RoboCup Soccer

Small Size Robot and Platform Design Proposal

“I pledge my honor that I have abided by the Stevens Honor System.”

October 1, 2009

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Daniel Silva
Executive Summary

This proposal is written to help outline the time, research, and funds that go into the Stevens Institute of Technology’s Mechanical Engineering Department Robotic Senior Design Project. It is the start of a yearlong effort to compete in the RoboSoccer Cup competition in the Small Size League. This proposal is broken down into sections contributed by each member depending upon the details determined by the team’s design. Utilizing resources from previous designs, many other schools, and the technology made available, the team will construct and program a team of five fully operational and autonomous robotic soccer players during the semester. This will then give the team the opportunity to compete with other schools in the United States.
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Introduction

The RoboCup Small Size League (SSL) Soccer competition consists of a team of five fully autonomous robots that collectively play a successful game of soccer. The members of the Design Team include Patrick Alfonzo, Andrew Domicolo, Michael Fatovic, Amanda Goldman, and Daniel Silva, along with advisor Dr. David Cappelleri. The following is a written proposal of the team’s budget, research, programming, design concepts and future planning of the proposed project.

The original goal of the project was to design and fabricate the robotic team in order to compete in the World RoboCup 2010 Competition in Singapore. However, due to time constraint and funds the team decided that competing in Singapore is not a feasible option. The team then established communications with other RoboCup “regulars”, Georgia Tech and Carnegie Mellon University in order to find out the details about the Robotics US Open taking place at Harvard University in November 2009. Again, due to time restraints the team will not be able to compete in November; however, this event will serve as a good scouting opportunity to refine the team’s robot design and game strategy. The team now is looking to have several small scrimmages with numerous schools (Carnegie Mellon University, MIT, Harvard, and NYIT) around the East Coast in late spring 2010.

As stated before, funds are the most restricting stipulation for the design team. Although specific hardware sets have not yet been selected and materials have not yet been purchased, a preliminary budget forecast shows that a budgetary extension is going to be necessary. Some of the more expensive pieces of hardware that are not negotiable and need to be purchased are the globalization camera, motors, wireless communications, on-board electronics, and materials.

In short, the RoboCup SSL Design Team is proposing to design, build, and program up to five small sized robots to compete in a soccer scrimmage against other teams within the United States.
Plan of Action

The Stevens RoboCup SSL Design Team’s Gantt chart can be found attached in Appendix A. As of the documentation of this proposal the design team has only planned a schedule through December 2009. The reasoning behind this truncated schedule is due to the unknown scrimmage schedule that will be determined at a later point with other competing schools.

The design team has decided the best way to undergo the beginning of RoboCup Competition is to divide the work up evenly amongst all the group members. As shown in the previous chart, the team also decided to assign specific components of the overall project for each member to research and provide data for the rest of the group. After all of the information was collected, it has been compiled into this proposal. The rest of this proposal has been divided into each corresponding section as per each member’s research—Rules/Regulations, Internal Deadlines, Drive Train/ Motors, Motor Control, On-board Electronics, Communications, Programming, Ball Handling Mechanism, and Materials.

After looking into past competitors’ selections, the team members have made a suggestion on a specific piece of hardware to use for the rest of the design process. Each hardware option will be presented in each corresponding section and the datasheets will be available in the listed appendixes.

The team has organized several tasks to ensure all processes are being completed on time and the project as a whole is staying on schedule. As referenced in the previous chart, weekly meetings have been set up so the team can bring their research together, compile all their ideas, and choose the best option of each facet of the project. The team also created a weekly meeting time with the advisor, Dr. David Cappelleri, to provide the details within courses regulated deadlines. The team also utilizes our weekly meeting times with Dr. Cappelleri to gain professional insight to the project and problems we may oversee.
In terms of deliverables, the team is completing a predetermined amount of write-ups which are due early October and early December, as well as multiple progressive presentations throughout the semester, that are mandated by the Stevens Mechanical Engineering (ME) Department. The ME Department asks that each design group provides three write-ups this semester. The first paper is the proposal which discusses the project in general, conceptual designs, and design selection. The second progressive presentation discusses engineering design and analysis. The last final write-up includes a comprehensive presentation which justifies the final design using engineering tools.

Other than these mandatory reports and presentations the design group already foresees several additional deliverables that will be necessary to complete the design project. One unavoidable obstacle that the team must tackle is early equipment purchase. While other design groups will be spending the majority of their time this semester planning then utilizing next semester to purchase material and fabricate their designs, the RoboCup group needs to have all planning and fabrication done by early November of this semester due to possible competition and scrimmage dates. The team will need to expedite the design time and propose to the ME Department that all purchase orders get processed by the end of November, so that the team will be able to concentrate on programming and debugging the master program on an actual constructed robot at the end of the semester.

The team will also be submitting a budgetary extension proposal. When looking at the preliminary cost for each of the necessary materials and pieces of hardware to both complete the design project as well as be up to par with other competitors, the team is already well over budget. One leading factor that may help the team in requested an extension to their budget is that this design project may be offered year after year, thus making certain purchases a onetime expenditure. Each of these proposals have been compiled into the previous chart.

The design team has also created a process flowchart to help establish an order of what tasks need to be accomplished before others. This flowchart can be found on the following page.
| Planning       | • Material and Concept Selection  
|               | • Hardware Selection            
|               | • Preliminary Design Specifications  
|               | • Rules and Regulations        
|               | • Budgeting                    |
| Designing     | • Chassis                      
|               | • Programming Framework       
|               | • Hardware/Software Compatibility  
|               | • Visual Network              
|               | • Wireless Communications     
|               | • Game-play Strategy          |
| Preliminary   | • Partial Material Purchase   
|               | • Visualization Purchase      
|               | • Partial Fabrication         
|               | • Practice Field Creation and Set-up  
| Software Testing | • Run Subroutines          
|               | • Run Program Framework       
|               | • Debug Any Complications and Errors |
| Purchase      | • Remainder of Material       
|               | • Remainder of On-board Electronics  
|               | • Remainder of Sensors        |
| Team Fabrication | • Assemble Remaining Team Members  
|               | • Create Alternate Robot for Substitution (tba) |
| Final Software Test | • Team Communication  
|               | • Team Compatibility          
|               | • Program Execution           
|               | • Strategy Completion         |
| Final Presentations | • Oral and Powerpoint Presented to Panel  
|               | • Technical Poster            
|               | • Technical Website           
|               | • Final Technical Documentation |
Rules and Regulations

The rules that govern the RoboCup SSL 2010 Competition can be found in full in Appendix B. The following section is a paraphrased portion of the laws and rules that are the main proponents that create the requirements and stipulations for the team’s design.

Also included in this section are updated amendments made by the “F180 Technical Committee” which serves are the RoboCup SSL governing body. These sections will be indicated by italics.

Law 1 – Field of play
• Rectangular Field similar to a full size soccer field
• Length of 6,050 mm (238.19 inches)
• Width of 4,050 mm (159.45 inches)
• Made of green felt with white lines
• Out of bounds continues 675 mm (26.57 inches) further than white boundaries
• White lines are 10 mm (0.394 inches) wide
• Defensive areas semicircular in shape and located at the opposite ends of the field
• Goals are indicated by the gray rectangles adjacent to the defensive area
• Goals are colored dark to not interfere with any robot’s vision
• A video equipment mounting bar is located 4 meters (13.1 ft) above the playing field.
  o Teams could use to capture a live video feed in order to keep track of the ball and the position of each of their players at any location on the field

Figure 1: Schematic of RoboCup SSL 2010 approved field
**F180 Committee decisions:**

1. The organizing committee must use uniform lighting; however, the teams must cope with the ambient lighting all around the playing field at any scrimmage location.
2. No advertising may be completed by any robot, camera, or anywhere inside or on the goal while on the playing field.
3. The surface of the area underneath the field may vary, but all efforts should be made to made the playing surface both flat and level

**Law 2 – The ball**

- Size of a golf ball approximately 43 mm (1.69 inches) in diameter
- Orange in color
- A defect ball will result in a stoppage of play and will be replaced only by an official

**Law 3 – The number of robots**

- A maximum of 5 robots are allowed on the field during play, including the goalkeeper.
- Each robot must be visibly numbered to easily identify during play.
- There must be at least one robot per team to start a match.
- There is no limit to how many times spare robots are allowed to substitute for robots in play.

