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FIRST VIRTUAL CHALLENGE

An Interactive Qualifying Project Report
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By

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Abstract

Since the founding of US *FIRST* in 1989, there has been a consistent impetus to find new areas of growth to expand *FIRST*'s message of inspiration and recognition of science and technology in the K-12 educational market. To supplement their other programs, *FIRST* hopes to use the 5thGear simulator, designed and programmed by software engineers at Lockheed Martin, to expand their message and impact to any student with access to a computer. The scope of the *FIRST* Virtual Challenge project is to make recommendations on the best methods, competition models, and necessary improvements in the 5thGear simulator to allow the creation of the *FIRST* Virtual Challenge. These recommendations are made based upon extensive background research and thorough data from tests run at select *FIRST* and *FIRST*-related events. The final recommendations for this project discuss use of the 5thGear simulator in an auxiliary competition on Thursday at FRC Regional and Championship Event, use of the simulator internally at *FIRST* for game design and animation uses, use for recruiting, marketing, and outreach by teams, use for driver training by teams, and use for strategy planning by teams.

Acknowledgements

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The basis for the project could not have existed without the engineers at Lockheed Martin who wrote the simulation itself: Blake Ross, Dave Stevens, and David Dobbs. In addition to writing the code, they have also helped throughout with our communications with competitions, as well as helping us run the exhibits at Chesapeake and the Championships, as well as on their own at the Washington, DC and the Virginia regionals. We would also like to thank the Lockheed Martin organization for their support of the simulator, and for running exhibits at several other competitions.

We also owe a debt of gratitude to the regional contacts that helped us run exhibits at each event: Steve Krawic (Manchester Regional/Championship Event), Steve Cremer (Boston), Michael Sperber(Connecticut), and Carol Black(Chesapeake).

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Executive Summary

FIRST is a 501(c)3 non-profit organization founded in 1989 dedicated to fostering the inspiration and recognition of science and technology for K-12 students. The organization has been designing and hosting various robotics competitions since 1992 to use a vehicle for engaging students and mentors to work together to solve problems. The *FIRST* Robotics Competition (FRC) was founded in 1992 and is targeted towards high school students. In 1999, the *FIRST* LEGO League (FLL) was created to bring the excitement of FRC to a younger (age 9-14) audience using LEGO Mindstorms robots and themed game challenges. In 2005, the *FIRST* Tech Challenge (FTC) was founded to serve as a bridge between FLL and FRC for middle and high school age students. Between FRC, FTC, and FLL combined, there are tens of thousands of teams with hundreds of thousands of students[1] involved from all across the world.

The idea behind the 5thGear simulator started as a side project among several software engineers at Lockheed Martin, as a means to create a virtual FRC simulation. The first version of the simulator was created for the 2008 FRC game, Overdrive. *FIRST* had wanted to develop a virtual robotics competition and had contacted WPI in an effort to bring about a study of the potential of the simulator within both the *FIRST* community and for growth potential. When they found out about the Lockheed Martin program, they decided to use it as the basis for the competition. The project at WPI was founded as the *FIRST* Virtual Challenge, which is the working title of a competition format based upon the simulator that would be one of the primary project focal points. Therefore the goal of the IQP

[1] *FIRST, "FIRST* At-A-Glance," http://www.usfirst.org/who/content.aspx?id=160 (accessed May 28, 2009)

is to ascertain the best methods, competition models, and critical simulator improvements necessary for success. In order to do this, we studied the simulator's potential for use:

- as a virtual design assistant
- to test robot ideas in a virtual simulator
- as a strategy tool to for teams to test and refine game strategy
- as a driver training tool for use by teams
- as a marketing/outreach tool for use by teams
- for a separate (possibly standalone) competition with the working title *FIRST* Virtual Challenge
- for internal use at *FIRST* for both the game design process of their annual games as well as the game animation released by *FIRST* at the Kickoff Event to illustrate the new game

To best research these ideas and grasp a sense of the community reaction to the simulator, a series of public demonstrations of the simulator were held at various *FIRST* or robotics-related competitions, workshops, or other events to gauge the initial response to the simulator. The results from these surveys were then used throughout the project, via suggestions of improvements to the development team at Lockheed Martin, for marketing purposes by *FIRST* HQ, and for internal use by the *FIRST* Virtual Challenge project team to shape future surveys. During the demonstrations in late 2008, the simulator was run as an open-access session, where anyone could use the simulator at any time. Throughout the events of 2009, various competition formats were tested at select FRC Regionals and the Championship Event by both the Lockheed Martin developers and the WPI *FIRST* Virtual Challenge project team.

Based upon these results, our project team has come to the following conclusions. Several features are crucial to add to the 5thGear simulator, with the primary one being robot customization. The other sought after features are online (WAN) play, better graphics, and support for an autonomous

mode. We believe the simulator as it stands is useful for the following applications: by teams for testing and developing team strategies, for training potential student drivers to control robots in an FRC environment, by teams for community outreach and marketing purposes, internally by *FIRST* for the FRC game development process and creating the game animation, and as an auxiliary competition to be held during the Thursday practice rounds at FRC Regional and Championship events. Use of the simulator as a virtual design assistant, capable of testing custom mechanism ideas in the simulator, is not feasible at this time due to computer limitations, and support for a separate standalone competition would not be strong until major improvements are made to the 5thGear simulator, such as support for play over wide-area networks.

1. Introduction

1.1 General Background

1.1.1 For Inspiration and Recognition of Science and Technology (*FIRST*)

FIRST Robotics is a non-profit organization founded in 1989 by inventor Dean Kamen to accentuate the need for engineers and scientists in today's society. The goal of the program is to inspire youth to go into the technical fields and to try to swing modern culture back toward admiring engineers and scientists. The flagship program of the *FIRST* organization is the *FIRST* Robotics Competition (FRC), which currently has approximately 1785 teams[2] from several countries.

