<u>P2 – Product Assessment Report</u>

AME30362: Design Methodology
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Executive Summary

The purpose of this project was to analyze the first generation mechatronic football robots in order to develop a more efficiently designed second-generation product. In this process, the group was able to evaluate the fabrication, quality, and assembly of two first-generation robots. The insight gained from this disassembly process resulted in a number of key findings as detailed below.

Due to the use of computer aided modeling, the design of the manufactured parts was suitable for the task at hand, and the quality of fabrication was ensured by utilizing computer assisted machining. Even so, some of the design work was inaccurate, which required more work during the assembly process to correct for these flaws. The design could be optimized to not require such a large number of holes, grooves, and hardware to mount the specific assemblies for skill position players. For the quarterback robot, a simple overall design was exploited to keep the total number of frame parts to a minimum, which drove down the cost of production. In order to maintain structural integrity, the majority of the assembled pieces were bolted and then glued together in a variety of ways. While this process holds the assembly together under high stress, it leads to very difficult maintenance and repair operations. For the receiver, a large number of frame parts were interlaced in order to help support the structure during tackles. Yet, it was observed that there were multiple bolts that were not accompanied by a nut to successfully hold the parts together. On both players, maintenance or reconstruction of the electronics system would be a hassle, unless the one maintaining the robot had intricate knowledge on the setup of the electrical systems. Finally, it was discovered that a large number of parts were outsourced, namely those not manufactured out of HPDE. Some of the parts included in this category were brackets, bolts, nuts, washers, and traction motors. While the cost of acquisition of outsourced parts is higher than the material and manufacturing costs to construct them in-house, buying parts from other sources ensures their quality.

From the observations made while disassembling the robot, it is possible to arrive at a variety of conclusions which will better the fabrication, assembly, maintenance, and quality of the second-generation mechatronic football players. First and foremost, it was observed that parts were added to the design of each robot on an as-needed basis. This resulted in an inefficient design with a high number of interconnected pieces, and maintenance of such a design is difficult. It would be preferable to have a ‘design freeze,’ in which the design is finalized before manufacturing and assembly begins. Additionally, proper labeling of all electronic systems and wiring is vital to achieving a good design. It will be important to consider maintenance during the design of next year’s robots. On the first-generation players, it was impossible to repair or swap out numerous parts without the prior disassembly of a larger section of the robot. Overall, however, both robots had a robust construction and were well-apt to handle their assigned tasks.

Qualitative Design Assessment
Gold Team Player

The goal of the disassembly process was to divide the Gold Team's receiver into several subgroups and subassemblies. The function of this player was to catch a thrown ball from the quarter back in its nest, retain the ball in its grasp, and clasp upon the ball to hold it securely. Overall the player quality was decent with moderately skillful machining. The robot was dividing into the following categories:

Overall Assembly:

1. **Receiver Top Assembly**
   a. Net Assembly
   b. Ball Grasping Assembly

2. **Base Assembly**
   a. Tackle Sensor Assembly
   b. Electrical Assembly
   c. Structural Assembly
   d. Drive Assembly

The main components of each assembly as well as highlights of the disassembly process are depicted below.

Overall Assembly:

Overall the robot had an effective design and construction was of moderate quality. Most of the parts were fastened together correctly but a number of bolts had loose nuts, missing washers, or were not tightened. The machining of the parts was fairly dimensionally accurate, especially on the four side body panels. The hardware and outsourced servo, motors, and batteries seemed appropriate for their application.

1) Receiver Top Assembly

The top assembly was as the core of the receiver's functionality. It was a mix of manufactured and purchased parts, with a net structure composed of purchased and cut PVC and netting, the grasping arm of machined plastic, and the servo and actuating features of purchased components.

a) Net Assembly

Part Assessment: The most obvious component of the receiver was the PVC framed net used to catch the ball thrown from the quarterback. The PVC and net were both low cost and effective material choices. PVC has commercially available connectors that were used by the Gold Team to maintain a very rigid frame. The net material seemed effective at containing the ball with its bungee cords to absorb some impact and preventing the ball from bouncing out. However, the design would have required a very precise throw from the quarterback. There was limited area of entry into the net so most horizontal passes would not have made it into the net.

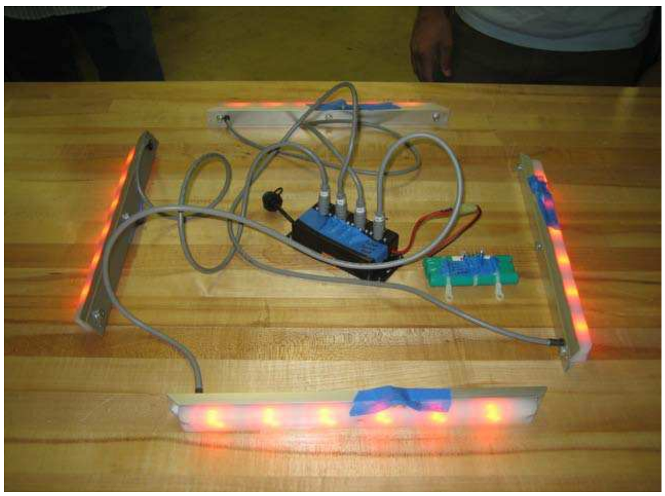
b) Ball Grasping Assembly

Part Assessment: If the net captured the ball it would fall through the opening in the bottom of the net. Once through this opening the ball had to be secured while running to prevent a fumble or incompletion. The Gold Team had an ingenious idea of using an IR or light sensor to detect when the ball landed in the ball grasping area. This area was also covered by bubble wrap, a great way to absorb the impact from the ball. When the ball landed, the servo would actuate the grasping arm, rotate it around and pin the ball between the static and moving grasping arm. Overall the machining of the servo mount was of high quality, with the team accounting for the hard-to-machine interior angles and the part was dimensionally accurate. Similarly, the electrical connections to the servo had to pass through a small hole and if the servo had to be replaced or overhauled it would require a lot of time.

2) Base Assembly

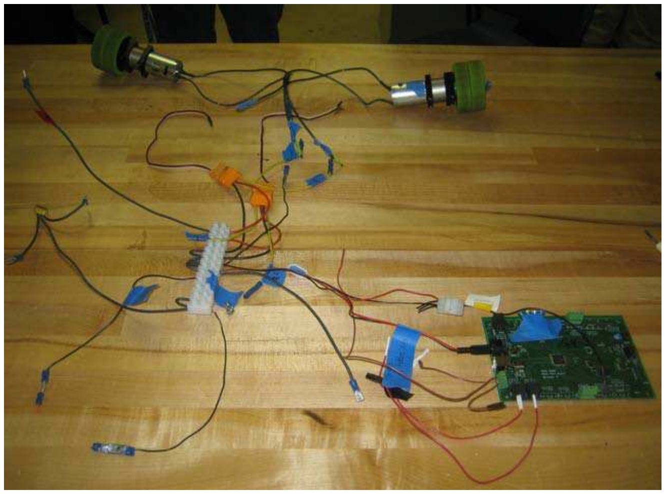
The base assembly consisted of a rectangular box with each face machined from plastic. The square base was reinforced by four thick black plastic pieces that ran the length of the board, connected by hex head screws. These four structural members also functioned as the support for the motors and wheels. The four sides were designed to interlock with each other for increased structural integrity and each was connected to its neighbor by square metal brackets. Only four small bolts secured the top and it might have sustained damage from the opposing team.

a) Tackle Sensor Assembly



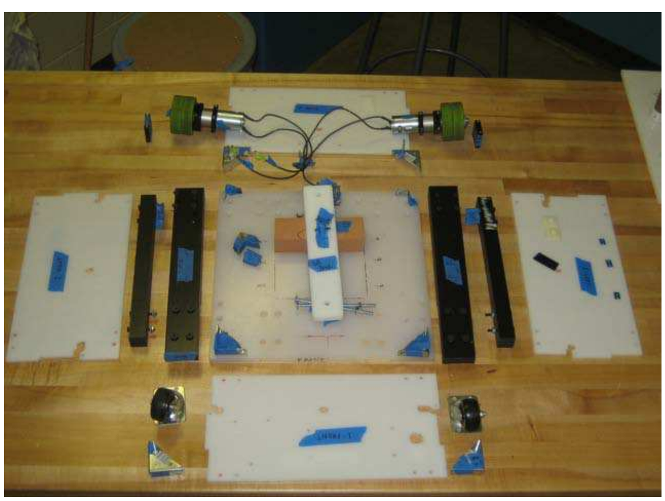
Part Assessment: While all parts in this assembly appeared to be of good quality, our group noted some issues with the quality of the assembly itself and its suitability for maintenance and repair. The removal of the tackle sensors was difficult due to close placement of screws in the interior corners. There was no way to gain access to these corners without first removing other parts, like cables, brackets, or wires, from the side plates. It would therefore be difficult to perform maintenance or repair on the tackle sensors without taking the time to teardown and reconstruct portions of the other assemblies. In addition, we noted a few flaws in the overall tackle sensor assembly, which included loose connections and missing washers in the attachment of the front tackle sensor.

b) Electrical Assembly



<u>Part Assessment:</u> During our examination of the wiring system, it became clear that there were a few issues with the quality of the assembly. The wiring itself seemed functional but inefficient, an example of which was a mismatched wire connector. The method of securing and organizing wires within the robot, which consisted of a series of zip-ties, was somewhat unreasonable. Since the zip-ties needed to be cut in order to gain access to the wires, they were not reusable and served as a hindrance in the maintenance process. Regardless of the assembly concerns, the individual parts and outsourced components of the wiring assembly were all deemed to be of sufficient quality.

c) <u>Structural Assembly</u>



<u>Part Assessment:</u> The structural assembly consisted of the highest number of fabricated parts, all of which were of good quality. Our group was especially impressed with the fabrication of the side plates, which had a nice interlocking fit at the edges. All parts seemed to be able to be secured effectively to the plates with screws alone, so the red "loctite" employed to strengthen connections only made disassembly more difficult. Our remaining concerns regarding the structural assembly related to maintenance and repair, specifically with the external ball-catching mechanism. The servo motor and ball detector mechanism were attached in such a way that they could not be easily exchanged if necessary.

d) Drive Assembly

Part Assessment: The main drive consisted of the two powered wheels attached to the aft section of the robot and the two, free coasting wheels on the forward section. The motor selection seemed appropriate for this design and the wheels had considerable traction. The use of free coasting wheels on the front might have presented issues. Turning on a sticky floor like the one in Stepan Center can lock these wheels and prevent a sharp turn. Additionally, replacing the motors would be challenging because the connecting wires were run through very small holes.