**F180 Committee decisions:**

1. Each team must have one team member designated to physical handle the interchanging and placing of robots in their specified positions. The movement of robots not approved by the official is strictly prohibited.

**Law 4 – Robotic equipment**

- Maximum of 180 mm (7.09 inches) diameter
- Maximum height of 150 mm (5.91 inches)
- Each team will be designated a color (yellow or blue)
- Color markers may be placed in any orientation about the center of the top of the robot
- Color markers have a diameter of 50 mm (1.97 inches)
- Other colors that may be used without restrictions are black, white, light green, light pink, and cyan
- The wheels must be made of material that is harmless to the material of the field.
- Any global visual systems that are used are not allowed to hang more than 150 mm (5.91 inches) below the mounting bar.

![Figure 2. Drawing of RoboCup SSL 2010 approved chassis dimensions]
**Other Stipulations**

All robots must be autonomous and at no point may a member of the design team input any digital information to their robots. The spin and force that is created by the dribbling and shooting mechanism must be perpendicular to the field (straight in front of the robot itself). Side dribblers and mechanical dribblers are not allowed.

Breaking of Law 4 need not stop the play of the match; however, the robot at fault is asked to leave the field to correct its equipment. This robot at fault may not reenter the field unless authorized to do so, where the referee will then check its equipment, and a robot is only allowed to reenter play when the ball is out of play.

**F180 Committee decisions:**
1. The local organizing committee must be notified of what mode of wireless communications each team will be using during play
2. Kicking devices are allowed
3. Metal spikes and Velcro are not allowed
4. Bluetooth is not allowed
5. Official colors will be provided before play of the match
6. Adhesives may not be using to control the ball
7. All robots will be checked prior to the match for adhering to all rules
Drive Train

An integral part of the team’s strategy involves the motors responsible for moving the robot as commanded by the remote processing unit. Upon researching previous motor/drive train designs, the team decided on the most cost efficient option that would meet all the design specifications.

Many designs use a four motor system, with direct drive to four Omni-wheels as shown in Figure 3 below:

![Figure 3: 4 Motor/Wheel Design Used by Kasetsart University](http://iml.cpe.ku.ac.th/skuba/drupal/comment/reply/1352)

The four motor designs provide maximum maneuverability and motion control options. However, the four wheel design creates several issues. Firstly, because this design requires four direct drive motors and 4 Omni-wheels, cost may become an issue. Also, the large amount of hardware required in this design may cause space issues, making it difficult to meet the robot’s size constraints. Lastly, the geometry and programming logic needed for motion control with a four wheel system becomes very complex.

Another design utilized two motors/wheels and a ball bearing caster (Figure 4). This design only uses two direct drive motor and does not require the use of Omni-wheels. This will reduce the price greatly, but this design also greatly limits maneuverability and motion control options as it eliminates the ability to move the robot side to side. This function to move the robot in a translational mode will prove to be a great asset in terms of offensive and defensive strategies when trying to maneuver around a defender or to stop an offensive attack.
The last design the team researched utilized three direct drive motors with Omni-wheels, such as the design shown in Figure 5.

This design allows great maneuverability and motion control options. In addition, because it uses only three motors and three Omni-wheels it will reduce both cost and space requirements. The programming however, will be somewhat complex because the robot has the capability to move in two dimensions (unlike the 2 motor/caster design). Ultimately, the group decided this design provides maximum flexibility and the greatest performance/cost ratio.
Motor Selection

The team researched various DC motors that met the performance requirements and compiled a list of compatible parts:

<table>
<thead>
<tr>
<th>Motor</th>
<th>Price/Unit</th>
<th>Size</th>
<th>Speed</th>
<th>Peak Torque</th>
<th>Peak Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaheim Automation BLWR17 Brushless DC Motor</td>
<td>$50</td>
<td>1.18&quot; long 1.65&quot; diam.</td>
<td>5000 rpm</td>
<td>8.5 oz/in</td>
<td>-</td>
</tr>
<tr>
<td>Premotec BL48 EB Brushless DC Motor</td>
<td>-</td>
<td>3.7cm long 5.4cm diam.</td>
<td>4600 rpm</td>
<td>43 mNm</td>
<td>2.13 A</td>
</tr>
<tr>
<td>Maxon EC45 Flat Brushless DC Motor</td>
<td>$60</td>
<td>1.6cm long 4.3cm diam.</td>
<td>4400 rpm</td>
<td>260 mNm</td>
<td>2.30 A</td>
</tr>
<tr>
<td>LynxMotion GHM01 DC Motor</td>
<td>$22</td>
<td>4.8cm long 3.7cm diam.</td>
<td>200 rpm</td>
<td>-</td>
<td>2.30 A</td>
</tr>
</tbody>
</table>

Wheel Selection

The team researched various Omniwheel models that met the performance requirements and compiled a list of compatible parts:

<table>
<thead>
<tr>
<th>Model</th>
<th>Price/Unit</th>
<th>Size</th>
<th>Capacity</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>AcroName R76</td>
<td>$12.75</td>
<td>4cm diam.</td>
<td>15 lbs</td>
<td></td>
</tr>
<tr>
<td>AcroName R129</td>
<td>$26.25</td>
<td>6cm diam.</td>
<td>50 lbs</td>
<td></td>
</tr>
<tr>
<td>Vwx Omni-Wheel</td>
<td>$19.99</td>
<td>7cm diam.</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Visual and Wireless Communications

During the RoboCup SSL match there will be five robots communicating on the playing field while simultaneously competing in the autonomous scrimmage. In order to accomplish this task, each robot will need to wirelessly communicate to a host computer, which will relay the game strategy via the main program to each robot. The host computer will be connected to a globalization camera positioned over the playing field in order to track all robots and the ball in play. The team has decided to use LabVIEW as the programming interface due to the powerful image processing tools that are integrated within the program.

The globalization camera is one of the key components of the design team’s hardware selection. The camera decided upon will be used to track the positions of each robot on the field, as well as the location of the ball. In addition, the camera will need to track the ball as it is being shot across the field at high speed. The camera that the team is discussing to purchase and work with is a Prosilica EC750C firewire camera, shown to the right in Figure 6 (http://www.graftek.com/pages/EC750C.htm, $750.00).

This camera gives a 752 by 480 color pixel image at a refresh rate of 60 frames per second. The camera will be ideal in capturing the fast pace movements of the game. Color detection is necessary in order to distinguish between opposing teams, as well as identifying a single robot on the field by the color assigned on top of the chassis that is built.

After the camera processes the image, a set of commands will then be sent to each robot. This needs to be done wirelessly to avoid a cluster of cables going into each robot and the rules and regulations provided about communication. The team has decided on using the XBee wireless modules ($20/each) to accomplish this task, as shown in Figure 7.

The XBee is a wireless module that conforms to the ZigBee wireless standard. The XBee will be seen as a Serial Communications (COM) port on the computer, allowing information, such as motor speeds and sensor outputs, to be easily sent to and from the host computer and robots.
**Motor Control**

*As of the documentation of this proposal the design team has not made a final selection on a motor controller to operate each robot. In the next few weeks a final choice will be made. This section presents several options that the team has compiled to choose from.*

The motor control board is the most essential piece of hardware for each of the team’s robotic players in terms of overall operation. The motor control board operates as the on-board electronic brain for each robot. It will connect to the wireless communications chip and receive a signal from the central processing unit (CPU). The board will then take those serial signals and send them to the various motors and operate each at the desired speed. The board is also able to take signals from the various sensors and encoders and transmit them back to the CPU to complete a closed loop signal complete with error feedback control.