FRC is intended for high school students to work with professional engineers to design and build a robot in six weeks. Each year the game changes completely, with a new field, rules, and robot constraints. The changing game and tight build schedule help encourage the professionals and the students to work together closely, giving the high school students insight into what it's like to be a professional engineer.

After the six-week robot build season, there are a series of regional competitions leading up to the championship event. Regional events usually consist of thirty to fifty teams, and last for three days; while the championship has approximately three hundred teams but divides them up amongst four

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[2] *FIRST, "FIRST* At-A-Glance," http://www.usfirst.org/who/content.aspx?id=160 (accessed May 28, 2009)

divisions to maintain the three day schedule. For all of the competitions, the *FIRST* day is devoted to practice matches, allowing teams to get some time on the field before any of the match results matter. The next day and a half are spent playing qualification matches, followed by elimination matches with the top eight teams (based on record and average scores) choosing two more teams to join their alliance.

The alliance method, which is three FRC teams working together verses three other FRC teams, holds through all of the competition, with practice and qualification matches having two randomly assigned alliances of three teams compete against each other. During elimination matches, the alliances are constant and are chosen by the highest ranking teams at the event. The alliance system is intended to maintain cooperation in the setting of a competition, also called coopertition.

The *FIRST* Organization is not limited to FRC though; they have programs that are designed for elementary school students, middle school students, and high school students. *FIRST* Lego League and *FIRST* Tech Challenge use smaller robots, less intense build seasons, and simpler challenges to open the organization to a broader range of participants.

1.1.2 *FIRST*, Lockheed Martin, and WPI partnership

During the 2008 build season, a team of engineers at Lockheed Martin's Manassas location began developing a simulation of the *FIRST* Overdrive challenge called 5thGear. After a few months of work on their own, they demonstrated their simulator at the VCU Regional. *FIRST* wanted to use the simulator to extend its reach, and after several discussions between *FIRST,* Lockheed Martin, and WPI, it was decided that the simulators developers at Lockheed Martin and a project group at WPI would pilot and study the role a simulator would have in *FIRST.*

1.2 Project Goals

The goal of this project is to provide a plan for the use of the 5th Gear match simulation, provided by Lockheed-Martin, to promote the goals of the *FIRST* organization. The project took two paths of investigation:

1) Use of 5th Gear as a tool for FRC teams. Two major uses as a tool were identified, one being the simulator's use as a match strategy tool. Teams would be able to develop match strategies by playing out virtual matches before the actual game is ever played. The other use being a robot concept design tool. This option hinged on the creation or greater customization of the robots in the simulator or possibly a robot creation tool.
2) Use of 5th Gear as a new competition option for *FIRST.* The simulator's use to facilitate a virtual competition was identified, and several options were investigated on how a competition could operate. The competition's location could be on the Internet, at its own location or run at an existing *FIRST* event. There were also several options in competition structures, such as single and double elimination tournaments and a FRC style qualification-elimination style tournament.

1.3 Project Approach

To evaluate and test the project goals, extensive testing of 5th Gear was done with a number of different groups of people in many different locations. Surveys were primarily used to test the response to and success of 5th Gear and to gain input from its intended users on what they felt the simulator could be used for.

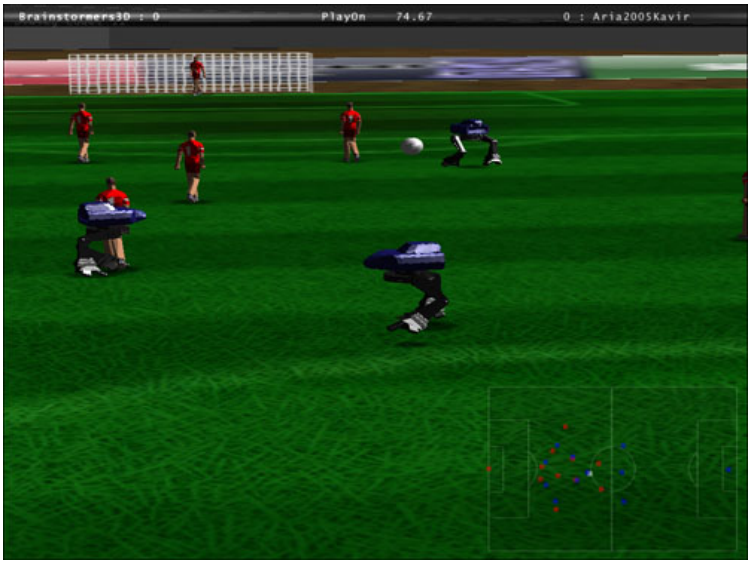
2. Background

2.1 Existing Competitions

In our research, we studied other programs that might be similar to 5th Gear. There are many video games that contain similar concepts to 5th Gear, like Robot Arena[3] and Spore[4], but not many that highlighted the robotic competition and education aspects. Below are the most similar programs that we found.

2.1.1 RoboCup[5]

The point of this program is to build and program a team of robots that can play soccer. Most teams in this competition build physical robots in different classes, put them on the field, and play matches. For teams that prefer to concentrate on the software in the robots, there is a RoboCup Simulation League. This game takes place on a virtual field like the



[3] Robot Arena, "Game Description," http://www.robotarena.com/ (accessed April 24, 2009)
[4] Spore, "What is Spore?," http://www.spore.com/what (accessed April 24, 2009)
[5] RoboCup Soccer, "Rules 3D simulation league RoboCup 2006,"
http://www.uni-koblenz.de/~jboedeck/robocup/rc06/3d_rules.pdf (accessed April 24, 2009)

one pictured in Figure 1, which resembles many modern video games. The robots are loaded with the competition software, and play soccer with no human intervention. The main similarity between the RoboCup Simulation League and 5thGear is that they are both simulations of robotics events that use physical robots. However, RoboCup is geared towards college and graduate students and is academically advanced. Since the competitors are not driving the robots during their matches, the teams that compete here must be made up of competent programmers.