Qualitative Design Assessment
Blue Quarterback

The goal for the disassembly process was to divide the robot player up into several subgroups of components. The function of the player (in this case the robot was a quarterback) dictated the number and types of component groups. Overall player quality as well as the quality of the subassemblies and individual parts were observed and documented during the dismantling process. The robot was divided into the following categories:

Overall Assembly:

1. **Quarterback Top Assembly**
    a. Loading Assembly
    b. Throwing Arm Assembly
        i. Arm Mount Assembly
2. **Base Assembly**
    a. Shock Absorber Assembly
    b. Force Sensor Assembly
    c. Electronics Assembly

The main components of each assembly as well as the disassembly process are depicted and described below. Quality of part fabrication is noted and part suitability and design are also noted with respect to the player function.

Overall Assembly:

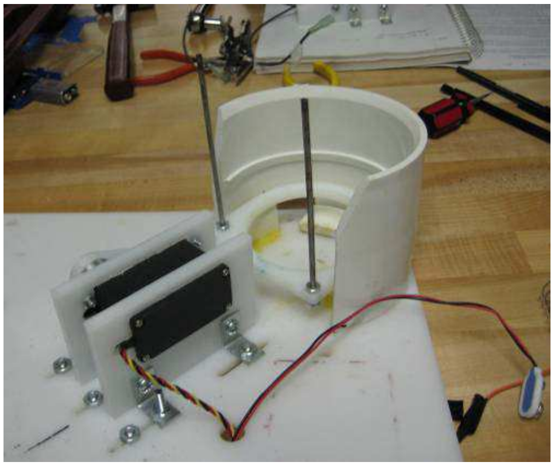
The overall assembly and construction of the robot, though appearing to lack design, was appropriately strong and well put together. All of the parts were tightly fastened with little to no movement in the structural component and there were no broken, loose, or hanging parts on the robot. The machined parts performed their respective function but many lacked precision and often looked like scrap pieces rather than the finished product. The bolts, nuts, and other hardware didn't always seem entirely appropriate for each application. One example is the L-bracket seen in use on the throwing arm support in the picture to the right. It was too large and hung over the edge of the arm support. Often the parts performed the desired function but appeared to have little planned out design. Another example of this involved nuts and bolts glued together, or multiple nuts glued together. This made dissassembly very

hard, which meant making any alterations would also be difficult if necessary.]

1) QB Top Assembly –

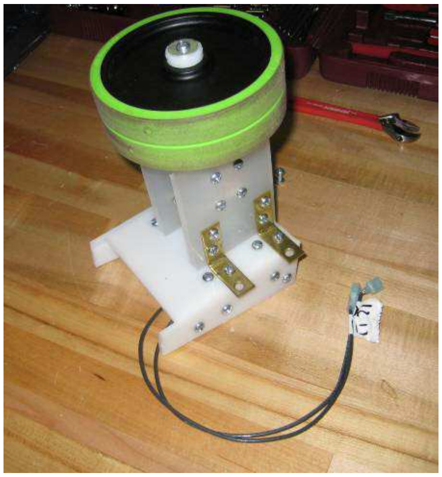
The top assembly included a mix of machined plastic parts created by the students and parts that were ordered. Most of the student-made components were structural, while the motors, gear boxes, and throwing wheels were all outsourced. The assembly was quite well done with specific angles of rotation created by the throwing arm bases and a smooth feeding arm for a fairly complex and precise system of projecting a football.

a) Loading Assembly



Part Assessment: The ball holder, mounting system for the motor, and feeding arms were all designed and fabricated at ND. They were all manufactured precisely and effectively to perform the task of loading the football into the throwing arm assembly. There did not seem to be any weaknesses in the parts or machining mistakes. The ball holder was heavily glued onto the top plate which gave the impression of sloppy assembly. The servo motor that was purchased and used for moving the loading arms was a good size for its function. It also provided a high torque at low speed which was convenient for the design and use of the part.

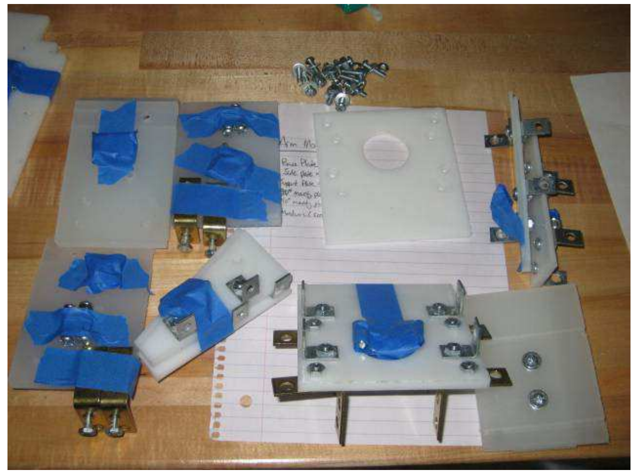
b) Throwing Arm Assembly



Part Assessment: The throwing arm motor assembly had machined plastic spacers that were chipped and falling apart. The outsourced components however were in good condition and seemed to function well to produce the desired throwing effect. The BaneBots motors and gearboxes were fairly lightweight and fit easily into the assembly. The gearboxes were a simple (and fairly inexpensive) way to increase wheel torque and lower unneeded motor speed.

i) Arm Mount Assembly

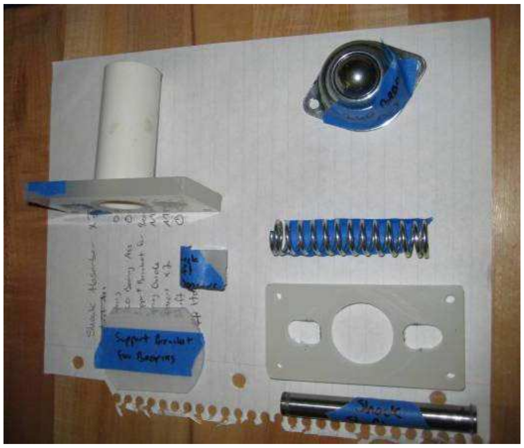
Part Assessment: The entire arm mount assembly was fabricated out of plastic pieces and was secured using L braces and assorted nuts and bolts. The smaller plastic pieces had some scratches and rough edges to them, however the other hardware seemed to be in good condition. There were some counter bore holes that were well-machined on several parts in this assembly.



2) Base Assembly –

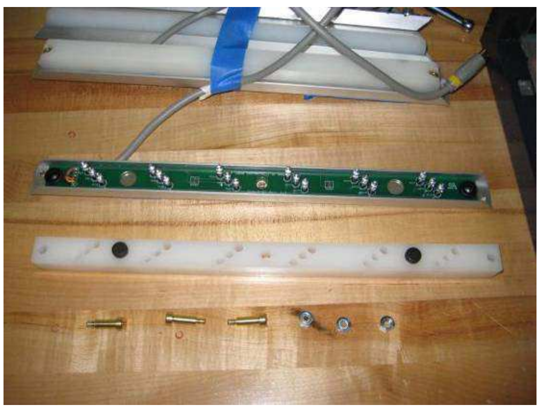
The base assembly consisted of the structural frame, the electronic components, and the wheels. The frame was built with plastic parts cut by ND students and screwed together. Some parts were well made while others were not so well made with rough edges and imprecise cuts. However the overall structure was strong and didn't seem to have any real damage from the game. The electronic assembly appeared disorganized though the wires were numbered for matching mates. The electronic components involved minimal design with just a few fairly simple parts which made disassembly easy and would have made replacements and alterations quite easy. The wheels and their respective motors were solidly mounted at the bottom of the base assembly with little undesired movement. The actual foam rubber tires looked a bit worn. The shock absorbing roller assemblies that kept the robot balanced on the two powered wheels were pretty poorly put together. Inaccuracies in the machining of the parts caused problems with proper functioning. However, they appeared to be well designed and fit onto the robot nicely. Overall the assembly of the base was pretty solid, with the inner parts appropriately fastened and safe from damage by collisions.

a) **<u>Shock Absorber Assembly</u>** –



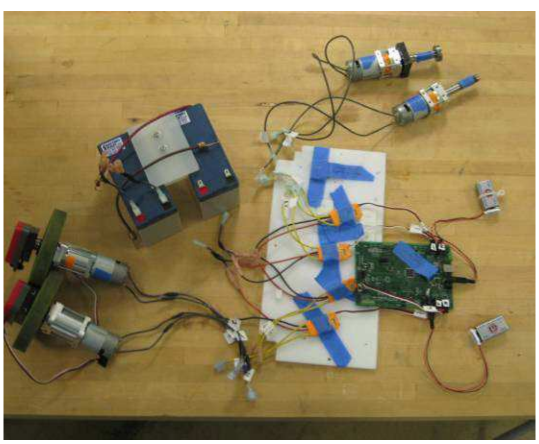
<u>Part Assessment</u>: The support bracket, spacer, and spring guide were all machined at Notre Dame. The shock absorber assembly took a good amount of load during the game and the plastic pieces showed some obvious wear. Also, the machined bracket was given slots in order to readjust the shock absorber positioning which could have been avoided with accurate drilling. The shaft, bearing, and spring provided a simple and creative way to protect the robot from jarring forces. They appeared to be in good condition and seemed to mesh well with the rest of the base assembly.

b) **<u>Force Sensor Assembly</u>** –



<u>Part Assessment</u>: The buffer bar and sensor support bracket were very well-made parts of the robot. The support bracket was metal and provided a lightweight way to hold and protect the force sensors and lights. The buffer bracket was machined out of plastic and had very precise holes drilled to expose the lights on the sensor. The force sensor seemed to be suitable for the design however it may have been required for use and therefore had to be incorporated.

