belts are fully tensioned. Either untension the belt and manually readjust, or use a fine, flat-head screwdriver to wedge the belts back into position.

- Arm Motion
  - Arm chains skip/jump during motion
  - Caused by:

- Arm Motion
    - Arm chains skip/jump during motion
    - Caused by:
        - Loose Chain

    Occasionally, the arms can skip and jump when moving. Particularly when changing direction abruptly. Tighten the chain to remedy this problem.

Notes from ppt:
Potential problems with the design
How to solve those problems when they occur
Comments:
Section needs to be completely written, and honestly we have a ton of stuff to talk about. Talk about alignment of wheels on the legs and the belts not staying on the tracks. Basically everything we're having trouble with (and can fix) mention it with the solution.

6. Regular Maintenance

- Chain
    - Chain can loosen over time causing slippage. The primary motor chains have tensioners which can be adjusted to alleviate this manually. Secondary motors do not have any tensioner and may require a new chain to be applied instead.
- Gears
    - The small gears responsible for transmitting motion from the secondary motors to the arms are only secured using roll pins. Though they provide a tight fit, on rare occasions, they can fall out. This is either a result of plastic deformation in the pin compressing it to be smaller than the hole, or they were not initially secured properly. If it is the latter, they can be easily re-pressed into the hole. If it is the former, a new pin will need to be used.

Notes from ppt:
The routine maintenance
Key component replacement
Comments:
Section needs to be completely written. Talk about everything that can potentially wear. Maybe mention ways to replace the driven wheels or keys on the tracks. Maybe talk about how to replace batteries in case batteries eventually fail and are unusable. Possible instructions on how to replace various shafts or sprockets throughout the robot. Idk, think of stuff that can possibly break and write up how to replace it.

This is something good to work on while the robot is being disassembled tonight.

References

Appendix A

Appendix B

Biography

Abdur-Rasheed Muhammed is a Senior Computer Engineering student from Jacksonville, FL currently enrolled at FAMU. He is overseeing the programming aspects of the robot competing in the robot pentathlon under ASME.

Ben Edwards is a Senior Mechanical Engineering student at Florida State University from Tampa, FL. He pentathlon under ASME.

Ben Edwards is a Senior Mechanical Engineering student at Florida State University from Tampa, FL. He is currently designing and building the system for the hit event.

Natalia Cabal is a Senior Electrical Engineering student from Cali, Colombia currently enrolled at Florida State University. She is currently overseeing the circuit design and power aspects of the robot.

Troy Marshall is a senior in the Department of Mechanical Engineering at Florida State University from Panama City, Florida. Troy is the Webmaster responsible for designing and managing the Team 23 website.

Ryan Alicea is a senior in the Department of Mechanical Engineering at Florida State University from West Palm Beach, Florida and is the project lead. Currently, he is designing and machining the drive system of the robot.

Michael Jones is a senior in the Department of Mechanical Engineering at Florida Agricultural & Mechanical University from Ft. Lauderdale, Florida. Michael is the Financial Advisor and is currently overseeing the design of the pitching machine for the “Golf Ball Hit” competition.