2.1.2 BattleCode[6]

BattleCode is quite similar to the RoboCup Simulation League, but is not based on physical robots. Players in this competition program a team of Java-based robots that try to destroy other teams of robots on a field that looks like a video game, as shown in Figure 2. Like 5thGear, the robots in this program are premade, as the competition is based on player skill. However, this skill is primarily from programming ability and not from driving ability. Like RoboCup, the teams in BattleCode are made up of skilled programmers, who are primarily college and graduate students.

Figure 2 – Screen Shot of BattleCode

[6] BattleCode MIT Programing Competition, "What is BattleCode?," http://battlecode.mit.edu/2009/info (accessed April 24, 2009)

2.2 The 5thGear Simulation

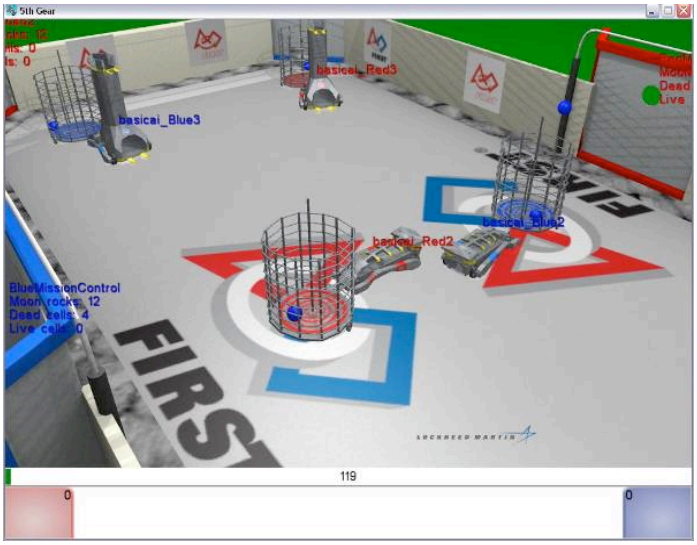


Figure 3- Screen Shot of 5thGear

5thGear was created by engineers at Lockheed Martin who were also mentors on *FIRST* robotics teams. Though originally created in their spare time, the engineers at Lockheed Martin have recently received the support they need from their management to put more focus and effort into the project.

The simulator itself allows each user to control one of the six robots on a virtual FRC field. The user is given the choice of three distinct robots to operate during the two minute match. These three robots represent the three most common archetypes for robots in each year's challenge.

During testing, two different versions of 5thGear were used. The first version was only used for the first tests of the simulator. This version had been created to simulate the 2008 FRC game. In addition, as it was an early version, the physics engine was still very basic and lacked such things as realistic friction and conservation of momentum, and even allowed players to sometimes drive off the field of play.

The second version created for the 2009 FRC game was used for the vast majority of testing. This version fixed the major issues with a new physics engine and also had several small aesthetic improvements. The aesthetics of both versions are simple and cartoonish, as seen in the screen shot of the simulator in Figure 3, as most of the developers' focus and expertise were in the function of the simulator and not its appearance.

2.3 Desired Traits

While the existing simulator based competitions share some similarities to 5th Gear, there are some different elements that are more appropriate to the project goals. Chief among these differences is the engagement of the competitors. Since RoboCup and BattleCode involve preprogrammed robots, there is little for the competitor to do during a match besides watch. While there may be some autonomy in 5th Gear, the robots are controlled by the players during the game. As a result, these players are able to change their strategy during the game and talk to each other in order to change the way the game is played. Another part of engaging the competitors is the element of robot design. The designs in RoboCup and BattleCode are simply for aesthetic purposes, as all of the robots have the same physical abilities. 5th Gear gives competitors the option to experiment with different designs that might be useful in a real robot. In the future, it would be helpful to have a robot editor, which would allow teams to build robots inside the game

An additional concern with this simulator is that it may detract from the physical element of *FIRST*. This simulator is a tool. It must not be used in place of real robot testing. Furthermore, we have noticed that people will use the simulator instead of working with their robot or team at competitions. It can be addicting to play, but players need to remember that it really is just a tool, and its purpose is to further the goals of *FIRST,* so this must be kept in mind during the 5th Gears continuing development.

3. Methodology

3.1 Comparison to Existing Competitions

The first step undertaken in the project was to research what had been previously done in robotics simulation competitions, as well as a brief look into robotics simulations and virtual competitions on their own. This background research was intended to prove ideas for the future of the 5thGear Simulator, both on what needs to be added to the simulator itself, and on how and it should be used as a competition.

There are few virtual robotics competitions, and while several had provided interesting ideas, the scope of the established programs are rather limiting. We decided to expand the research to multiplayer video game styles outside of robotics, as well as into robotics simulations that did not incorporate competitions.

3.2 Surveying

The major source of data in this project was accumulated through the surveying of people using the simulator at many different locations and times. Three different surveys were used during the project; each designed to collect different kinds of information and designed for different circumstances. These surveys were designed to solicit feedback from teams given both the current state of the simulator (Savage Soccer, Kickoff Workshops, and the Founders Reception were held prior to release of the Lunacy version of the simulator, so then-current Overdrive was used) and whether the participants were part of an open-access period or a competition model.

The first survey was used at the Savage Soccer competition held at WPI. This was only the second time the simulator was demonstrated to the public, so our survey was designed under the assumption that the participants had never seen the simulator before. Also, because of the variety if people who attend Savage Soccer, the assumption was that some of our participants had never seen FRC or the past years game before. Because of these factors, the first few questions of the survey are demographic questions to gauge who exactly is taking the survey.