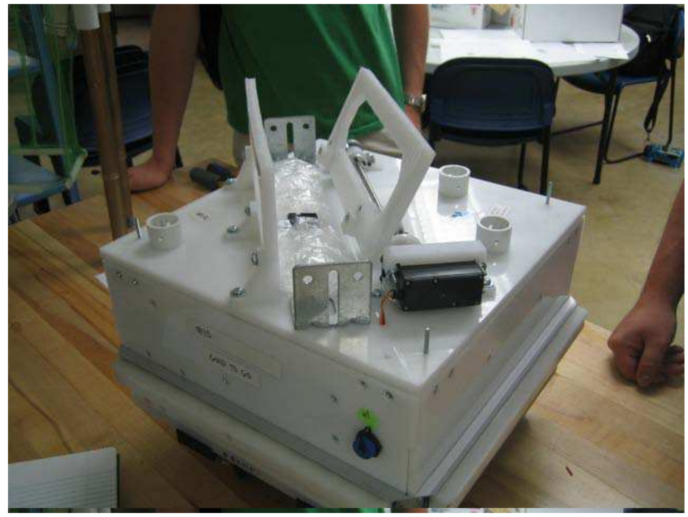
c) **<u>Electrical Assembly</u>** -



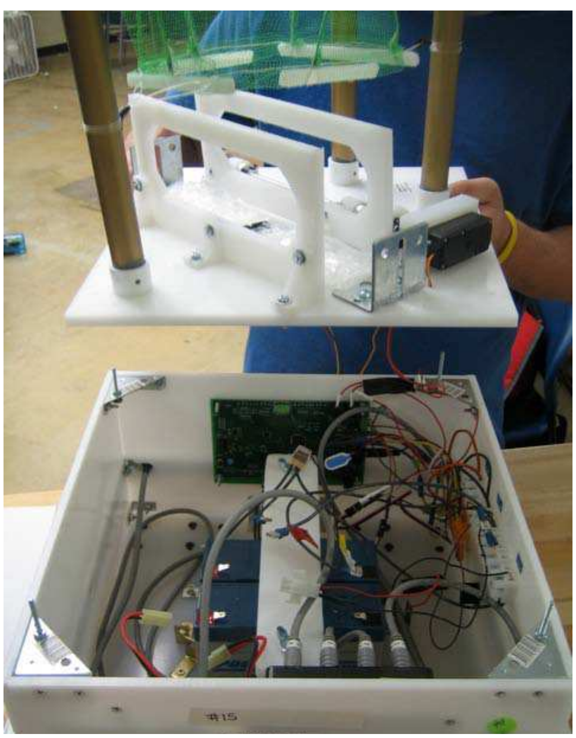
<u>Part Assessment</u>: The majority of the components in the electrical assembly were outsourced parts assembled for robot control and motion. The motors and gearboxes seemed to be well-chosen for the lightweight and good low-end torque requirements of the two sets of wheels. The circuit board and wiring were compact but not very well organized within the assembly. The battery packs were very heavy and probably could have been reduced in size while still providing the needed power to the player.

Photographic Record of Disassembly
Gold Receiver

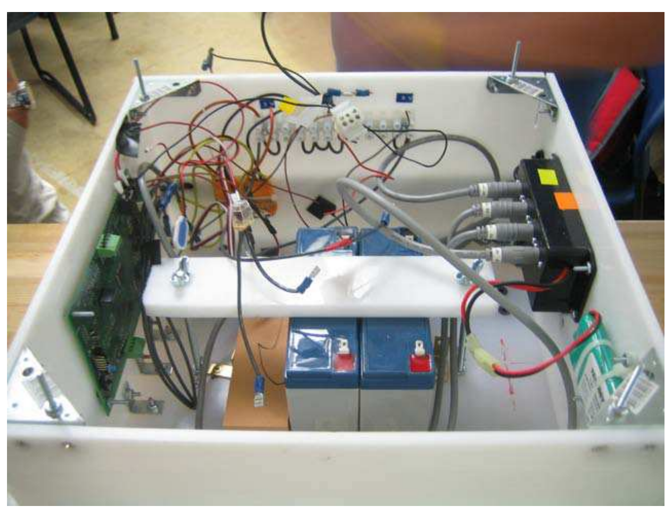
Gold Team receiver before teardown



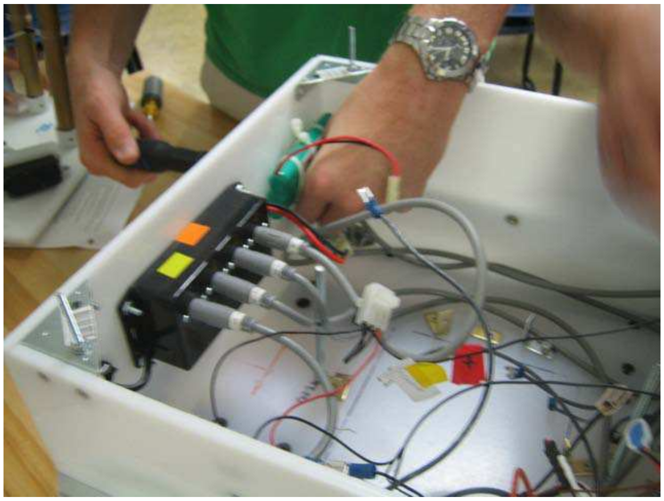
Receiver with top netting and support removed, shows clamping arms



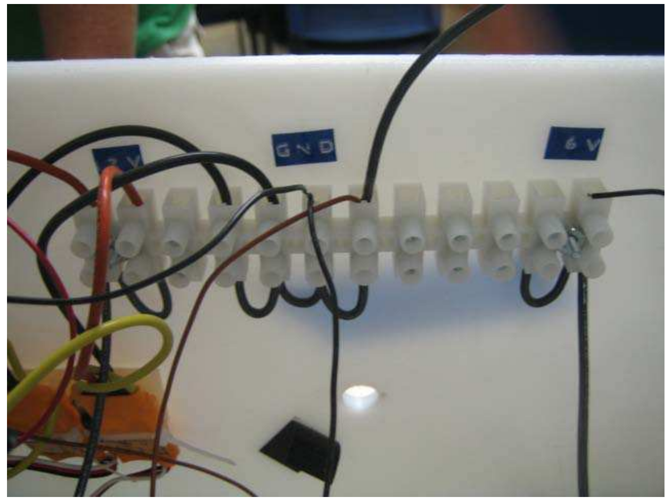
Receiver with top face removed, showing problematic connection wires



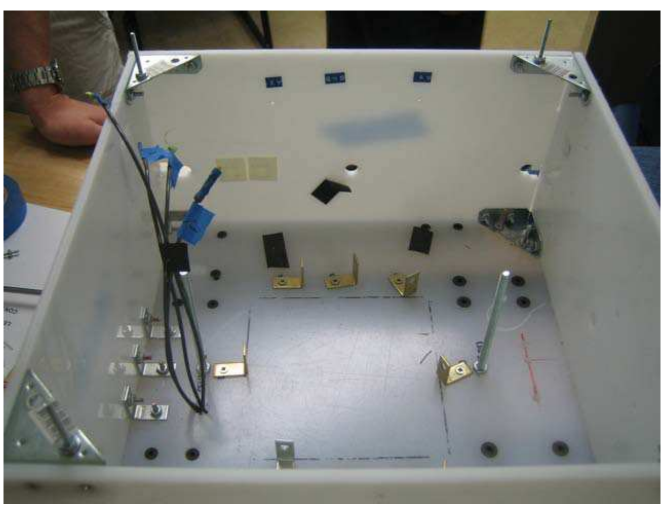
Internals of robot, processing board on the left, power strip on top, tackle sensor to right and batteries in center



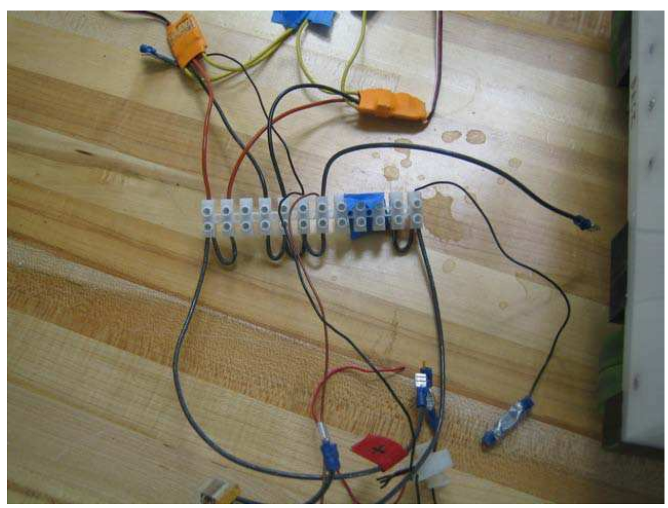
Removing tackle sensor battery pack



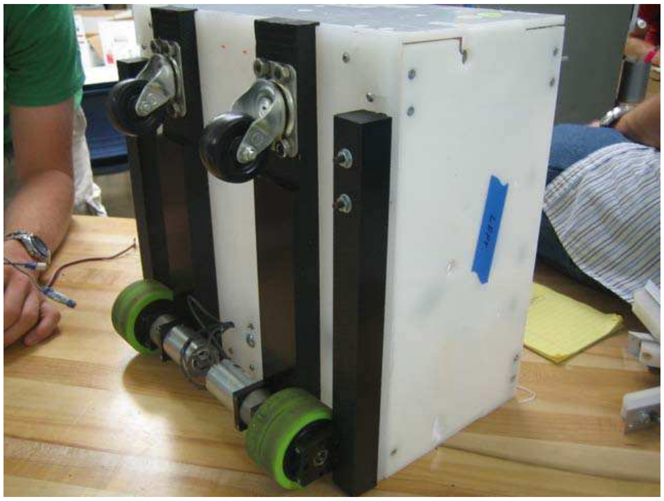
Power supply system, 3V to electric driving motors, ground, and servo 6V

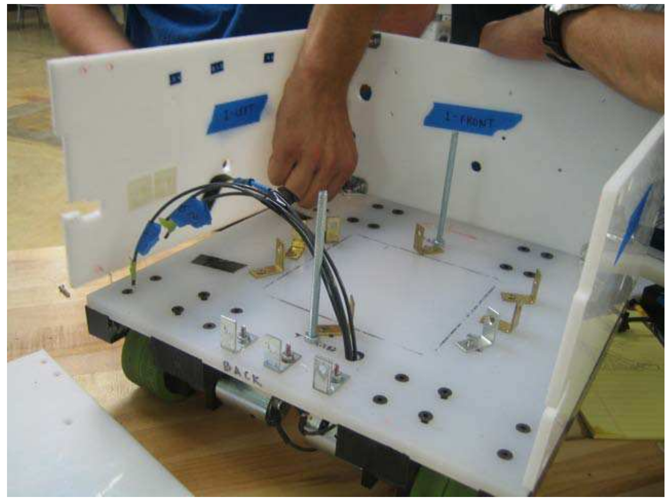


Internal cavity with microprocessor, batteries, tackle sensors, and power supply board removed