The team has several components that create a list of requirements which will determine whether or not a chosen motor control board is the best fit for the team. The first and foremost important requirement is that the motor control board must be compatible with the team’s chosen wireless communications protocol—ZigBee. ZigBee’s main requirement is that the motor control board can receive an input signal coming from a serial port to operate various motors, sensors, and solenoid valves.

Another piece of hardware which creates a stipulation for the motor control board is the collection of drive train motors. The team has decided upon an Omni-wheel drive train system consisting of three motors and three specialized wheels, which when oriented in the correct manner allow the whole system to not only travel forward and backwards but allow it to translate and shift in all directions. Adding to the on-board motor count is the motor needed to run the solenoid valve which will operate the ball handing mechanism in terms of shooting. Collectively, the drive train motors and the solenoid valve require that four motors be wirelessly operated—thus at least a four channel output motor control board.

Other than these created requirements, there are mandated stipulations which are incurred through the rules and regulations for the RoboCup Competition itself. The main rule from these set of laws that help govern the motor control board selection is the allowed size restraint for the robot. After all on-board components are incorporated into the confines of the robot’s walls; there will be limited space for a motor control board, so the board must be rather small.

After taking all of these requirements into consideration and doing research, the team was able to find several potential motor control boards. Each of these boards are presented on the following page with several key features as well as retail price.
Net-Bee Zig Controller

**Price:** $49.00

**Features:**

- ~ 2.047 x 1.299 x 0.591 inches
- Microchip PIC18F24K20 controller@64MHz
- 3 Channels, 10-bit A/D Inputs
- Input Voltage Range – 8-16 VDC
- Input Current Transmitting – 65 mA@12VDC


The Motor Mind C: Dual DC Motor Controller

**Price:** $46.00

**Features:**

- ~ 2.362 x 0.748 x 0.354 inches
- 2 Channels, can be tied in parallel to add extra Channels
- Input Voltage Range – 6-24V
- Continuous Current – 4.5A dual motor


Wireless ZigBee Relay Controller with Relay Interface

**Price:** $113.00

**Features:**

- 2 Channel, 1-Amp

As it can be seen most of these motor controller boards do not fulfill the team’s 4 channel requirement to operate all three drive motors as well as the solenoid valve. At most, each of these controllers would have to be wired in parallel with another to be able to cover all required channels. Not only would that significantly increase the amount on controllers needed, but due to the retail price listed for each the team’s budget would need an even larger increase than it does already.

Also found is a Radio Transceiver Module which supports the ZigBee protocol which can be used to both receive and transmit signal from the CPU. The transceiver module then can be tied in through a 4 wire Serial Peripheral Interface Bus (SPI) to a Peripheral Interface Controller (PIC) capable up to 5 output channels. The details of each of these devices are listed below:

MRF24J40MA Radio Transceiver Module

Price: $18.95

Features:
- ~ 0.7 x 1.1 x 0.0394 inches
- PIC16F, PIC18F, PIC24F/H, dsPIC33, PIC32 Family
- Input Voltage Range – 2.4-3.6V
- Low-Current Consumption – RX: 19mA, TX: 23mA


PIC18F4321 Motor Controller

Price: ~$4.00

Features:
- Serial Peripheral Interface Equipped
- 5 Pulse-width Modulation Channels

Kicker and Dribbler Assembly

The Stevens RoboCup SSL Design Team is still deliberating on a final decision on the kicker and dribbler hardware and assembly. This section presents several options used by the Carnegie Mellon University RoboCup team the “CMDragons” which the Stevens Team will take into careful consideration when deciding on a final design. These models have been made available online at http://www.cs.cmu.edu/~robosoccer/small/hardware/.

The kicker and dribbler assembly is the most integral component of the robot during game play. The assembly typically consists of two main pieces, a motor driven spinning roller, dribbler, and a solenoid powered plate-kicker. This assembly allows the robot to complete its main objectives of controlling, passing, and shooting the ball. An example of a kicker and dribbler assembly designed by the Carnegie Mellon University (CM) Dragons robotics team can be seen in the figure below:

![Figure 8: Kicker/Dribbler Assembly Designed by the CMDragons](image)

As can be seen in the Figure 9, the dribbler exerts backspin on the ball to keep the ball in the robot's possession. Without the dribbler, the ball can roll away if the robot is to stop or slow down.

![Figure 9: RoboCup SSL 2010 approved dribbling method](image)
The dribbler consists of three components, the motor, the gears, and the roller. The main component of the dribbler is the motor. When choosing a motor, the major factors the team is looking for are the size, cost, and speed of the motor. The team wants a small sized motor, because of the previously mentioned size restrictions on the robot. The team also needs a motor which can transfer enough speed to the ball so that it will stay in contact with the robot. The final factor needed is a motor which fits into the already exhausted budget. The table on the following page shows a list of different motor options with their pros and cons:

<table>
<thead>
<tr>
<th>Motor</th>
<th>Price</th>
<th>Size</th>
<th>Speed</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>MicroMo 2230F006S</td>
<td>-</td>
<td>1.75&quot; long</td>
<td>8,000 rpm</td>
<td>High speeds</td>
<td>-Expensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.85&quot; diam.</td>
<td></td>
<td>-Small</td>
<td></td>
</tr>
<tr>
<td>MicroMo 1331T006SR</td>
<td>-</td>
<td>1.75&quot; long</td>
<td>12,000 rpm</td>
<td>High speeds</td>
<td>-Expensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.50&quot; diam.</td>
<td></td>
<td>-Small</td>
<td></td>
</tr>
<tr>
<td>Lynxmotion Gear Head Motor - 7.2vdc 30:1</td>
<td>$22.00</td>
<td>1.75&quot; long</td>
<td>291 rpm</td>
<td>Inexpensive</td>
<td>-Low speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5&quot; diam.</td>
<td></td>
<td>-Small</td>
<td></td>
</tr>
</tbody>
</table>

The kicker assembly is what allows the robot to both pass and shoot the ball. As seen in the figure to the right by the CMDragons, a kick plate can be pushed forward by either an electric or pneumatic solenoid.

When choosing a solenoid for the kicker, the major factors that the team considers are the force, the cost, and the size. The team wants a solenoid which could produce a great amount of force, because this translates into how fast the ball can be shot. As was the case with the dribbler motor, the team also needs a solenoid which could fit within the size restrictions of the competition and was also within their budget. The following table shows a list of different solenoid options and their pros and cons:

<table>
<thead>
<tr>
<th>Solenoid</th>
<th>Price</th>
<th>Size</th>
<th>Power</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bimba 0071 Pneumatic Solenoid</td>
<td>$12.00</td>
<td>2&quot; long</td>
<td>17.5 psi (78N)</td>
<td>-Relatively inexpensive</td>
<td>-Complex air system</td>
</tr>
<tr>
<td>Solenoidcity S-20-100-H Electric Solenoid</td>
<td>$45</td>
<td>2&quot; long</td>
<td>125 oz-f (34.75N)</td>
<td>-Easy installation</td>
<td>-Less force than pneumatic -Expensive</td>
</tr>
</tbody>
</table>
Body and Chassis

The design team plans to build the body and chassis in-house in order optimize cost and also to ensure that all their components will fit correctly. The construction plan is to machine the chassis out of aluminum and would be similar to the chassis shown in the Figure 11. Aluminum has been chosen because it can be easily machined, is inexpensive, and is a very light weight material. The body of the robot will be made out of acrylic plastic which will be cut on a laser cutter and shaped into a cylindrical external body that fits well within the boundary set up the RoboCup SSL F180 Technical Committee.