Because this was the first survey we were running, it was designed to collect a broad array of information on the simulator's possible uses. It asked questions on both the simulator's use as a tool for teams on strategy and robot design, and also asked questions on how receptive people would be to its possible use in a competition.

This survey set up a base set of data to compare with our future surveys, and also contained a number of open-ended response questions to help us determine if there were further areas to explore with the simulator. The data we collected gave us a good idea of what people's first impressions of the early version of the simulator were, and also how to focus and better construct our future surveys. One important fact we learned about was the problems with open response questions. Not only were some answers nearly impossible to read or decipher; some were not answers to the question or provided no useful information.

Our second survey was used at all the regional competitions where the 5thGear Simulator was demonstrated. This survey was designed with two distinct parts: the first of which asked about the simulator itself, and the second, which asked about virtual competitions. The focus of the first section was to find out if the participants had heard of the simulator before seeing the exhibit, their opinion of the simulator, and what features they would like to see added to it. The participants that took part in a virtual competition filled out the second section. It asked questions about competition structure.

In addition to the data on the simulator we collected, we also learned some valuable lessons on survey construction for a broader audience. First, there was a question on this survey that required assigning five characteristics a position one to five on a list. While many understood what the question was asking, there were many answers where the same number was used multiple times, showing that some did not understand the question. There were other questions that had strange answers, where instead of numbering, answers were checked off, showing that those participants did not even read what the question was asking. The second problem we encountered was that there were several surveys per regional competition that were left incomplete as the participant lost interest in answering the questions. These two facts were kept in mind when the survey for the Atlanta Championship Event was designed.

We used the final survey at the Championship Event, and it only asked questions about virtual competitions. At this point in our research, we had collected enough data about the simulator itself, and decided to focus on investigating several different competition structures and the different dynamics of concurrent virtual and real competitions. When we designed this survey, we combined all the lessons learned from the previous survey experience. This survey was short, only one page, using both front and back, to maintain the attention of the participant. The questions were written to have very simple answers to avoid confusion. Also, the only open response question was a general comments section at the end of the survey. We also limited who took the survey to those who competed in virtual competitions.

Since these surveys were technically human research studies, each survey required the approval of the WPI Institutional Review Board (IRB). Because of the nature of the study, we were able to receive exemption from a full board review, only requiring the approval of the head of the board, Prof. Rissmiller. In addition, because of IRB regulations, we were required to inform all participants in our

study of their full rights in writing and to obtain their written acknowledgement that we informed them. Because of this, we collected a signed consent form from every person surveyed.

3.3 Savage Soccer

Savage Soccer is a tournament held at WPI every December, which was towards the beginning of the project. We saw this tournament as an opportunity to test the simulator and give the team a base set of data. This early data would shape recommendations for the most critical improvements to the simulation before the new version would be released in January. The version of the simulator used at this event was the first version ever released and used a different physics engine and was less accurate than the later versions.

The tournament was also a good fit for the final target audience of the simulation. Savage Soccer is a robotics competition geared towards middle and high school students, intended to build interest in engineering and the sciences, much like FRC. Many of the high school competitors and team mentors also had FRC experience, so the tournament would be quite familiar to the FRC environment. For these reasons, it was decided that it would be advantageous to host a demonstration of the simulator at the event.

A survey on the simulator was created for the event, and a demonstration of the simulator was set up in one of the adjacent conference rooms. We received the room, equipment, and Institutional Review Board (IRB) exemption approval in about a week, and started setting up the demonstration the night before the event. The basic setup includes seven computers, an Ethernet switch, a projector, and a projector screen. Six of the computers (referred to as clients) are used by participants in two teams of three; the seventh computer is referred to as the server. This computer controls the game matches on the client computers via the network switch. The server also displays an overview of the match in

progress on its screen. This screen output is then cloned onto the projector, so that viewers not currently participating in a match can watch a match in progress.

However, we ran into an issue where the laptops borrowed from the Academic Technology Center (ATC) would not connect properly to each other over the WPI network. The Windows Vista firewalls would prevent any communication from the server back to the laptops, and crash the entire simulation. After trying several different ways of changing the firewall settings and turning off the firewalls completely we were still unable to get the simulator communications working properly, and had to use personal laptops instead.

The room was already equipped with a projector and a large screen, which we found immensely useful for attracting attention. We kept the server view displayed on the screen so that any passersby would be able to tell what was going on, or at least stop and ask if they were unfamiliar with the FRC program. It is likely the large display helped draw in additional crowds to the demonstration room.

We invited people to stop by and try the simulation at their leisure, and requested that they take a survey whenever they were finished. Unfortunately, many people simply would not stop using the simulation, and others walked out without taking the survey.

While there was nothing we could do about people skipping the survey, as pressuring them would invalidate our IRB exempt status, we needed to find a way to cycle people through the event more quickly. We tried simply asking them to let other people try when a crowd would arrive, but if they listened they would just return as soon as the rush had passed. Since we had not started off limiting the amount of time people could spend we had trouble kicking them out now, especially if we wanted to collect data from them. While it was not too much of a problem at such a small event, we knew it could cause problems at larger events in the future and would need to find a way to resolve it.

We finally decided to close down the exhibit during the elimination rounds of Savage Soccer, and reopened once the awards ceremony was over to try to get data from those who were too busy to participate during the event. This proved to be one of the busiest times of the day, and we were able to get about 18 participants between the end of Savage Soccer and finally packing up for the day. The results are listed in Section 4.1.