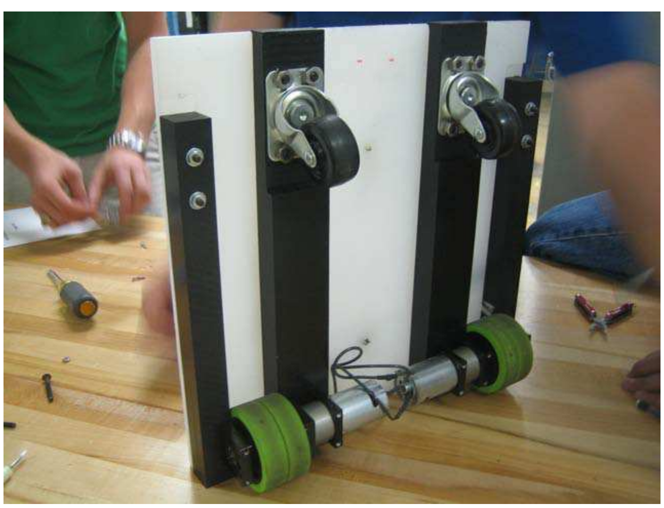
Power supply systems, MOSFETs in orange jackets supplying 6V to electric motors, and battery connections

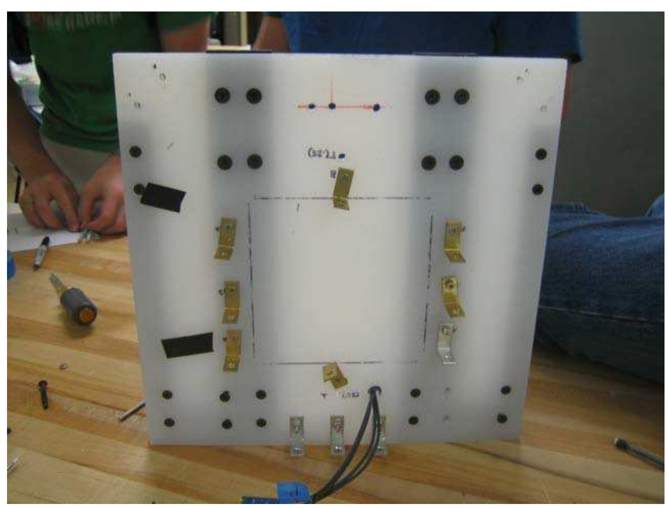




Receiver's bottom drive system with the powered green wheels and free spinning plastic wheels on top

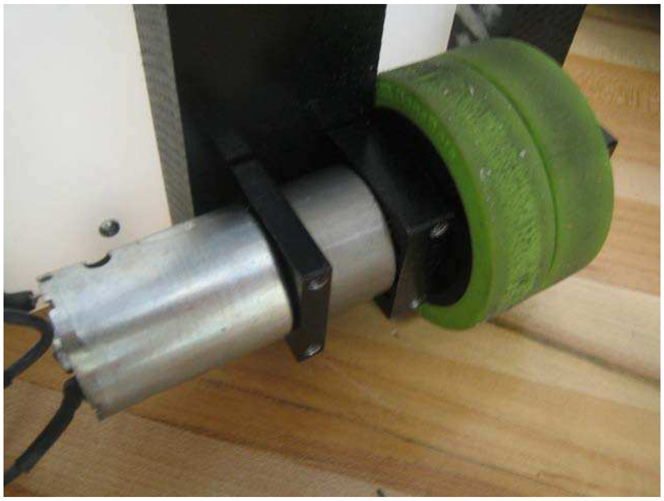
Removing side walls of receiver





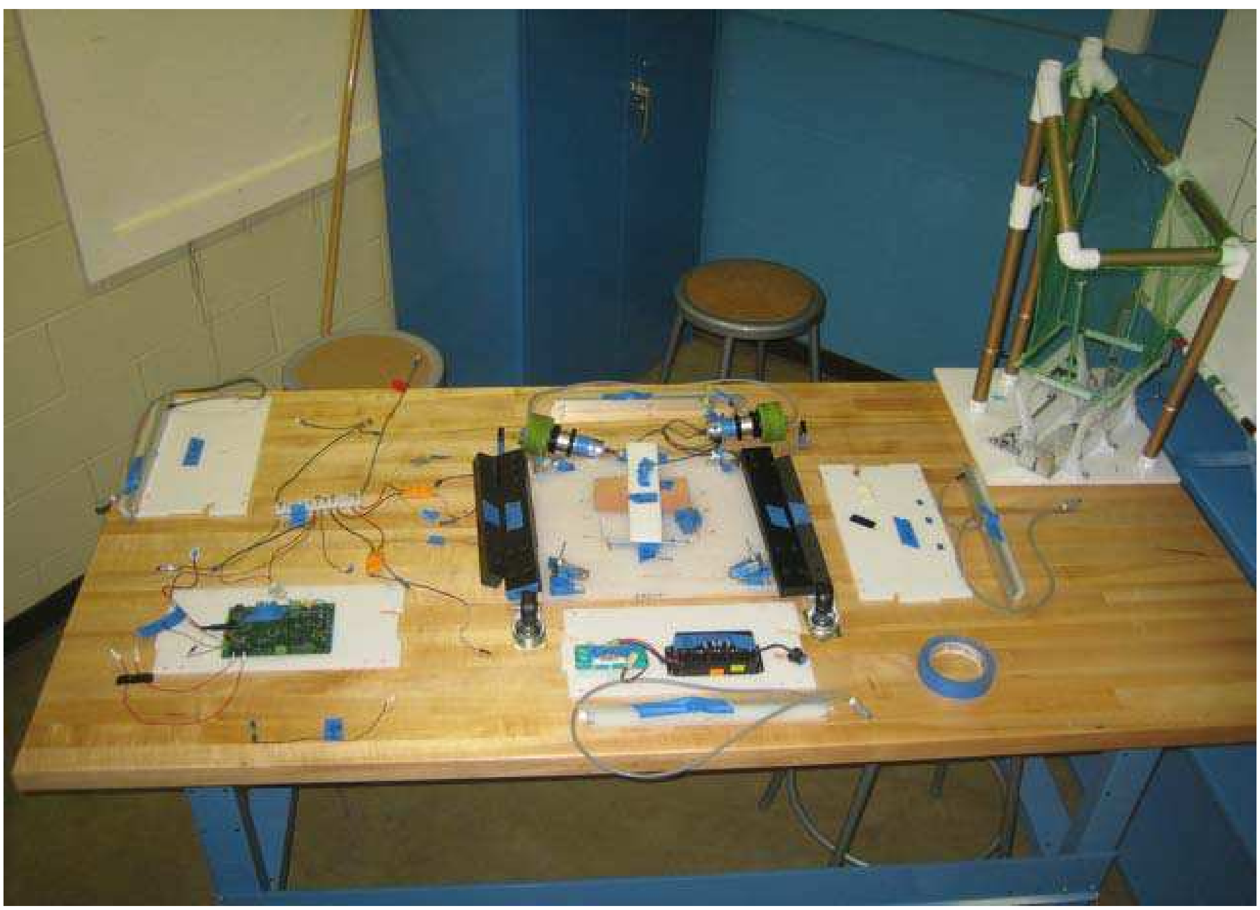
Bottom drive system before removal. The wheel and motor anchors doubled as effective support systems

Bottom reinforcements and countersunk fasteners

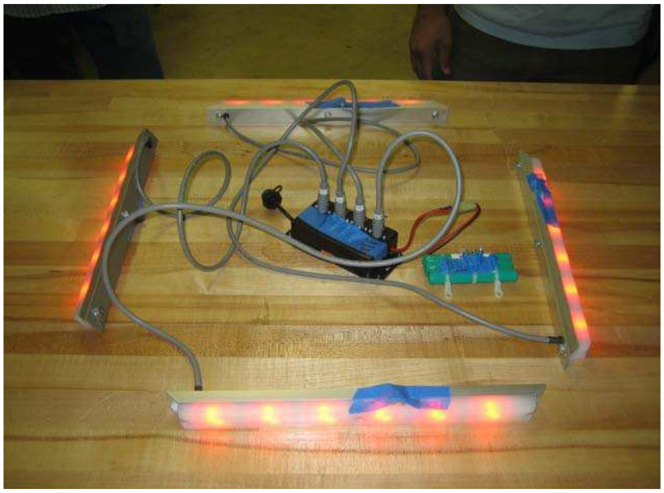


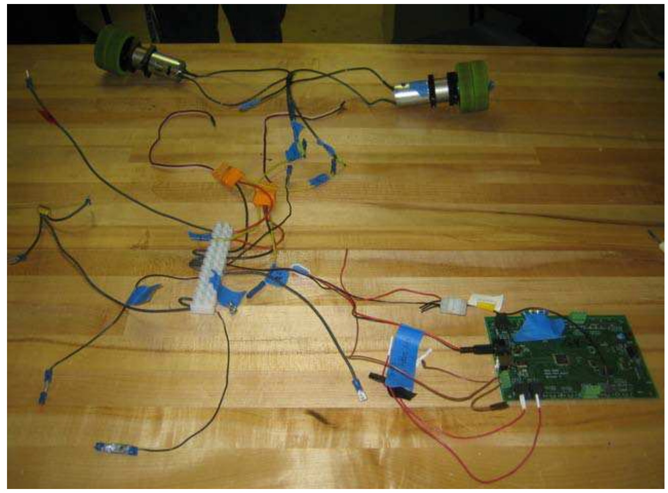
Receiver's driven wheels and motor, one in each back corner