Figure 11: Chassis design for the CMDragons
Preliminary Program

The main program that runs the robots will consist of five “while” loops to handle the following scenarios:

1. When a team has possession of the ball:
   a. playing offense
   b. playing defense
2. For each type of restart of play
   a. kick-offs
   b. penalty kicks
   c. free kicks
   d. indirect free kicks

Below is the program flowchart of the offense loop, this loop will also be used as the free kick loop:
Below is the program flowchart of the indirect free kick, it is identical to the free kick flowchart, except that the ball must be passed first before a shot is taken:

Below is a basic program flowchart for the defensive loop:
Below is the flowchart of the free kick loop. The purpose of initially moving side to side in front of the ball is to prevent the goalie robot from the other team to predict where the robot will shoot into the goal. The rationale behind picking a random angle to shoot at the goal is so that the robot does not constantly shoot at the same location, thus making the shots less predictable. The random angle will be calculated internally, providing the values for the ball to land inside the goal.

Below is the program flowchart for the kick-off loop:
Conclusion

To conclude, the team is to design, construct, and program up to five small sized autonomous robots, which then compete in a soccer scrimmage. There are many focus points within the confines of the project as a whole—drive train, motor control, deadlines, budget, and program. The drive train and motor control have multiple options to choose from but as said before budget is a heavy factor in the final decision. Deadlines are an important aspect when proposing the preliminary ideas. The team would ideally like to begin purchasing by early November 2009, so this proposal is an in-depth, strongly researched and focused report on the items that will hopefully be purchased later in the semester. The budget will be given in detail within the coming weeks which will include a requisition for an extension. One proponent aiding in this request will be the recommending that the RoboCup SSL Senior Design Project becomes an annual design project. The program is going to take the longest to complete due to the inevitable error debugging next semester. This part of the project that should be ready to commence in January and in order to do so fabrication of the robots should begin December 2009. In the coming weeks the team will be expected to present a complete conceptual design, 3D models, CAD drawings, and a final budget of all external and internal parts.
Appendix A

Gantt Chart

Stevens Institute of Technology RoboCup SSL Design Team
<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Predecessors</th>
<th>Resource Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>11 days</td>
<td>Thu 9/17/09</td>
<td>Thu 10/1/09</td>
<td></td>
<td>Team</td>
</tr>
<tr>
<td>Rules and Regulations</td>
<td>6 days</td>
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Appendix B

RoboCup SSL 2010

Official Rules and Regulations of the F180 League
Laws of the F180 League 2009

LAW 1 - The Field of Play
LAW 2 - The Ball
LAW 3 - The Number of Robots
LAW 4 - The Robotic Equipment
LAW 5 - The Referee
LAW 6 - The Assistant Referee
LAW 7 - The Duration of the Match
LAW 8 - The Start and Restart of Play
LAW 9 - The Ball In and Out of Play
LAW 10 - The Method of Scoring
LAW 11 - Offside
LAW 12 - Fouls and Misconduct
LAW 13 - Free Kicks
LAW 14 - The Penalty Kick
LAW 15 - The Throw-In
LAW 16 - The Goal Kick
LAW 17 - The Corner Kick

Appendix A - The Competition Rules

**Notes**

**Male and Female**

References to the male gender in the Laws with respect to referees, assistant referees, team members and officials are for simplification and apply to both males and females.
**LAW 1 - The Field of Play**

### Dimensions

The field of play must be rectangular. The dimensions include boundary lines.

Length: 6050mm  
Width: 4050mm

![Figure 1: The field dimensions](image)

### Field Surface

The playing surface is green felt mat or carpet. The floor under the carpet is level, flat and hard.

The field surface will continue for 675 mm beyond the boundary lines on all sides. The outer 425mm of this runoff area are used as a designated referee walking area (see LAW 5). At the edge of the field surface, a 100 mm tall wall will prevent the ball and robots from running off the edge.

### Field Markings

The field of play is marked with lines. Lines belong to the areas of which they are boundaries.

The two longer sides are called touch boundaries. The two shorter sides are called goal boundaries.

All lines are 10 mm wide and painted white.
The field of play is divided into two halves by a halfway line. The centre mark is indicated at the midpoint of the halfway line. A circle with a diameter of 1000 mm is marked around it.

**The Defence Area**

A defence area is defined at each end of the field as follows:

Two quarter circles with a radius of 500 mm are drawn on the field of play. These quarter circles are connected by a line parallel to the goal line. The exact configuration is depicted in Fig. 1.

The area bounded by this arc and the goal line is the defence area.

**Penalty Mark**

Within each defence area a penalty mark is made 450 mm from the midpoint between the goalposts and equidistant to them. The mark is a 10 mm diameter circle of white paint.

**Goals**

Goals must be placed on the centre of each goal boundary.

They consist of two 160 mm vertical side walls joined at the back by a 160 mm vertical rear wall. The inner face of the goal has to be covered with an energy absorbing material such as foam to help absorb ball impacts and lessen the speed of deflections. The goal walls, edges, and tops are white in color.

There is a round steel cross bar that runs across the top of the goalmouth and parallel to the goal line. It is no larger than 10 mm in diameter, but is sufficiently strong to deflect the ball. The bottom of the bar is 155 mm from the field surface, and the bar is dark in color to minimise interference with vision systems. The top of the goal is covered in a thin net to prevent the ball from entering the goal from above. It is attached securely to the cross bar and goal walls.

The distance between the side walls is 700 mm. The goal is 180 mm deep. The distance from the lower edge of the crosswire to the playing surface is 150 mm.

The floor inside the goalmouth is the same as the rest of the playing surface.

The goal walls are 20 mm thick.

Goals must be anchored securely to field surface.

![Figure 2: The Goal in detail](image)
Equipment Mounting Bar

A mounting bar will be provided 4 m above the field. The bar will run above the midline of the field from goal to goal. The bar should be mounted securely so that it does not swing or sway under a small external force, and it should not bend or twist significantly when the weight of typical video equipment is added.

Decisions of the F180 Technical Committee

• Decision 1

The local organising committee should aim to provide uniform, diffuse lighting conditions of approximately 500 LUX or brighter. No special lighting equipment will necessarily be used to provide these conditions. The brightness is not guaranteed nor expected to be fully uniform across the field surface. Teams are thus expected to cope with the variations that will occur when using ambient lighting. The organising committee will release details of the lighting arrangements to the competitors as early as practical.

• Decision 2

No kind of commercial advertising, whether real or virtual, is permitted on the field of play and field equipment (including the goal nets and the areas they enclose) from the time the teams enter the field of play until they have left it at half-time and from the time the teams re-enter the field of play until the end of the match. In particular, no advertising material of any kind may be displayed inside the goals or walls. No extraneous equipment (cameras, microphones, etc.) may be attached to these items.

• Decision 3

The specific colour and texture of the surface is not specified and may vary from competition to competition (just as real soccer fields vary). The surface underneath the carpet will be level and hard. Examples of approved surfaces include: cement, linoleum, hardwood flooring, plywood, ping-pong tables and particle board; carpeted or cushioned surfaces are not allowed. Every effort shall be made to ensure that the surface is flat; however, it is up to individual teams to design their robots to cope with slight curvatures of the surface.
Qualities and Measurements

The ball is a standard orange golf ball. It is:
- spherical
- orange in colour
- approximately 46 g in mass
- approximately 43 mm in diameter

Replacement of a Defective Ball

If the ball becomes defective during the course of a match:
- the match is stopped
- the match is restarted by placing the replacement ball at the place where the first ball became defective

If the ball becomes defective whilst not in play at a kick-off, goal kick, corner kick, free kick, penalty kick or throw-in:
- the match is restarted accordingly

The ball may not be changed during the match without the authority of the referee.
LAW 3 - The Number of Robots

Robots
A match is played by two teams, each consisting of not more than five robots, one of which may be the goalkeeper. Each robot must be clearly numbered so that the referee can identify them during the match. The goalkeeper must be designated before the match starts. A match may not start unless both teams have at least one robot.

Interchange
Robots may be interchanged. There is no limit on the number of interchanges.

Interchange Procedure
To interchange a robot, the following conditions must be observed:
- interchange can only be made during a stoppage in play,
- the referee is informed before the proposed interchange is made,
- the interchange robot enters the field of play after the robot being replaced has been removed,
- interchange robot enters the field of play at the halfway line.