3.4 Team Surveys

With the data from Savage Soccer being encouraging for the future of the 5thGear Simulation, this fared well for an upcoming review of the project by the Lockheed Martin management. Their review of the project was positive, and It was decided to run another round of surveys to collect some more data to encourage continuation of the project. Without any more upcoming events like Savage Soccer, it was decided to host an event at WPI dedicated to the simulator to solicit further feedback. We invited the WPI FRC Team (Team 190) to come try it out in an office in Higgins Lab, and spread the word to a few other local teams.

We put together a similar setup to the one at Savage Soccer, albeit with a large wall-mounted TV instead of a projector. We had identical surveys to those used at Savage Soccer as well, since the IRB exemption carried over. We also tried to build participation by giving free food to those who took a survey. The results are in Section 4.1.

3.5 Kickoff Workshops

As previously stated, the *FIRST* Robotics Competition game challenge changes every year, with the new competition announced in Manchester, NH on the first non-holiday Saturday each January. On the Friday prior to the Kickoff Event, workshops are held at *FIRST* Place, a small museum at the headquarters of *FIRST* in Manchester, NH, for mentors of local teams traveling to the Kickoff Event.

These workshops are comprised of a variety of topics related to *FIRST*, and are hosted by teams, mentors, and sponsors of the program.

With the large number of mentors in attendance at a single event, it was decided that the workshops would be an excellent place to demonstrate the simulation (with the 2008 game), and begin to build excitement for the release of the 2009 version of the simulator, slated for later that month. Conveniently, *FIRST* Place had a computer lab on the premises, complete with a projector. In addition, the software engineers from Lockheed Martin were present for the workshops and Kickoff Event, bringing with them six Xbox controllers. While the simulator could be played on either a computer keyboard or Xbox controller, many found the Xbox controllers easier to use. We were able to use these resources throughout the entire event, and exhibited the simulator for the morning and a good portion of the afternoon. No surveys were collected, as the game being played in the simulator would be superseded with a new FRC game the next day, and the overall intent of the event was to build interest and participation for the rest of the project.

The number of mentors attending the 2009 Kickoff Workshops was less than prior years, and thus the exposure of the simulator was more limited than originally anticipated. Another drawback for participation at the event was that many adults had initial reservations about using the simulator, as it appeared to be a video game. Many of these people with initial reservations often passed off the controller to a younger child if they had one with them. From watching the mentors participate in the simulator, most did not adapt to the simulator nearly as quickly as the students did, which was somewhat expected due to the prevalence of video games among children. Despite these drawbacks, many of the mentors expressed optimism towards having the students on their team use the simulator in the upcoming FRC season.

3.6 Founder's Reception

The culmination of the Kickoff Workshops at *FIRST* Place is the annual Founder's Reception for selected *FIRST* team mentors, employees, and the Board of Directors is held at Dean Kamen's residence in New Hampshire. This was also an excellent event to hold a demonstration of the 5thGear simulator, to familiarize the *FIRST* directors with this project, and provide exposure of the simulator for the large number of team mentors in attendance.

Space for a compact setup of the simulator was given inside the media viewing room inside Dean Kamen's residence, which was equipped with a projector and power outlets. Five laptops were loaned from *FIRST* Place to run the clients, while two additional personal laptops used to run the last client and the server. The six laptops were all arranged on a single table, with the two sets of three computers for each alliance occupying a respective side of the table. The server computer was placed at the head of the table, and the projector was pre-mounted on the ceiling of the room. Just like the Kickoff Workshops earlier that day, the software engineers from Lockheed Martin were able to provide six Xbox controllers for the client computers to allow for easier control of the simulator.

Due to the impending release of the 2009 FRC game the following day, we were only allowed to show off the 2008 Overdrive version of the simulator at the event. For this reason, no surveys were offered. Despite this, the 5thGear simulator at the Founder's Reception was much better received than it had been at the Kickoff Workshops. Many expressed interest in the simulator.

3.7 Regional Testing

The majority of our tests were done at the FRC regional events. Before going to these events, we developed several different options for how to run our exhibits. We decided upon hosting small tournaments at each event to determine how receptive people were to virtual competitions. The three competition options we designed were single elimination, double elimination, and FRC style, where

teams played through qualification and elimination rounds. Throughout the majority of the event, we also ran demonstration rounds, where anyone could play, in order to advertise the tournaments and gain feedback.

The exhibits were run at nine regional events around the country. For each of these events, we communicated with the Regional Directors to get permission to attend, tables, and power. We traveled to the BAE Granite State Regional, Boston Regional, Connecticut Regional, and ran a joint exhibit with the Lockheed Martin developers at the Chesapeake Regional. The developers also attended the DC and VCU regionals. Other Lockheed Martin employees attended the Florida, Peachtree, and Seattle regionals. At each of these events, we administered surveys to find out if players had been familiar with 5thGear, and what players had thought of the game.

3.7.1 BAE Granite State Regional

The original plan for the Manchester Regional was to keep the exhibit open for demonstrations for Friday, and then shift to a competition for Saturday morning, then packing up before the FRC elimination matches in the afternoon. This competition was going to be styled after the FRC competition, with a set of qualification matches followed by eliminations to determine a final winner. We felt that since Manchester was a rather large regional with several established teams, this would be a good event to try the more complex tournament structure.

However, we quickly ran into some issues at the competition. When we arrived, our table did not have any power hooked up to it. While we did have some supplies on hand to do this by ourselves, and there were power outlets nearby, we were concerned about taking matters into our own hands, as events like this are generally wired only by unions. We were not able to get information about how to proceed until almost noon, at which time we just hooked up power for ourselves.

The laptops we were using for this event were borrowed from both the WPI Academic Technology Center, and from *FIRST* itself. However, we were not able to get the laptops from *FIRST* until we were at the event. So while the 5thGear program, as well as the supporting software, was already installed on the WPI ATC computers, the *FIRST* machines did not have the program on them. Even though we had brought the installation files with us to the event on a flash drive, we needed an Internet connection to install some of the supporting software (a problem that had never arisen at WPI). The venue did not have Internet available, so we had to take the laptops a few blocks away to *FIRST* headquarters. While this was not overly time consuming, it still kept us from getting the event up and running until around 2pm on Friday.