Free coasting wheel in both front corners of the reciever



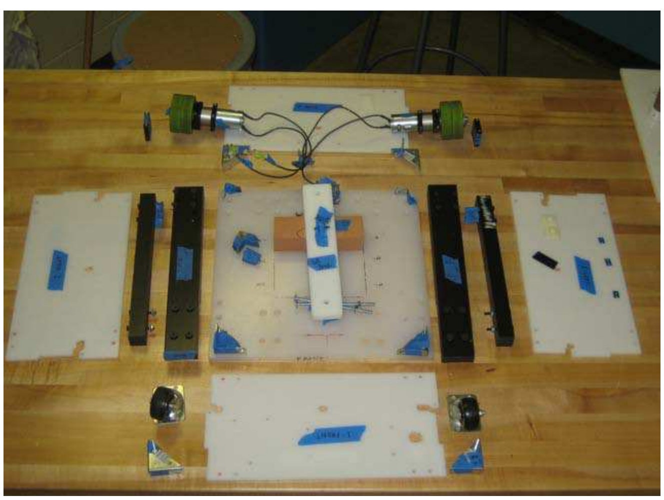
Completely disassembled receiver with the electronic system on the left, structural components in the middle, and receiving arm on the right





Tackle sensor system

Electronic network with the microprocessor lower right, power strip in the center then electric motors on top

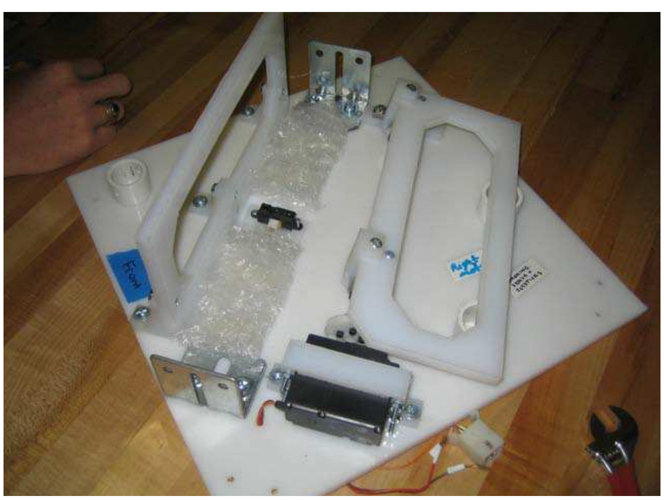


Receiver's structural and driving components

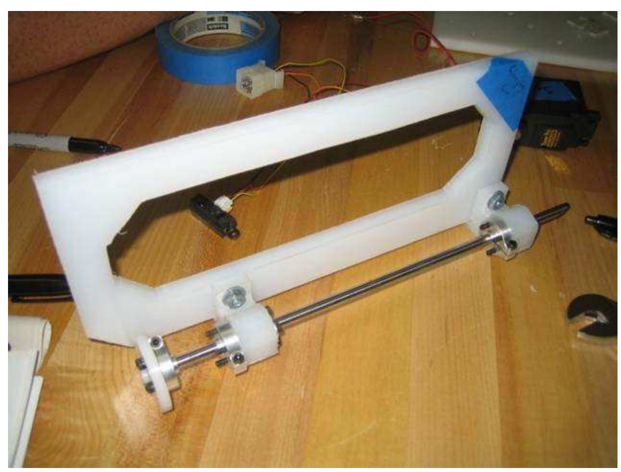
Receiver's top netting and ball grasp pre-disassembly

Football grasping system with the servor and ball reception sensor

Electronic network with the microprocessor lower right, power strip in the center then electric motors on top



Receiver's structural and driving components

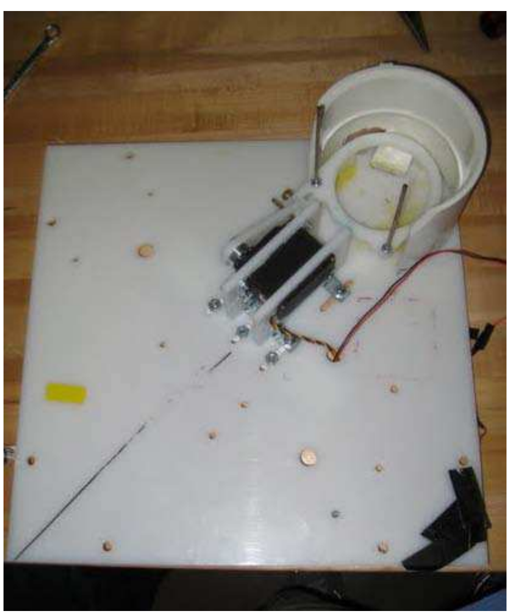


Receiver's top netting and ball grasp pre-disassembly

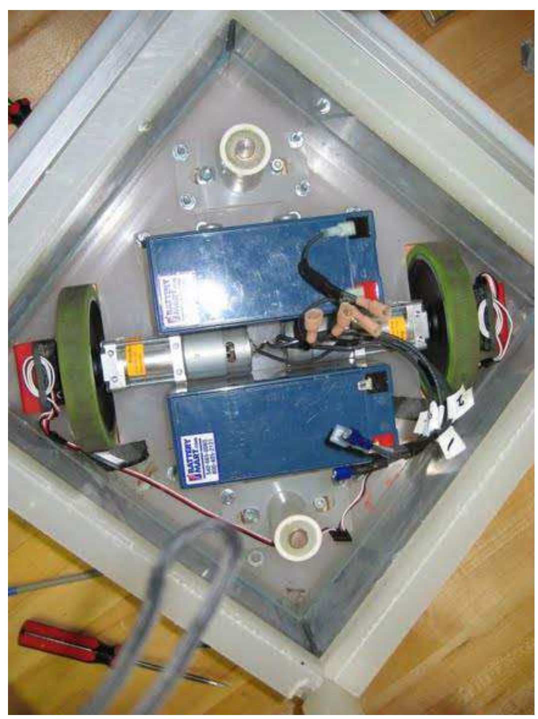
<u>Photographic Record of Disassembly</u>
Blue Quarterback

Blue Team quarterback robot before teardown.

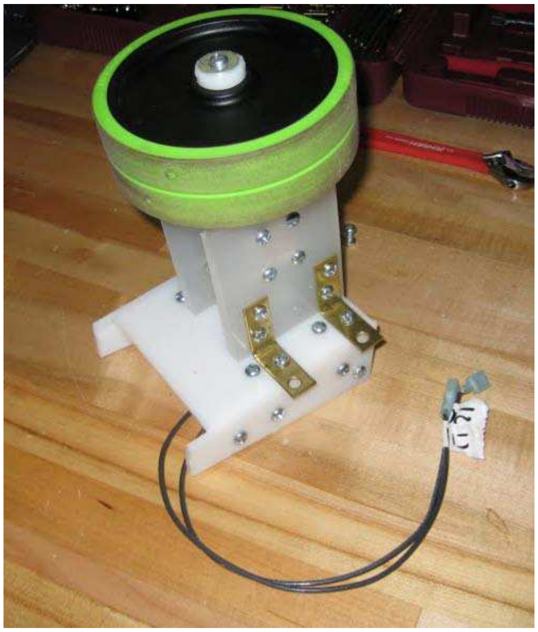
Robot with top top mounting plate removed. From top to bottom the components shown are the processing board, batteries, wheel motor, and tackle sensor.



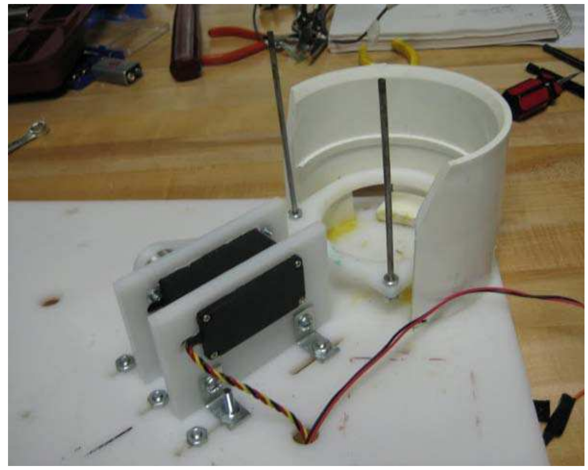
The top plate of the quarterback removed from the base of the robot.



The drive system for the robot including wheels, gearboxes, motors, battery packs, and shock absorbers.



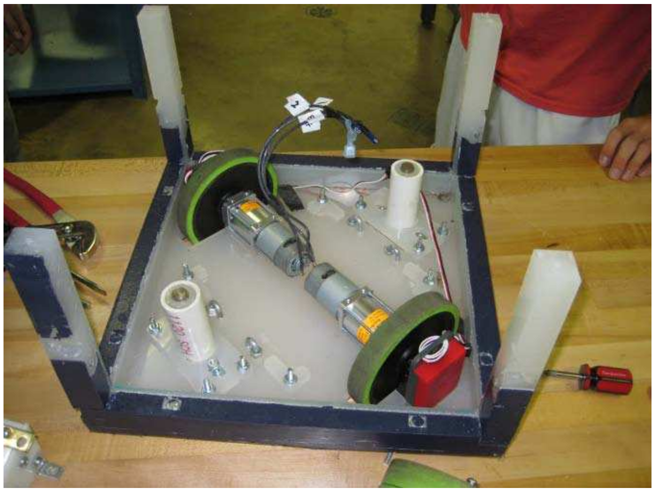
Throwing arm assembly. Includes motor, gearbox, wheel, and support assembly.



Ball-loading assembly on the top plate of the quarterback.

Exploded view of the one throwing wheel, motor and bracing assembly.

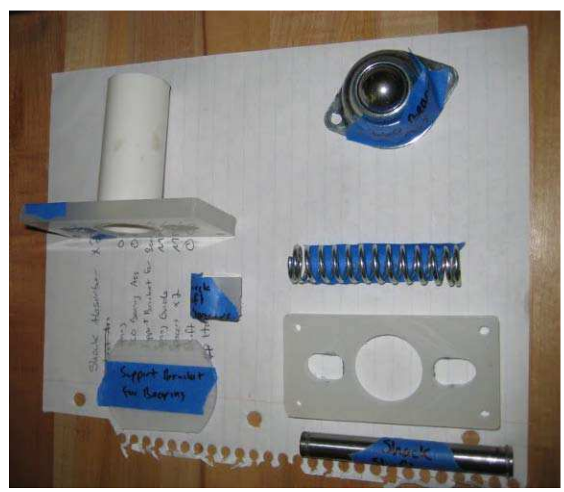
Exploded view of the ball-loading assembly including the motor, supports, and loading arms.



Base Assembly with the side plates and electrical assembly removed.