Changing the Goalkeeper
Any of the other robots may change places with the goalkeeper, provided that:
- the referee is informed before the change is made
- the change is made during a stoppage in the match

Robots Sent Off
A robot that has been sent off may interchange for another robot that leaves the field.

Decisions of the F180 Technical Committee
- Decision 1
Each team must have a single designated robot handler to perform interchange and robot placing when required. No other team members can encroach upon the area immediately surrounding the field. Movement of robots by the handler is not allowed.
LAW 4 - The Robotic Equipment

Safety
A robot must not have in its construction anything that is dangerous to itself, another robot or humans.

Shape
A robot must fit inside a 180 mm diameter cylinder and have a height of 150 mm or less.

![Figure 3: The maximum robot dimensions](image)

Colours and Markers
Before a game, each of the two teams has a colour assigned, namely yellow or blue. Each team must be able to use yellow and blue markers. Circular markers of the assigned colour must be mounted on top of the robots. The centre of the marker must be located in the visual centre of the robot when viewed from above. The markers must have a diameter of 50 mm.

Robots may use black and white colouring without restriction. Robots may also use light green, light pink and cyan markers.

Locomotion
Robot wheels (or other surfaces that contact the playing surface) must be made of a material that does not harm the playing surface.

Wireless Communication
Robots can use wireless communication to computers or networks located off the field.

Global Vision System
The use of a global vision system or external distributed vision systems are permitted, but not required, to identify and track the position of robots and ball. This is achieved by using one or more cameras. Cameras may not protrude more than 150 mm below the bottom of the mounting beam provided above the field (Law 1).

Autonomy
The robotic equipment is to be fully autonomous. Human operators are not permitted to enter any information into the equipment during a match, except at half time or during a time-out.

Dribbling
Dribbling devices that actively exert backspin on the ball, which keep the ball in contact with the robot are permitted under certain conditions. The spin exerted on the ball must be perpendicular to the plane of the field. Vertical or partially vertical dribbling bars, also known as side dribblers, are not permitted. The use of dribbling devices is also restricted as per Law 12, Indirect Free Kicks.

![Dribbler-Device (Side View)](image)

**Infringements/Sanctions**

For any infringement of this Law:
- play need not be stopped
- the robot at fault is instructed by the referee to leave the field of play to correct its equipment
- the robot leaves the field of play when the ball next ceases to be in play
- any robot required to leave the field of play to correct its equipment does not re-enter without the referee's permission
- the referee checks that the robot's equipment is correct before allowing it to re-enter the field of play
- the robot is only allowed to re-enter the field of play when the ball is out of play

A robot that has been required to leave the field of play because of an infringement of this Law and that enters (or re-enters) the field of play without the referee's permission is cautioned and shown the yellow card.

**Restart of Play**

If play is stopped by the referee to administer a caution:
- the match is restarted by an indirect free kick taken by a robot of the opposing side, from the place where the ball was located when the referee stopped the match

**Decisions of the F180 Technical Committee**

- **Decision 1**
  Participants using wireless communications shall notify the local organising committee of the
method of wireless communication, power, and frequency. The local organising committee shall be notified of any change after registration as soon as possible.

In order to avoid interference, a team should be able to select from two carrier frequencies before the match. The type of wireless communication shall follow legal regulations of the country where the competition is held. Compliance with local laws is the responsibility of the competing teams, not the RoboCup Federation. The type of wireless communication may also be restricted by the local organising committee. The local organising committee will announce any restrictions to the community as early as possible.

- **Decision 2**
  Kicking devices are permitted.

- **Decision 3**
  Metal spikes and Velcro are specifically prohibited for the purpose of locomotion.

- **Decision 4**
  Bluetooth wireless communication is not allowed.

- **Decision 5**
  Official colours will be provided by the organising committee. Teams must use the official colours unless both teams agree not to.

- **Decision 6**
  Adhesives such as glue or tape may not be used for the purpose of ball control or to construct dribblers. Dribbling devices which use such an adhesive to affix the ball to a robot are considered a violation of Law 12, Decision 4, by "removing all of the degrees of freedom of the ball". In addition, the use of adhesives for any purpose on the robot which results in residue left on the ball or field, is considered as damage and sanctioned as per Law 12.

- **Decision 7**
  A rules check will be performed on all robots at the competition prior to the first match. Any team's robot which is found to violate a rule must be modified to be compliant before it can participate in matches.
The Authority of the Referee

Each match is controlled by a referee who has full authority to enforce the Laws of the Game in connection with the match to which he has been appointed.

Powers and Duties

The Referee:
- enforces the Laws of the Game
- controls the match in co-operation with the assistant referees
- ensures that any ball used meets the requirements of Law 2
- ensures that the robotic equipment meets the requirements of Law 4
- informs the assistant referees when periods of time lost begin and end in accordance with Law 7
- stops, suspends or terminates the match, at his discretion, for any infringements of the Laws
- stops, suspends or terminates the match because of outside interference of any kind
- stops the match if, in his opinion, a robot is likely to cause serious harm to humans, other robots or itself and ensures that it is removed from the field of play
- repositions the ball to a neutral position if it becomes stuck during play
- allows play to continue when the team against which an offence has been committed will benefit from such an advantage and penalises the original offence if the anticipated advantage does not ensue at that time
- punishes the more serious offence when a robot commits more than one offence at the same time
- takes disciplinary action against robots guilty of cautionable and sending-off offences. He is not obliged to take this action immediately but must do so when the ball next goes out of play
- takes action against team officials who fail to conduct themselves in a responsible manner and may at his discretion, expel them from the field of play and its immediate surrounds
- acts on the advice of assistant referees regarding incidents which he has not seen
- ensures that no unauthorised persons encroach the field of play
- restarts the match after it has been stopped
- provides the technical committee with a match report which includes information on any disciplinary action taken against team officials and any other incidents which occurred before, during or after the match

Decisions of the Referee

The decisions of the referee regarding facts connected with play are final.

The referee may only change a decision on realising that it is incorrect or, at his discretion, on the advice of an assistant referee, provided that he has not restarted play.

Referee's Signalling Equipment

A device will be supplied to convert the referee's signals into both serial and ethernet communication signals that are transmitted to both teams. The equipment will be operated by the assistant referee. Details of the equipment are to be supplied by the local organising committee before the competition.

Signals from the Referee
During a match the referee will signal the start and stop of play in the usual fashion. The assistant referee will send signals reflecting the referee's call over communication links to each team. No interpretation of the referee's signals by human operators is permitted.

The whistle signal indicates that the referee has stopped play, and that all robots should move 500 mm from the ball to allow the referee to place the ball for a restart. All robots are required to remain 500 mm from the ball as the ball is moved to the restart position.

For a goal (Law 10), or caution or send off (Law 12), an informational signal will be sent to indicate the referee's decision.

The restart signal will indicate the type of restart. Robots should move into legal positions upon receipt of this signal. For restarts other than a kick-off (Law 8) or a penalty kick (Law 14), the kicker may kick the ball when ready without further signals from the referee.

For a kick-off (Law 8) or a penalty kick (Law 14), a start signal will be sent to indicate that the kicker may proceed. This signal will not be sent for other types of restart.

Signals indicating periods of time-out and time lost will also be sent when required.

The referee will be deemed to have given a signal when the assistant referee has relayed that signal over the communications links.

**Decisions of the F180 Technical Committee**

- **Decision 1**

  A referee (or where applicable, an assistant referee) is not held liable for:
  - any kind of injury suffered by an official or spectator
  - any damage to property of any kind
  - any other loss suffered by any individual, club, company, association or other body, which is due or which may be due to any decision which he may take under the terms of the Laws of the Game or in respect of the normal procedures required to hold, play and control a match.