Once the exhibit was finally up and running, we opened for anyone to stop by and try out the simulation. Participation was slow at *FIRST*, but picked up as the day progressed. Although we had a lot of repeat participants, there was still a large amount of interest at the event. While we received sixty-five surveys, we were not able to get anyone interested in participating in our test tournament.

As the event started on Saturday, we continued trying to get FRC teams to sign up for the tournament, but without any success. By eleven in the morning, we still had no one signed up for the competition, and we made the decision to cancel the tournament. We kept the event open until the elimination rounds began on the FRC field to try to get more surveys, but were not able to test a competition structure.

3.7.2 Boston Regional

We went to the Boston regional with the same plan as the BAE Regional, with demonstrations on Friday, followed by a tournament Saturday afternoon. Since the tournament at the Manchester regional failed, we decided to test the same FRC style structure at Boston. This would still be a good fit,

since a large amount of the attending teams were veterans. However, unlike Manchester, Boston also had a large contingent of rookies and recently founded teams, broadening our sample base.

We arrived early Friday, and were set up and running by the end of opening ceremonies. While there was once again no power set up for us, we were able to find the right people to get permission to wire the exhibit ourselves. Also, since we had already set up an exhibit once (and with the same equipment), everything was ready in less than half an hour after moving all the equipment into the building.

Interest at Boston was slow at first, but picked up as Friday progressed. Unlike Manchester, most of those who tried the simulator would simply play a couple of rounds, take the survey, and leave without anyone from the project team having to push them along. A much higher percentage of participants took the survey than at Manchester as well, and there was even more interest in the tournament. We were able to get three teams in time for the competition on Saturday morning, and asked some members of WPI Team 190 to fill in as a fourth to give us an even eliminations bracket.

The tournament started off with qualification rounds, set up so that each team would play every other team at some point in the morning. They were not strictly scheduled, and were simply played whenever teams were available. We also asked each team to leave a phone number so that we could call them if they were needed at the exhibit. We were able to get through the qualification rounds in about a half an hour, and played a best two out of three elimination bracket starting with semifinals. We followed the standard FRC format for this as well, with the team with the best record facing off against the team with the worst, and the middle two teams playing each other in the first round. The winners of these rounds played in the finals. The entire elimination round took approximately 45 minutes.

From the Boston regional we learned that getting started right after opening ceremonies makes a massive difference in the end result of the exhibit. We also found that keeping team phone numbers would make all future competitions run much more smoothly, as we could avoid having to search for the teams.

3.7.3 Chesapeake Regional

The exhibit we worked with at the Chesapeake Regional was substantially different than the ones we had set up at the other events we had attended. This was the first regional where we tested the simulator with representatives from Lockheed Martin. While we were unfamiliar with many of the teams in this region, we found out that many of them were already familiar with 5thGear.

We had a great amount of visibility at the event. The exhibit was in a space next to an entrance to the pit area, and was visible from the stands. The engineer from Lockheed Martin provided the equipment that the simulator was played on, including large monitors, and prizes for the winners of the virtual tournament. This worked out very well, and many people had the opportunity to play.

The engineers from Lockheed Martin developed the tournament plan for this event. On Thursday we ran practice rounds and we advertised the tournament. We allowed anyone to play on Friday, and we recorded the high scores of the teams that played. Throughout the day, we had announcements of the top teams made from the field in order to get more visibility for the tournament. Teams that were trying to qualify often checked their scores and would try to raise them if they no longer qualified. On Saturday, we began by running exhibition matches and finding the teams that had qualified for the tournament. A single elimination bracket was set up, and the competition lasted for several hours. During the final matches, we asked the players to bring their FRC teams to watch, and we amassed a large crowd. When the matches were over, the finalists and winners were given prizes and their team numbers were announced on the field.

This event made several things clear to us, particularly about being visible to teams. Out of any regional we had been to, this one had the greatest number of players. We think this is attributable to the high visibility of the exhibit, and the fact that the FRC field announcer was constantly reminding teams that there was another event going on.

3.7.4 Connecticut Regional

The Connecticut Regional was set up in a way most similar to Chesapeake. The exhibit was in the back of the pit area next to the FRC robot inspection tables and near the food concession area. This created a higher traffic area than either Manchester or Boston. In addition, this was the first event we went to that was set up with everything we requested: five tables wired with power. Also, seeing how helpful it was at Chesapeake, we attempted to have announcements made on the FRC field about the 5thGear exhibit in the pits. Unfortunately, we were unable to have announcements made on the playing field, but we did receive permission to have limited announcements made by Pit Administrations in the pit area.

Having everything we requested and being able to enter the event earlier than usual allowed us to have the exhibit set up and running before opening ceremonies began. We again planned to run exhibitions on Friday and part of Saturday, and then run an FRC type tournament on the second half of Saturday with qualifying matches and eliminations. Interest in the simulator itself seemed high with a large volume of different people using the simulator, though many were not receptive to taking our survey. By the end of the day Friday, only two teams had signed up to compete in the tournament Saturday morning.

Saturday morning we continued demonstrations of the simulator and searched for teams to register to compete in a tournament later that morning. By 10:30 am we had four teams signed up to compete and decided that with the limited time we had before FRC elimination rounds started that it

would be better to have a tournament with a smaller number of teams than none at all. We had announcements made informing those that had signed up that the tournament was beginning and advertising that we still had space for more teams.