Force sensor assembly components. From top to bottom are the force sensor and lights, sensor buffer bar, and mounting hardware.

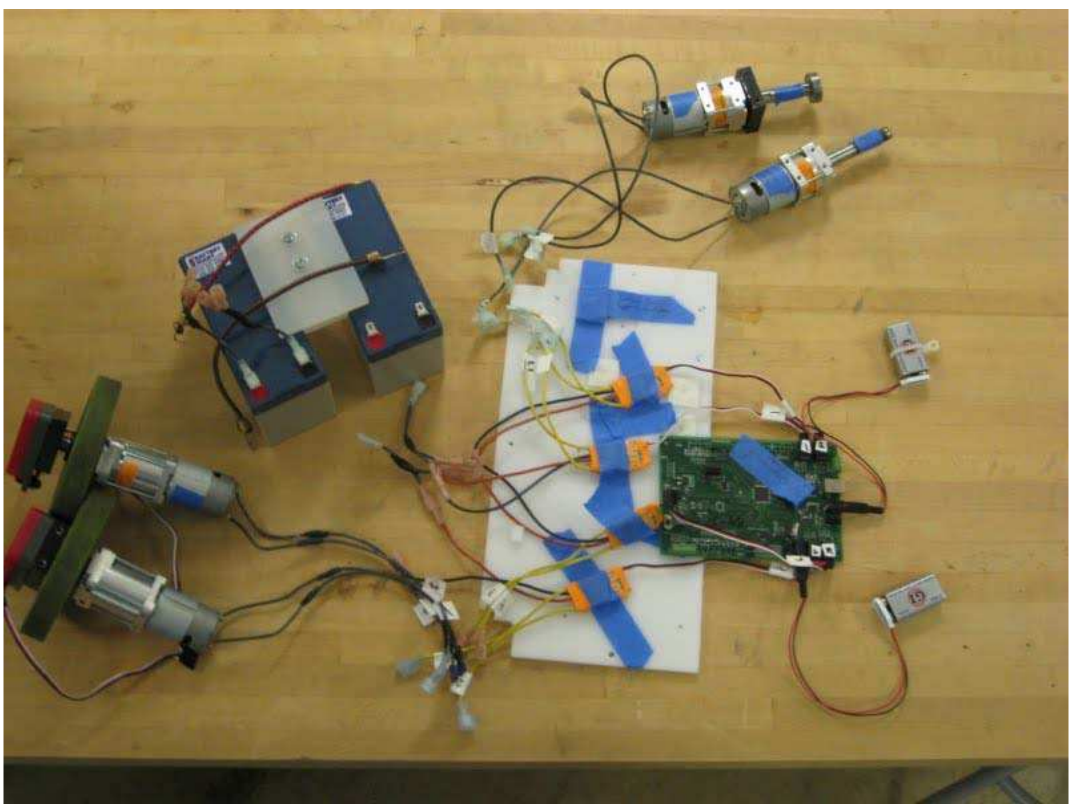
Base structural support assembly with other components removed for clarity.



The components of the shock absorber assembly. From left to right are the spring guide, support bracket, spacer, ball bearing and housing, spring, mounting bracket, and shock shaft.

Motor used for player movement.

Shock absorber ball bearing, housing, and spring guide.



Electrical assembly components and connecting cables. From left to right are the driving wheels, motors, batteries, mounting board, throwing motors, and circuit board.

Key Positives of Design of Receiver (Gold Team)

1. Catching Net
   - The use of PVC pipe for the structure of the catching net was cost effective and sturdy.

2. Clamping Mechanism
   - The use of bubble wrap provided malleable support for the clamping mechanism. It was also cost effective.

3. Zip Ties
   - Zip ties for attaching objects to the walls were cost effective.

4. Frame
   - Interlocking walls added stability to the design.

5. Catching Net
   - The use of netting was cheap and allowed for inaccuracy from the QB.

6. Battery Tie Down Bar
   - Battery tie down bar was simple and kept the batteries in place.

7. Drive System
   - Wheels allow a sharp turning radius for the robot.

8. Frame Support
   - The use of brackets to support the sidewalls provided structural stability.

9. Battery Expansion
   - Using a battery spacer secured the batteries inside the robot. Also, the design allowed for simple battery pack expansion.

10. Battery Power
    - The 9V batteries used to power the small circuits within the robot were cheap and readily available.

11. Internal Component Access
    - Top plate allowed easy access to the internal components of the robot.

12. Clamping Sensor
    - The use of a sensor to determine a reception decreased operator responsibility.

13. Simple Design
    - Three independent subsystems helped simplify design and facilitate troubleshooting.

14. Traction
- The driving wheels provided ample traction.

15. USB Port
- Easy connectivity via capped mini USB port.

<u>Key Negatives of Design of Receiver (Gold Team)</u>

1. Frame
- Poor placement of the screws that connected the sidewalls. Difficult to remove the bolts.

2. Zip Ties
- Zip ties presented a problem when a replacement part was needed because the zip ties must be cut.

3. Tackle Sensors
- Tackle sensors were loose and missing parts.

4. Assembly
- Washers were not used correctly. The tackle sensor box was missing washers.

5. Machining
- Extra holes were machined and not used.

6. Wire Length
- Wires were too long which caused the inside to be cluttered.

7. Servo Motor Arm
- Servo motor closing arm could dislocate itself. Also, the motor would be difficult to exchange.

8. Clamping Mechanism
- Bubble wrap will eventually wear down and all the bubbles will pop.

9. Tackle Sensor Replacement
- Wiring harness was constrictive at the hole. Replacing the tackle sensors would be difficult because the holes were machined too small.

10. Clamping Sensor Replacement
- The sensor to detect a loose ball could not be changed without removing other parts of the robot.

11. Finished Parts

- Burrs not removed from the machined surfaces. This took away from the presentation of the robot.

12. Wire Labels
    - No wire labeling made it difficult to trace wires around the robot.

13. Size of Catching Net
    - Need to maximize the cross section of the net to allow for inaccuracy from the QB.

14. Loctite
    - Unnecessary red Loctite on the bolts.

15. Pin Connections
    - Male and female pin connectors were not appropriate size.

<u>Key Positives of Design of Quarterback (Blue Team)</u>

1. Ball holder/guide
    - The holder was simply made, held the ball in the necessary position for passing, and seemed to secure the ball through evasive/running maneuvers.

2. Strength of plastic frame material
    - Seemed completely indestructible.

3. Simple overall design
    - Total number of frame parts was relatively low, which helped simplify design and keep cost low, structural integrity was easy to maintain.

4. Sturdy construction
    - Everything was bolted and glued together several times and in different ways, meaning breakage was extremely unlikely.

5. Accomplished player function
    - In the video it seemed the QB did everything it needed to do effectively.

6. Outsourced parts
    - Purchased and incorporated into design appropriately and effectively for functionality.

7. 9V batteries
    - Light, small, cheap, and effective for powering smaller electronic components.

8. Shafts
    - Used shaft keys rather than other methods of attachment which was easy, simple, light, cheap, and effective while allowing for a large factor of sturdiness in assembly.

9. Force tackling sensors

- Used only necessary items to decrease cost and complexity, fulfilled function.

10. Motors
    - Motors were very powerful and allowed for strong throwing and movement speed capabilities.

11. Circuit mounting board
    - Very simple, strong, and effective. Held everything in place without overcomplicating design.

12. Interchangeable tops
    - Allows base of robot to perform any positions necessary functions with minimal interchange of parts.

13. Inexpensive imitation of existing devices
    - Use of double-wheel throwing arms imitates professional throwing machines without inherent cost.

14. U bolts
    - Ingenious method of anchoring batteries to base in conjunction with bungee chords without over-complicating things as well as allowing for easy change-outs.

15. Circuitry
    - All wires, connectors, switches and functions were clearly labeled and held together in multiple ways to ensure they wouldn't be jostled out of place or disconnected by hits or maneuvers.

Key Negatives of Design of Quarterback (Blue Team)

1. Throwing arms
    - Use of wheels as throwing arms only allowed for trajectory of ball to be changed by wheel speed, which severely limited flexibility in passing due to the need for precise positioning.

2. Arm supports
    - Used an extremely unnecessary amount of brackets and bolts to hold assembly together, which made assembly/disassembly long and tedious, as well as dramatically adding to numbers of parts and overall weight as well as cost.

3. Side plates
    - Required an unnecessary amount of parts and assembly bolts, some of which were extremely long, which added to complexity of design without adding to functionality; could've been implemented more efficiently to cut down on machining, cost, and assembly time.

4. Side panels

- Served only for decoration and their use rather than a single framework for the entire upper portion of robot unnecessarily added to complexity of design and required assembly.

5. Stud-mount ball transfers
   - Essentially was a pair of casters that served as balance for the robot, however, the casters didn't roll so much as drag so their performance in the design was a hindrance, and increased overall cost and weight significantly.

6. Dampers
   - Attached to casters but were completely unnecessary, since the length of stroke was extremely minimal and force required for displacement was extremely high.

7. Overall wiring
   - Extremely cramped and complicated; must've been a nightmare to fix should any electrical issue occur.

8. Large batteries
   - Extremely heavy and costly, took up a lot of space, required a number of extra parts to hold in place, could've been smaller since battery life needed for game was greatly exceeded by design.

9. Power controllers
   - Single most expensive parts of entire robot, which together cost more than the rest combined; most likely could've used a simpler, cheaper method of controlling power output.

10. Wheel assemblies
    - Heavy, ungainly, large, and were placed diagonally in relation to robot body, which made other supports necessary as well as unbalancing the entire robot, also greatly complicated unidirectional movement.

11. Ball loading assembly
    - Required servo motor to move ball into throwing arms, thus increasing cost and assembly, decreased sturdiness, and increased complexity of design unnecessarily.