  This may include:
  - a decision that the condition of the field of play or its surrounds are such as to allow or not to allow a match to take place
  - a decision to abandon a match for whatever reason
  - a decision as to the condition of the fixtures or equipment used during a match including the field and the ball
  - a decision to stop or not to stop a match due to spectator interference or any problem in the spectator area
  - a decision to stop or not to stop play to allow a damaged robot to be removed from the field of play for repair
  - a decision to request or insist that a damaged robot be removed from the field of play for repair
  - a decision to allow or not to allow a robot to have certain colours
  - a decision (in so far as this may be his responsibility) to allow or not to allow any persons (including team or stadium officials, security officers, photographers or other media representatives) to be present in the vicinity of the field of play
  - any other decision which he may take in accordance with the Laws of the Game or in conformity with his duties under the terms of the RoboCup Federation or league rules or
regulations under which the match is played

- **Decision 2**
  Facts connected with play shall include whether a goal is scored or not and the result of the match.

- **Decision 3**
  The referee should use a black stick or some other device when repositioning the ball to reduce the chance of interference with vision systems.

- **Decision 4**
  The referee may be assisted by an autonomous referee application provided by one or both of the competing teams, if both teams agree. The referee may also be assisted by an autonomous or semi-autonomous application provided by a team not participating in the current match, at the referee's own discretion, provided that the application is operated or monitored by a neutral party.

- **Decision 5**
  The outer region of the field surface which is further than 250mm away from the boundary line is used as a designated walking area by the referee and/or assistant referee during gameplay. Teams should control their robots to stay out of this area to not interfere with the referees. Referees are not responsible for any obstructions to robots or vision systems within this area. Nevertheless, referees are requested to wear clothes and shoes which do not contain any color reserved for the ball or for robot markers.
Duties

The assistant referee is appointed whose duties, subject to the decision of the referee, are to:
- act as timekeeper and keep a record of the match
- to operate the communications equipment to relay the referee's signals over the communications links
- monitor the robot operators for illegal signals being sent to the robots
- indicate when an interchange is requested
- indicate when misconduct or any other incident has occurred out of the view of the referee
- indicate when offences have been committed whenever the assistants are closer to the action than the referee (this includes, in particular circumstances, offences committed in the defence area)
- indicate whether, at penalty kicks, the goalkeeper has moved forward before the ball has been kicked and if the ball has crossed the line

Assistance

The assistant referees also assist the referee to control the match in accordance with the Laws of the Game. In the event of undue interference or improper conduct, the referee will relieve an assistant referee of his duties and make a report to the organising committee.

• Decision 1

A second assistant referee will be used whenever possible. The second assistant referee will help the referee in ball placement on the field, as well as helping monitor compliance with all laws and procedures.
LAW 7 - The Duration of the Match

Periods of Play

The match lasts two equal periods of 10 minutes, unless otherwise mutually agreed between the referee and the two participating teams. Any agreement to alter the periods of play (for example, to reduce each half to 7 minutes because of a limited schedule) must be made before the start of play and must comply with competition rules.

Half-Time Interval

Teams are entitled to an interval at half time. The half-time interval must not exceed 5 minutes. Competition rules must state the duration of the half-time interval. The duration of the half-time interval may be altered only with the consent of both teams and the referee.

Timeouts

Each team is allocated four timeouts at the beginning of the match. A total of 5 minutes is allowed for all timeouts. For example, a team may take three timeouts of one-minute duration and thereafter have only one timeout of up to two minutes duration. Timeouts may only be taken during a game stoppage. The time is monitored and recorded by the assistant referee.

Allowance for Time Lost

Allowance is made in either period for all time lost through:
- substitution(s)
- assessment of damage to robots
- removal of damaged robots from the field of play for treatment
- wasting time
- any other cause

The allowance for time lost is at the discretion of the referee.

Extra Time

Competition rules may provide for two further equal periods to be played. The conditions of Law 8 will apply.

Abandoned Match

An abandoned match is replayed unless the competition rules provide otherwise.

Decisions of the F180 Technical Committee

- Decision 1
  
  The local organising committee will make every effort to provide both teams access to the competition area at least two hours before the start of the competition. They will also strive to allow at least one hour of setup time before each match. Participants should be aware, however, that conditions may arise where this much time cannot be provided.

- Decision 2
  
  Within these rules, the term "game stoppage" is used to describe the times when the gameplay is in a stopped state. Gameplay is not considered stopped when any robot is allowed to kick the ball. For example, gameplay is stopped after the "Kickoff" command has been issued, but it is
no longer stopped after the corresponding "Ready" command has been issued. Similarly, gameplay is no longer stopped after a "Freekick" has been issued.
Preliminaries

If both teams have a common preferred frequency for wireless communications, the local organising committee will allocate that frequency for the first half of the match. If both teams have a common preferred color, the local organising committee will allocate the color for the first half of the match.

A coin is tossed and the team which wins the toss decides which goal it will attack in the first half of the match.

The other team takes the kick-off to start the match.

The team that wins the toss takes the kick-off to start the second half of the match.

In the second half of the match the teams change ends and attack the opposite goals. Teams may agree not to change ends and attack the opposite goals with the consent of the referee.

If both teams have a common preferred frequency for wireless communications, the teams should swap the allocation of that frequency for the second half of the match. Teams may agree not to change the allocation of the preferred frequency with the consent of the referee.

If both teams have a common preferred marker color, the teams should swap marker colors for the second half of the match. Teams may agree not to change the marker colors with the consent of the referee.

Kick-off

A kick-off is a way of starting or restarting play:
- at the start of the match
- after a goal has been scored
- at the start of the second half of the match
- at the start of each period of extra time, where applicable

A goal may be scored directly from the kick-off.

Procedure

- all robots are in their own half of the field
- the opponents of the team taking the kick-off are at least 500 mm from the ball until the ball is in play
- the ball is stationary on the centre mark
- the referee gives a signal
- the ball is in play when it is kicked and moves forward
- the kicker does not touch the ball a second time until it has touched another robot

After a team scores a goal, the kick-off is taken by the other team.

Infringements/Sanctions

Any infringement as listed in Law 9 is handled accordingly

For any other infringement of the kick-off procedure:
- the kick-off is retaken
Placed Ball

A placed ball is a way of restarting the match after a temporary stoppage which becomes necessary, while the ball is in play, for any reason not mentioned elsewhere in the Laws of the Game.

Procedure

The referee places the ball at the place where it was located when play was stopped. By Law 9, all robots are required to remain 500mm from the ball while the ball is being placed. Play restarts when the referee gives a signal.

Infringements/Sanctions

The ball is placed again:
• if a robot comes within 500 mm of the ball before the referee gives the signal

Special Circumstances

A free kick awarded to the defending team inside its own defence area is taken from a legal free kick position nearest to where the infringement occurred.

A free kick awarded to the attacking team in its opponents' defence area is taken from a legal free kick position nearest to where the infringement occurred.

A placed ball to restart the match after play has been temporarily stopped inside the defence area takes place on the a legal free kick position nearest to where the ball was located when play was stopped.
LAW 9 - The Ball In and Out of Play

Ball Out of Play

The ball is out of play when:
- it has wholly crossed the goal boundary or touch boundary whether on the ground or in the air
- play has been stopped by a signal from the referee

When the ball goes out of play, robots should remain 500 mm from the ball as the ball is placed, until the restart signal is given by the referee.

Ball In Play

The ball is in play at all other times.

Infringements/Sanctions

If, at the time the ball enters play, a member of the kicker's team occupies the area closer than 200 mm to the opponent's defense area:
- an indirect free kick is awarded to the opposing team, the kick to be taken from the location of the ball when the infringement occurred * (see Law 13)

If, after the ball enters play, the kicker touches the ball a second time (without holding the ball) before it has touched another robot:
- an indirect free kick is awarded to the opposing team, the kick to be taken from the place where the infringement occurred * (see Law 13)

If, after the ball enters play, the kicker deliberately holds the ball before it has touched another robot:
- a direct free kick is awarded to the opposing team, the kick to be taken from the place where the infringement occurred * (see Law 13)

If, after a signal to restart play is given, the ball does not enter play within 10 seconds, or lack of progress clearly indicates that the ball will not enter play within 10 seconds:
- the play is stopped by a signal from the referee,
- all robots have to move 500 mm from the ball, and
- a neutral restart is indicated

Decisions of the F180 Technical Committee

- Decision 1
  For all restarts where the Laws stipulate that the ball is in play when it is kicked and moves, the robot must clearly tap or kick the ball to make it move. It is understood that the ball may remain in contact with the robot or be bumped by the robot multiple times over a short distance while the kick is being taken, but under no circumstances should the robot remain in contact or touch the ball after it has traveled 50 mm, unless the ball has previously touched another robot. Robots may use dribbling and kicking devices in taking the free kick.