Unfortunately, only two teams in total returned by 11:00 am to compete in the tournament. Since none of the tournament structures we planned on testing involved only two teams we had a best three out of five competition between the two teams that showed up. This did not allow us to collect any data on competition structure, but still provided us with other valuable information and data.

3.7.5 Lockheed Martin Events

Lockheed Martin also demonstrated the simulator at several other regional events. These exhibits expanded the geographical sampling of our study to include areas like Florida, Texas, Washington and Virginia. These exhibits were put on by either the Lockheed Martin engineers who designed the software out of the Manassas Virginia division, or by Lockheed personnel at divisions near the event.

Most of these exhibits only demonstrated the simulator and did not attempt to hold a competition. Several events did administer our survey to those who used the simulation. We sent an electronic copy of the survey and consent forms, as well as written instructions on how to administer the survey correctly to the several groups running the exhibitions. After the events, the completed surveys were delivered to us and there information recorded. Only the surveys from the Florida regional arrived in a discrete package. The data from the other regional events are combined, as they came mixed in one box.

3.8 Championship Pilot

The *FIRST* Championship Event in Atlanta, GA draws tens of thousands of people to the Georgia Dome and Georgia World Congress Center over three days in April. The large number of students and

mentors interested in robotics at the event would provide the project team with a large and diverse set of data. Due to the limited number of people testing the various competition options at the FRC Regional events, it was decided to differ from the original plan and test each of competition options at the Championship Event. To help this event run smoother, we implemented many crucial steps learned at the FRC Regional Events, such as better queuing and numerous announcements.

Our exhibit at the Championships was much bigger than our exhibits at other events, which aided in visibility to draw in crowds Instead of having one set of seven computers, there were two sets, so two matches could be played at once. Projection screens and large plasma screens showed the game and Lockheed Martin information. In addition to our exhibit, there was also a satellite table in the center of the pit that advertised 5thGear. Flyers were distributed to teams, and announcements were made from both the field and pits. The engineers from Lockheed Martin brought giveaways for players and prizes for the competition winners. We also made small trophies for the competition winners.

Since we had two sets of computers, the Lockheed Martin engineers took one, and we took the other. Every few hours, there was a tournament on at least one set of computers. Following the tournament, every player was asked to take a survey about the tournament they participated in. The Lockheed Martin engineers favored running quick, single-elimination competitions made up of approximately four teams. On the other sets of computers, we preferred to run more time-intensive tournaments. On Thursday, there was a lot of interest in our FRC style tournament. Seven teams played in qualification matches, and the top four moved on to the elimination matches. We ran a double-elimination tournament with eight alliances on Friday. While both of these competitions took over an hour to complete, they were well received, and no players had to leave due to conflicts with their FRC team's schedule. Since these tournaments were so successful, we ran a 'Championship' on Saturday. The winners of each tournament, the finalists from the FRC style and double-elimination tournaments,

and the high-scoring teams were invited to compete here. This tournament was double-elimination style, and eight teams competed. The winners received trophies and recognition on 5th Gear websites.

4. Results

4.1 Savage Soccer and Team Surveys

The data collected from Savage Soccer and local team testing gave us a total of 53 surveys to use for the opinions of the first version of the 5thGear Simulation. The results were largely positive, and proved to be very encouraging for the future of the 5thGear project. The general responses to each question are detailed below, with the survey in Appendix A, the raw data is in Appendix B, and the completed surveys themselves are in Appendix C.

The first question regarded the participants' experience in the *FIRST* Robotics community, especially important, as not everyone at this event would necessarily have prior experience with *FIRST*. The time spent in the organization was split into five categories, from which we derived an average *FIRST* experience of slightly under 3 years. This validated our assumption that participants at the event would be a good cross-section of the *FIRST* Robotics community, as high school students leave the program with four years of experience, and some mentors will be involved for many more. The histogram (Figure 3) also shows a relatively even distribution, with a cluster in the 3-5 range, which includes high school juniors, high school seniors, and first year mentors (assuming participation

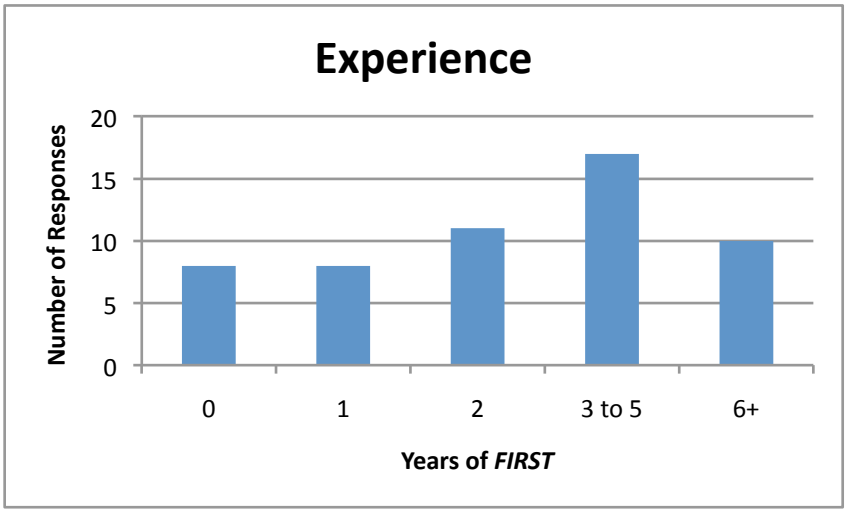


Figure 4 - *FIRST* Experience at Savage Soccer

starting freshman year of high school). We also ascertained the participants' familiarity with the game of *Overdrive*, the 2008 *FIRST* Robotics Challenge which the simulation modeled. The result was about 4.13/5.00, which gave us confidence that the data would represent a group that is familiar with the general premise of the simulation.