12. Bearings
    - Costly, as well as requiring a ridiculous amount of time and effort to assemble and mount.

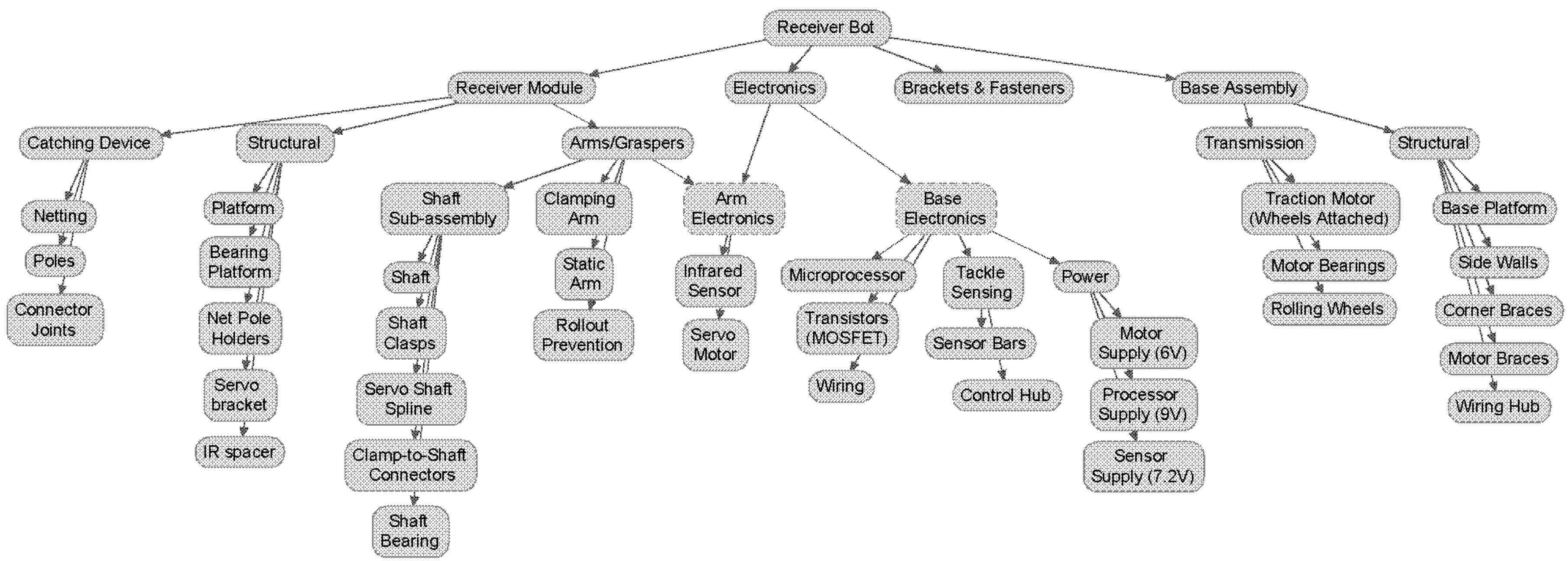
13. Top assembly
    - Required a large amount of holes, grooves, and hardware to mount throwing assembly; could've been greatly simplified.

14. Glued nuts and bolts
    - Unnecessarily hard to disassemble, therefore it would be nearly impossible to switch out

parts quickly.

15. Poorly-made machined parts
    - Seemed to be a large “slop factor” which required more work and shoddy fixes for design flaws.

Decomposition Map
Gold Receiver



Bill of Materials

Blue Quarterback

Part	Quantity	Part description	Assembly Group	Materials Used	Fabrication Process/Time	Model Number/Source	Cost estimate
Top Mounting Plate	1	Main part of QB top	QB Top	Plastic	CAD/CAM, Mill		
Ball Holder/Guide	1	Secured ball prior to loading	QB Top	PVC Pipe	Power/hand tools (15 minutes)		
Mounting Brackets	2	Secured Loading Ass.	QB Top			NA	<$1.00
Servo Motor	1		Loading Ass.			Hitec HS-755HB	$30.00
Bearing Block	1	Connection between motor and arm	Loading Ass.			BaneBots	$10.00
Arm	1	Rotates ball holder into wheels	Loading Ass.	Plastic	CAD/CAM, Mill (<5 minutes)		
Feeding Arm Support	2		Loading Ass.	Plastic	CAD/CAM, Mill (<5 minutes)		
Ball Holder	1	Secures ball but keeps it free to be launched by wheels	Loading Ass.	Plastic/Metal rods	CAD/CAM, Mill (<5 minutes)		
Base Plate Circ. Holes	1		Arm Mount Ass.	Plastic	CAD/CAM, Mill		
Part	Quantity	Part description	Assembly Group	Materials Used	Fabrication Process/Time	Model Number/Source	
Top Mounting Plate	1	Main part of QB top	QB Top	Plastic	CAD/CAM, Mill		
Ball Holder/Guide	1	Secured ball prior to loading	QB Top	PVC Pipe	Power/hand tools (15 minutes)		
Mounting Brackets	2	Secured Loading Ass.	QB Top			NA	$3.00-$5.00
Servo Motor	1		Loading Ass.			Hitec HS-755HB	$25.00
Bearing Block	1	Connection between motor and arm	Loading Ass.			BaneBots	
Arm	1	Rotates ball	Loading Ass.	Plastic	CAD/CAM, Mill		

		holder into wheels			(<5 minutes)		
Feeding Arm Support	2		Loading Ass.	Plastic	CAD/CAM, Mill (<5 minutes)		
Ball Holder	1	Secures ball but keeps it free to be launched by wheels	Loading Ass.	Plastic/Metal rods	CAD/CAM, Mill (<5 minutes)		$1.00
Base Plate Circ. Holes	1		Arm Mount Ass.	Plastic	CAD/CAM, Mill		<$1.00
Electronic Wires	1		Force Sensor Ass.				
Buffer Bar	1	Buffer between tackler and sensor	Force Sensor Ass.	Plastic	CAD/CAM, Mill (<5 min)		
Sensor Support Bracket	1	Housed circuit board	Force Sensor Ass.	Metal	CAD/CAM, Mill (10 min)		
Force Sensor Circuit Board	1	Tackle Sensor	Force Sensor Ass.			Unknown	$5.00-15.00
Motor Assembly	1	Rotates throwing wheels	Throwing Arm Ass.			BaneBots P60K-4-0004	$50.00
Spacer	3		Throwing Arm Ass.	Plastic	Power Tools (2 min)		
Ball Bearing	1		Throwing Arm Ass.			BaneBots	$1.00
Bearing Block	1		Throwing Arm Ass.			BaneBots	$10.00
Wheels	2	Propels ball forward	Throwing Arm Ass.			BaneBots	$5.00-10.00
Shaft Key Insert	1		Throwing Arm Ass.			Unknown	<$1.00
Shaft	1		Throwing Arm. Ass.			BaneBots	$1.00
Railings	4		Base	Plastic	CAD/CAM, Mill (5 min)		
Side Plates	3		Base	Plastic	Power Tools (10 min)		
Side Panels	4	Decoration	Base	Plastic			
Frame	1		Base	Plastic	Power Tools (25 min)		
Top	1		Base	Plastic	CAD/CAM, Mill (15 min)		

Large Batteries	2		Electronic Ass.			Powersonic PS-1271F2 12V 7.2AmpHr	$25.00
Power Controller	4		Electronic Ass.			Banebots BB-12-4	$60.00
Circuit Board	1		Electronic Ass.			Unknown	$15-$20
9V Battery	2		Electronic Ass.			G.I. Super Heavy Duty	$0.50
Wheel Ass.	2		Electronic Ass.			Unknown	$65.00
9V Battery Clip	2		Electronic Ass.			Unknown	<$0.50
Mounting Board	1		Electronic Ass.	Plastic	CAD/CAM, Mill		
Battery Plate	1	Connects two Large Batteries	Electronic Ass.	Plastic	CAD/CAM, Mill		
Assorted Wiring	NA					Assorted, Unknown	$10.00
Flat Head Bolt	14	2" Length				Unknown	<$0.10
Washers	39					Unknown	<0.10
Free Runner Nut	94	3/8"				Unknown	<0.10
Phillips Head Bolt	18	1" Length				Unknown	<0.10
Hexhead Shoulder Screw	3					Unknown	$1.00-$1.50
Pressfit Washer	3	3/8"				Unknown	<$0.10
Phillips Head Bolt	72	0.5" Length				Unknown	<$0.10
L Bracket	8	2"				Unknown	$0.50
L Bracket	22	1"				Unknown	$0.30
Rounded L-Bracket	8	1"				Unknown	$0.30
Phillips Screw	29	1/2" Length				Unknown	<$0.10
Phillips Head Screw (Flush Head)	3	1/2" Length				Unknown	<$0.10
Bolt	10	3" Length; 7/16"				Unknown	<$0.10
Washer	10					Unknown	<$0.10
Free Runner Nut	16	7/16"				Unknown	<$0.10

Bolt		3.5" Length; 7/16"				Unknown	<$0.10
Wingnut	8					Unknown	$0.50-$1.00
Flat Head Screw	12	3" Length				Unknown	<$0.10
U Bolts	4					Unknown	$0.50-$1.00
Metal Rod	2	5" Length				Unknown	$2.00
Small Free Runner Nut	6					Unknown	<$0.10
Small Flat Head Bolt	4	0.5" Length				Unknown	<$0.10
Small Phillips Head Bolt	5	0.5" Length				Unknown	<$0.10
Medium Free Runner Nut	4					Unknown	<$0.10
Misc Nut	1					Unknown	<$0.10
Brass Flat Head Bolt	1	1"				Unknown	<$0.10
Brass Flat Head Bolt	1	2"				Unknown	<$0.10

Bill of Materials
Gold Receiver

PART	QUANTITY	DESCRIPTION	ASSEMBLY GROUP	MATERIAL USED (M)	FABRICATION PROCESS/TIME (M)	MODEL # /SOURCE (O)	COST (O)
Green Netting	1	Plastic net to catch ball	Catching Device			UNK	$1.00
3/4" 45deg PVC connecter joint	2		Catching Device			Spears 475-007	$3.00
3/4" 90deg PVC connecter joint	3		Catching Device			Nibco D-2466	$2.00
3/4" H PVC connecter joints	4		Catching Device			Nibco D-2466	$2.00
3/4" corner PVC connecter joint	1		Catching Device			Nibco D-2466	$2.00
1" gold metallic pipes	10	Held green netting up	Catching Device			UNK	$3.00
Servo Motor	1	Double ball bearing servo	Top Assembly			Towerpro 9805BB	$25.00
Infrared Sensor	1		Top Assembly			Sharp 2D120X	$10.00
3/4" PVC caps	3	Held the gold poles for net	Top Assembly			Nibco 9447-007	$1.50
5/8" screws	3	Flat head counter-sunk	Top Assembly			UNK	$0.10
1/8" nuts	3		Top Assembly			UNK	$0.10
90deg elbow brackets	2	Kept ball from rolling out sides	Top Assembly			UNK	$1.50
3/4" D washers	8		Top Assembly			UNK	$0.10
3/8" nuts	4		Top Assembly			UNK	$0.10
1" L, 3/8" D bolts	4		Top Assembly			UNK	$0.10
Anchored bearing 1/4" shaft	1	Held other end of arm shaft	Top Assembly			UNK	$4.00
Shaft clasp 1/4"	3	Prevented axial movement on shaft	Top Assembly			UNK	$2.50
1.25" , 3/64" D	8	Hex-Head	Top Assembly			UNK	$0.10
3/64" washer, 3/8" OD	8		Top Assembly			UNK	$0.10
Servo shaft spline	1	Attach servo to shaft	Top Assembly			UNK	$3.00
1/2" hex-head bolts, 3/64" D	4		Top Assembly			UNK	$0.10
Arm shaft, 1/4" D, 10.5" L	1	Physically rotated by servo	Top Assembly			UNK	$2.50