- Decision 2
  The exclusion zone closer than 200mm to the opponent's defense area during restarts is designed to allow defending teams to position a defense against a kick without interference from
the opponents. This change was added to help teams defend against corner kicks in which teams use elevated "chip kick" passes directly into the defense area.
LAW 10 - The Method of Scoring

Goal Scored

A goal is scored when the whole of the ball passes over the goal line, between the goal walls, below the cross bar, provided that no infringement of the Laws of the Game has been committed previously by the team scoring the goal.

Winning Team

The team scoring the greater number of goals during a match is the winner. If both teams score an equal number of goals, or if no goals are scored, the match is drawn.

Competition Rules

For matches ending in a draw, competition rules may state provisions involving extra time, or other procedures approved by the RoboCup Federation to determine the winner of a match.

LAW 11 - Offside

Offside Rule

The offside rule is not adopted.
Fouls and misconduct are penalised as follows:

**Direct Free Kick**

A direct free kick is awarded to the opposing team if a robot commits any of the following four offences:
- makes substantial contact with an opponent
- holds an opponent
- holds the ball deliberately (except for the goalkeeper within his own defence area)
- is the second defending robot to simultaneously occupy the team’s defence area in such a way to substantially affect game play

A free kick is taken from where the offence occurred.

**Penalty Kick**

A penalty kick is awarded if any of the above four offences is committed by a robot inside his own defence area, irrespective of the position of the ball, provided it is in play.

**Indirect Free Kicks**

An indirect free kick is awarded to the opposing team if a goalkeeper, inside his own defence area, commits any of the following offences:
- takes more than fifteen seconds while holding the ball before releasing it from his possession
- holds the ball again after it has been released from his possession and has not touched any other robot

An indirect free kick is also awarded to the opposing team if a robot:
- contacts the goalkeeper where the point of contact is in the defence area
- dribbles the ball over a distance greater than 500 mm
- touched the ball such that the top of the ball travels more than 150 mm from the ground, and the ball subsequently enters their opponent’s goal, without having either touched a teammate (while below 150 mm) or remained in contact with the ground (stopped bouncing).
- kicks the ball such that it exceeds 10 m/s in speed
- commits any other offence, not previously mentioned in Law 12, for which play is stopped to caution or dismiss a robot

The free kick is taken from where the offence occurred.

**Disciplinary Sanctions**

**Cautionable Offences**

A team is cautioned and shown the yellow card if a robot on that team commits any of the following six offences:
1. is guilty of unsporting behaviour
2. is guilty of serious and violent contact
3. persistently infringes the Laws of the Game
4. delays the restart of play
5. fails to respect the required distance when play is restarted with a goal kick, corner kick or free kick
6. modifies or damages the field or ball
7. deliberately enters or travels within the referee walking area

Upon receipt of a yellow card, one robot of the penalised team must immediately move off and be removed from the field. After two minutes of play (as measured by the assistant referee using the official game time) the robot may reenter the field at the next stoppage of play.

**Sending-Off Offences**

A team is shown a red card if one of the robots or the team is guilty of severe unsporting behaviour. The number of robots on the team is reduced by one after every red card.

**Decisions of the F180 Technical Committee**

- **Decision 1**
  Substantial contact is contact sufficient to dislodge the robot from its current orientation, position, or motion in the case where it is moving. When both robots are moving at similar speeds, and the cause of contact is not obvious, the referee will allow play to continue. This law is designed to protect robots which are slow moving or stationary at the time of the contact, and as such should be detected by obstacle avoidance systems.

- **Decision 2**
  Cautions for serious and violent contact are a way to discourage teams from ignoring the spirit of the no-contact principle. Examples of cautionable offences include uncontrolled motion, poor obstacle avoidance, pushing, or rapid spinning while adjacent to an opponent. In a typical scenario, the referee would warn the team, and expect that they would modify their system to reduce the violence of their play. If the referee was still unsatisfied a caution would be issued.

- **Decision 3**
  A robot that is placed on the field but is clearly not capable of movement will be sanctioned for unsporting behaviour.

- **Decision 4**
  A robot is holding a ball if it takes full control of the ball by removing all of its degrees of freedom; typically, fixing a ball to the body or surrounding a ball using the body to prevent access by others. 80% of the area of the ball when viewed from above should be outside the convex hull around the robot. Another robot must be able to remove the ball from a robot with the ball. This limitation applies as well to all dribbling and kicking devices, even if such infringement is momentary.
Decision 5
A robot begins dribbling when it makes contact with the ball and stops dribbling when there is an observable separation between the ball and the robot.

The restriction on dribbling distance was added to prevent a robot with a mechanically superior dribbler having unchallenged control of the ball. The distance restriction still allows dribblers to be used to aim and receive passes, turn around with the ball, and stop with the ball. Dribblers can still be used to dribble large distances with the ball as long as the robot periodically loses possession, such as kicking the ball ahead of it as human soccer players often do. The technical committee expects the distance rule to be self-enforced, i.e., teams will insure their software complies beforehand and may be asked to demonstrate this prior to a competition. Referees, though, will still call fouls for violations and may give a caution (yellow card) for situations of repeated violations.

Decision 6
The limitation to kicking speed was added to prevent a robot with a mechanically superior kicker from having too great of an advantage over opponents, or kicking the ball at speed unsafe for spectators. It is also believed that this will help encourage team play over single robot ability, in a similar way to the restrictions on dribbling.

Decision 7
The current rule about scoring after chip kicks is defined in this section (subsection Indirect Free Kicks) only. During past competitions, some confusions occurred after robots chipped the ball and thereby caused own goals. For this reason, a strict interpretation of this rule is provided here:

- If a robot chips the ball (no matter at which height it travels) at a team mate and the ball subsequently enters the own goal, the opponent team scores.
- If a robot chips the ball at an opponent and the ball subsequently enters the own goal while staying below 150mm all the time after touching the opponent robot, the opponent team also scores.
- If a robot chips the ball at an opponent and the ball subsequently enters the own goal after having been above 150mm for some time (and not being in constant touch with the ground afterwards) after touching the opponent robot, the opponent team does not score.
Decision 8

The offence on deliberately entering the referee walking area was added to discourage teams from driving through this area to gain tactical advantages. In particular, it should prevent teams from exploiting the fact that other teams might not have vision coverage of the referee walking area. It is understood that on occasion a robot can enter the area if it is out of control, or if it has been pushed into this area. Such cases should not be considered offences. However, the final decision as to what constitutes a deliberate violation is left to the referee.
**Types of Free Kicks**

Free kicks are either direct or indirect.

For both direct and indirect free kicks, the ball must be stationary when the kick is taken and the kicker does not touch the ball a second time until it has touched another robot.

**The Direct Free Kick**

- if a free kick is kicked directly into the opponents' goal, a goal is awarded.
- if a free kick is kicked directly into the team's own goal, a goal is awarded against the team.

**The Indirect Free Kick**

**Ball Enters the Goal**

A goal can be scored only if the ball subsequently touches another robot before it enters the goal.

- if an indirect free kick is kicked directly into the opponents' goal, a goal kick is awarded
- if an indirect free kick is kicked directly into the team's own goal, a corner kick is awarded to the opposing team

**Free Kick Procedure**

If the free kick is awarded inside the defence area, the free kick is taken from a point 600 mm from the goal line and 100 mm from the touch line closest to where the infringement occurred.