Clamp-to-shaft connectors, 3/4" plastic	2	Attach clamping arm to arm shaft	Top Assembly	Plastic	CAD/CAM, Mill (30 min)		
3/16" D, 3/4" L bolts	2		Top Assembly			UNK	$0.10
3/16" washers, 1/2" OD	2		Top Assembly			UNK	$0.10
3/16" nuts	2		Top Assembly			UNK	$0.10
1/4" D, 3/4" L screws	2		Top Assembly			UNK	$0.10
Clamping arm, 7/16" plastic	1	Clamps down on ball once caught	Top Assembly	Plastic	CAD/CAM, Mill (15 min)		
Bearing platform, 1/4" plastic	1	Added height to anchored bearing	Top Assembly	Plastic	CAD/CAM, Mill (15 min)		
3/8" D, 1.5" L bolts	2		Top Assembly			UNK	$0.10
3/8" washer, 3/4" OD	2		Top Assembly			UNK	$0.10
3/8" nuts	2		Top Assembly			UNK	$0.10
Servo holding bracket, 3/4"	1	Holds servo motor in place	Top Assembly	Plastic	CAD/CAM, Mill (15 min)		
1/8" D, 1" L bolts	2		Top Assembly			UNK	$0.10
1/8" washer, 3/4" OD	2		Top Assembly			UNK	$0.10
1/8" nuts	2		Top Assembly			UNK	$0.10
3/16" D, 1.5" L bolts	4		Top Assembly			UNK	$0.10
3/16" washers, 3/8" OD	8		Top Assembly			UNK	$0.10
3/16" nuts	4		Top Assembly			UNK	$0.10
Top Platform, 14"x14"x7/16"	1	Top face of robot	Top Assembly	Plastic	CAD/CAM, Mill (15 min)		
IR Spacer, 3/4" plastic	1	Provide spacing for infrared sensor	Top Assembly	Plastic	CAD/CAM, Mill (15 min)		
1/16" D, 1.25" L bolts	2		Top Assembly			UNK	$0.10
1/16" nuts	2		Top Assembly			UNK	$0.10
Static ball clamp arm, 7/16" plastic	1	2nd arm for ball to clamp to	Top Assembly	Plastic	CAD/CAM, Mill (15 min)		
Static 90deg braces, 3/4" plastic	3	Held static arm to top platform	Top Assembly	Plastic	CAD/CAM, Mill (15 min)		
3/16" D, 3/4" L bolts	3		Top Assembly			UNK	$0.10
1/4" D, 3/4" L screws	3		Top Assembly			UNK	$0.10
3/16" D, 1" L bolts	3		Top Assembly			UNK	$0.10
3/16" nuts	6		Top Assembly			UNK	$0.10

3/16" washers, 1/2" OD	9		Top Assembly			UNK	$0.10
Microprocessor Board	1		Electronics			EE Department	
7/8" screws	4	Flat head counter-sunk	Electronics			UNK	$0.10
1/8" nuts	4		Electronics			UNK	$0.10
9V Supply-to-Battery	1		Electronics			UNK	$0.50
MOSFET Transistors	2		Electronics			BaneBots BB-12-45	$4.50
2.08mm Wires	3		Electronics			Essexep.com E53446B	$0.20
Wire Connector/Mounter	1	Plastic, allowed for wall mounting	Electronics			UNK	$4.00
7/8" screws	2	Flat head counter-sunk	Electronics			UNK	$0.10
1/8" nuts	2		Electronics			UNK	$0.10
1/16" Wires	8		Electronics			UNK	$0.10
6V 12.0Amp.Hr. Batteries	2		Battery			Power Sonic PS-6100 F1	$25.00
Battery Spacer	1	Brittle material. Spaces batteries	Battery	UNK	Hand Tools (10 min)		
Battery Brace	1	Holds batteries in place	Battery	Plastic	CAD/CAM, Mill (15 min)		
1/4" D, 4.75" L bolts	2		Battery			UNK	$0.10
1/4" nuts	2		Battery			UNK	$0.10
1/4" hand-twist fasteners	2		Battery			UNK	$0.10
Corner Brace Battery Holders	8		Battery			UNK	$1.00
5/8" screws	8	Flat head counter-sunk	Battery			UNK	$0.10
Tackle Sensor Box	1		Tackle Sensor			Eastwin 3553	$6.00
5/8" screws	4	Flat head counter-sunk	Tackle Sensor			UNK	$0.10
1/8" nuts	4		Tackle Sensor			UNK	$0.10
Battery 8-Pack, 7.2V 200mAh	1		Tackle Sensor			Tenergy	$9.00
5/8" screws	3	Flat head counter-sunk	Tackle Sensor			UNK	$0.10
1/8" nuts	3		Tackle Sensor			UNK	$0.10
Zip-ties	3	To tie battery pack to wall	Tackle Sensor			UNK	$0.10
Tackle Sensors	4	Physically "feel" impact	Tackle Sensor			UNK	$7.00
Base Platform, 14"x14"x7/16" plastic	1	Bottom face of robot	Base Assembly	Plastic	CAD/CAM, Mill (15 min)		

Side Walls, 14"x7"x1/4" plastic	4	Sides faces of robot	Base Assembly	Plastic	CAD/CAM, Mill (15 min)		
2" H.D. Triangular Corner Brace	6	Attached side/top/bottom faces	Base Assembly			UNK 2622	$1.00
1/8" D, 1.5" L bolts	8		Base Assembly			UNK	$0.10
1/8" D, 5/8" L bolts	24		Base Assembly			UNK	$0.10
1/8" washers, 3/8" OD	36		Base Assembly			UNK	$0.10
1/8" nuts	32		Base Assembly			UNK	$0.10
Corner Brace	5	Attached side faces	Base Assembly			UNK	$1.00
1/8" D, 5/8" L bolts	10		Base Assembly			UNK	$0.10
1/8" washers, 3/8" OD	10		Base Assembly			UNK	$0.10
1/8" nuts	10		Base Assembly			UNK	$0.10
Motor Brace 12"x1"x1" composite	2	Held traction motors in place	Base Assembly	UNK	Hand Tools (10 min)		
3/16" D, 1.5" L bolts	8		Base Assembly			UNK	$0.10
3/16" washers, 1/2" OD	8		Base Assembly			UNK	$0.10
3/16" nuts	8		Base Assembly			UNK	$0.10
Motor Brace 14"x2"x1" composite	2	Held traction motors in place	Base Assembly	UNK	Hand Tools (10 min)		
3/16" D, 1.5" L bolts	8		Base Assembly			UNK	$0.10
Motor Bearings	2	Bearings for traction motor	Base Assembly			UNK	$2.00
Rolling Wheels	2	Pivoting rear wheels	Base Assembly			UNK	$5.00
1/4" D, 1.25" L bolts	8		Base Assembly			UNK	$0.10
1/4" nuts	8		Base Assembly			UNK	$0.10
Traction Motor with Wheels Attached	2	Powered wheels that drove robot	Base Assembly			UNK	$50.00

P2 – Project Assessment Project 9/10/2009
Initial Disassembly Memorandum

Group 3: James Baummer, John Schaefer, Erik Miller, Cameron Hogue, Miroslav Brzobohaty, Brian Towle, Aron O'Connor, Michael Koehler, Allison Cudworth, Cameron Eckert, John Sabol

The purpose of this document is to establish an initial plan for the disassembly of two mechatronic football players from the previous year's project. This includes the physical dismemberment of the robots as well as the documentation and evaluation that will occur throughout the project.

Team Organization –

To make the best use of time and resources, the group has been split into two units. Each unit will undertake the task of disassembly and documentation of a mechatronic player. A 'Team Manager' has been assigned to take leadership of each group by leading group organization and communication. Although the teams will work closely with each other throughout the process, meeting availability and lab time will be chosen based on the smaller units. The groups will be divided as follows:

Gold Team - Brian Towle (Manager), John Sabol, Cam Hogue, Erik Miller, Allison Cudworth, Michael Koehler
Blue Team - James Baummer (Manager), Aron O'Connor, John Schaefer, Cameron Eckert, Miroslav Brzobohaty

Tasks Distribution – Both teams will execute similar tasks with their respective robots.
1) *Physical Disassembly*: (Blue- Cameron, Miro; Gold- Cam, Erik, Michael)
- Structural decomposition of robots
- Asses part fabrication quality and quality of assembly within 'player'
- Dictates observations to recorders

** Note: Everyone will take part in the disassembly process. This will ensure that all group members physically interact with the robots and get to better understand them.
2) *Recorder/Observer*: (Blue- James, John; Gold- Allison, John)
- Keep inventory of parts (differentiate between machined and outsourced parts)
- Decipher part function/usage (keep in mind overall utility of mechatronic player)
- Label parts with possible manufacturing process/manufacturer and function as well as part quality using categorization system (to be explained in final paper)
- Record observations/insights of disassembly members

3) *Photographer/Concept Map* (Blue- Aron; Gold- Brian)
- Record visual documentation of disassembly process (with labels from recorders)
- Document individual parts and placement within assembly (before and after disassembly)
- Sketch preliminary concept map—separate robot into sections and sketch individual sections to simplify process

Other Considerations – After completion of the disassembly process, the groups will meet to compare notes, share experiences, synthesize information gathered, and discuss the breakup of the final report.