If the free kick is awarded to the attacking team within 700 mm of the defence area, the ball is moved to the closest point 700 mm from the defence area.

Otherwise the free kick is taken from the place where the infringement occurred.

All opponent robots are at least 500 mm from the ball.

The ball is in play when it is kicked and moves.

**Infringements/Sanctions**

If, when a free kick is taken, an opponent is closer to the ball than the required distance:

- the kick is retaken

Any infringement as listed in Law 9 is handled accordingly

For any other infringement of this Law:

- the kick is retaken
A penalty kick is awarded against a team which commits one of the five offences for which a direct free kick is awarded, inside its own defence area and while the ball is in play.

A goal may be scored directly from a penalty kick.

Additional time is allowed for a penalty kick to be taken at the end of each half or at the end of periods of extra time.

Position of the Ball and the Robots

The ball:

- is placed on the penalty mark

The robot taking the penalty kick:

- is properly identified

The defending goalkeeper:

- remains between the goalposts, touches its goal line, and faces outward of the goal, until the ball has been kicked. It is allowed to move before the ball has been kicked, as long as its motion does not break any of these constraints.

The robots other than the kicker are located:

- inside the field of play
- behind a line parallel to the goal line and 400 mm behind the penalty mark

The Referee

- does not signal for a penalty kick to be taken until the robots have taken up position in accordance with the Law
- decides when a penalty kick has been completed

Procedure

- the robot taking the penalty kicks the ball forward
- it does not play the ball a second time until it has touched another robot
- the ball is in play when it is kicked and moves forward

When a penalty kick is taken during the normal course of play, or time has been extended at half-time or full time to allow a penalty kick to be taken or retaken, a goal is awarded if, before passing between the goalposts and under the crossbar:

- the ball touches either or both of the goalposts and/or the crossbar, and/or the goalkeeper

Infringements/Sanctions

If the referee gives the signal for a penalty kick to be taken and, before the ball is in play, one of the following situations occurs:

The robot taking the penalty kick infringes the Laws of the Game:

- the referee allows the kick to proceed
• if the ball enters the goal, the kick is retaken
• if the ball does not enter the goal, the kick is not retaken

The goalkeeper infringes the Laws of the Game:
• the referee allows the kick to proceed
• if the ball enters the goal, a goal is awarded
• if the ball does not enter the goal, the kick is retaken

A team-mate of the robot taking the kick enters the area 400 mm behind the penalty mark:
• the referee allows the kick to proceed
• if the ball enters the goal, the kick is retaken
• if the ball does not enter the goal, the kick is not retaken
• if the ball rebounds from the goalkeeper, the crossbar or the goal post and is touched by this robot, the referee stops play and restarts the match with an indirect free kick to the defending team

A team-mate of the goalkeeper enters the area 400mm behind the penalty mark:
• the referee allows the kick to proceed
• if the ball enters the goal, a goal is awarded
• if the ball does not enter the goal, the kick is retaken

A robot of both the defending team and the attacking team infringe the Laws of the Game:
• the kick is retaken

*If, after the penalty kick has been taken:
Any infringement as listed in Law 9 is handled accordingly
The ball is touched by an outside agent as it moves forward:
• the kick is retaken

The ball rebounds into the field of play from the goalkeeper, the crossbar or the goalposts, and is then touched by an outside agent:
• the referee stops play
• play is restarted with a dropped ball at the place where it touched the outside agent* (see Law 13)
LAW 15 - The Throw-In

A throw-in is a method of restarting play.

A goal cannot be scored directly from a throw-in.

A throw-in is awarded:

- when the whole of the ball passes over the touch boundary, either on the ground or in the air
- from the point 100 mm perpendicular to the touch boundary where the ball crossed the touch boundary
- to the opponents of the robot that last touched the ball

Procedure

- The referee places the ball at the designated position.
- All opponent robots are at least 500 mm from the ball.
- The ball is in play when it is kicked and moves.

Infringements/Sanctions

If, when a throw-in is taken, an opponent is closer to the ball than the required distance:

- the throw-in is retaken

Any infringement as listed in Law 9 is handled accordingly

For any other infringement:

- the kick is retaken

LAW 16 - The Goal Kick

A goal kick is a method of restarting play.

A goal may be scored directly from a goal kick, but only against the opposing team.

A goal kick is awarded when:

- the whole of the ball, having last touched a robot of the attacking team, passes over the goal boundary, either on the ground or in the air, and a goal is not scored in accordance with Law 10.

Procedure

- the ball is kicked from a point 500 mm from the goal line and 100 mm from the touch line closest to where the ball passed over the goal boundary
- opponents remain 500 mm from the ball until the ball is in play
- the kicker does not play the ball a second time until it has touched another robot
- the ball is in play when it is kicked and moves

Infringements/Sanctions

Any infringement as listed in Law 9 is handled accordingly

For any other infringement of this Law:

- the kick is retaken
LAW 17 - The Corner Kick

A corner kick is a method of restarting play.
A goal may be scored directly from a corner kick, but only against the opposing team.
A corner kick is awarded when:
- the whole of the ball, having last touched a robot of the defending team, passes over the goal line, either on the ground or in the air, and a goal is not scored in accordance with Law 10

Procedure
- the ball is kicked from the nearest corner, 100mm in from both the goal line and the touch line
- opponents remain 500 mm from the ball until the ball is in play
- the kicker does not play the ball a second time until it has touched another robot
- the ball is in play when it is kicked and moves

Infringements/Sanctions
Any infringement as listed in Law 9 is handled accordingly
For any other infringement:
- the kick is retaken
Appendix A - The Competition Rules

This appendix describes additional procedures for Small Size League matches.

Extra Time

If the game is drawn after the end of the second period and the game needs to end with a clear
winner, extra time will be played (as stated in laws 7 and 10). Before the first half of extra time,
there will be an interval that must not exceed 5 minutes.

Periods of Play in extra time

The extra time lasts two equal periods of 5 minutes, unless otherwise mutually agreed between
the referee and the two participating teams. Any agreement to alter the periods of extra time (for
example, to reduce each half to 3 minutes because of a limited schedule) must be made before
the start of play and must comply with competition rules.

Extra time half-time Interval

Teams are entitled to an interval at half-time. The half-time interval must not exceed 2 minutes.
The duration of the half-time interval may be altered only with the consent of both teams and the
referee.

Timeouts

Each team is allocated two timeouts at the beginning of extra time. A total of 5 minutes is
allowed for all timeouts. The number of timeouts and the time not used in regular game are not
added. Timeouts in extra time follow the same rules as in regular game (stated in law 7).

Penalty Shoot-Out

If the game is drawn after the end of the second period of extra time, kicks from the penalty
mark will be taken to decide which teams wins the game.

Preparation

Before the first penalty is kicked, there will be an interval that must not exceed 2 minutes. This
time is suggested to be used by the teams in dialogue with the referee and his assistants to
check whether the goalie's position is correct (on the line) and all other rules for penalty can be
fulfilled as stated in law 14. The referee determines (e.g. by flipping a coin) which team defends
which goal as well as which team has to take the first penalty kick.

Procedure

During the kicks from the penalty mark, a maximum of 2 robots per team is on the field in order
to avoid interference. The kicks from the penalty mark are taken alternately by the teams until
each team has kicked 5 penalties. If a decision is reached for one team, the kicks are stopped
by the referee. For all penalties, the rules of law 14 apply. A second kick (e.g. if the ball bounces
back from the goalie or a goalpost) or a bounce back from the kicker will not score, as soon as
the kicker touches the ball after he released it the first time the penalty is over. During the kicks
from the penalty mark no timeout is possible. Robots may be exchanged between the kicks
following the interchange rules of law 3. As switching sides would cost too much time and would
force the teams to touch their systems both goals are used.

If after 10 kicks no decision is reached, each team takes another penalty in the same order as
before. This procedure (one penalty each team) is continued until a decision is reached.