The next question on the survey asked the participants how accurately they thought this early version of the 5th Gear Simulation represented *Overdrive*. The average over all groups was 3.57/5.00, with the breakdown by experience level showing no pattern. This was still an encouraging response, as the simulator was in an early stage and this mean, coupled with the histogram (Figure 4), indicates that the vast majority of participants found 5th Gear to be at least an average representation, with only 4 responses of less than 3.00/5.00.

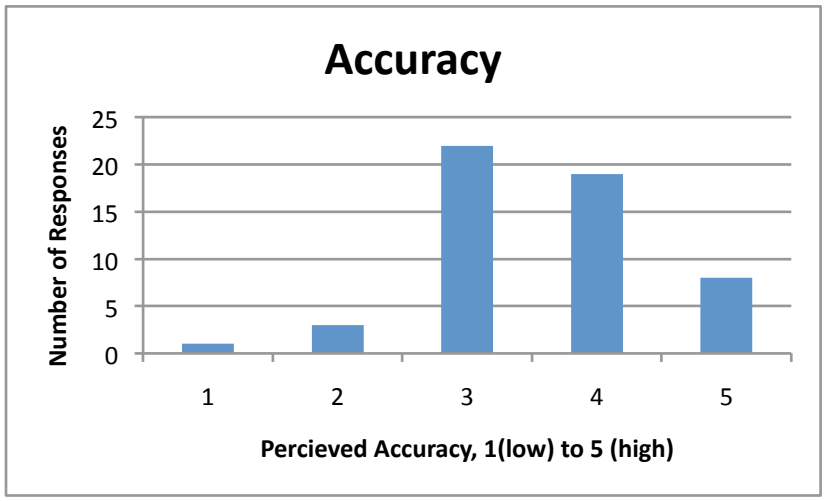


Figure 5 - Simulator Accuracy at Savage Soccer

There were also several useful qualitative responses, with participants giving feedback such as:

- "Easier to manipulate the track balls than in the competition"
- "Good representation of the game. Needs penalties and autonomous to be more accurate"
- "No penalties, but accurately portrayed the difficulty of the game in terms of robot functionality"
- "It would be nice to have an 'autonomous' period where the operator could choose basic logic blocks of canned code"

- "All robots are able to perform all functions even if they don't have attachment to do so"

These show that while the participants found the simulator as a whole to be a good general representation of the game, there are still several areas that need work, such as robot customization, an autonomous period, and the inclusion of penalties in the game rules. However, between these qualitative responses being so specific, and the positive quantitative feedback, the perceived accuracy of the simulator was excellent for such an early part of the project.

The next sections of the survey dealt with determining how people felt about the possible uses of the 5th Gear Simulation, starting with use as a strategy tool. The results were taken on a scale of 1 to 5 again, and the average response gave a perceived usefulness of 3.85/5.00. The histogram (Figure 5) of the results also shows that the vast majority of people gave it a rating of 3 to 5, with only 3 responses less than 3 out of 5. This signifies that the majority of people also think that the simulator modeled the potential strategies in *Overdrive* accurately enough to determine a plan for their entire *FIRST* Robotics season, impressive for the early simulator.

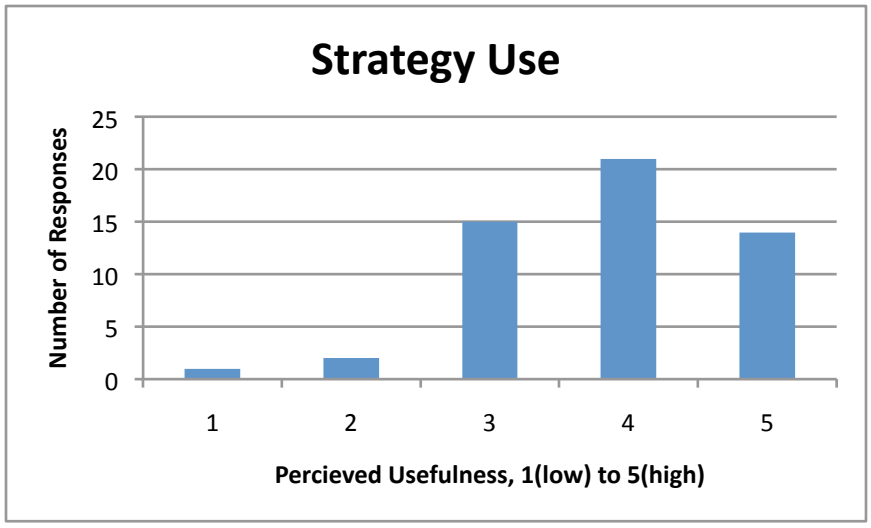


Figure 6 - Strategy Usefulness at Savage Soccer

This section had two qualitative response sections, the first of which asked what is already useful about the simulator when it comes to strategy testing. Some of the more comprehensible responses were:

- “It helps develop a thorough of strategy thinking ‘how can I help my team’”
- "One can try out many different strategies and see possible results"
- "You can see how the game is played w/o leaving your home"
- “Seeing how all 6 robots fit/operate on the field is useful”

We also asked for some opinions on what would improve the strategy aspects of the simulator:

- "Customizable robots, as *FIRST* has extreme varieties of robots"
- “A breakdown of scoring for individuals compared against the overall scores for all bots”
- “Assumption Input, i.e. 'I think a [certain robot] can go 18 ft/sec”

Some of these responses emphasize how important people felt that customized robots would be for the future of the 5th Gear Simulation.

The survey also tried to determine how useful people felt that the simulation would be for choosing a robot type or design for *Overdrive*. This idea was not quite as popular as using the simulator for strategy choices after picking out a robot, with an average rating of 3.53/5.00. While the mean does not show much of a change from the strategy tool, the histogram (Figure 6) shows a different clustering of ratings than on the previous question.

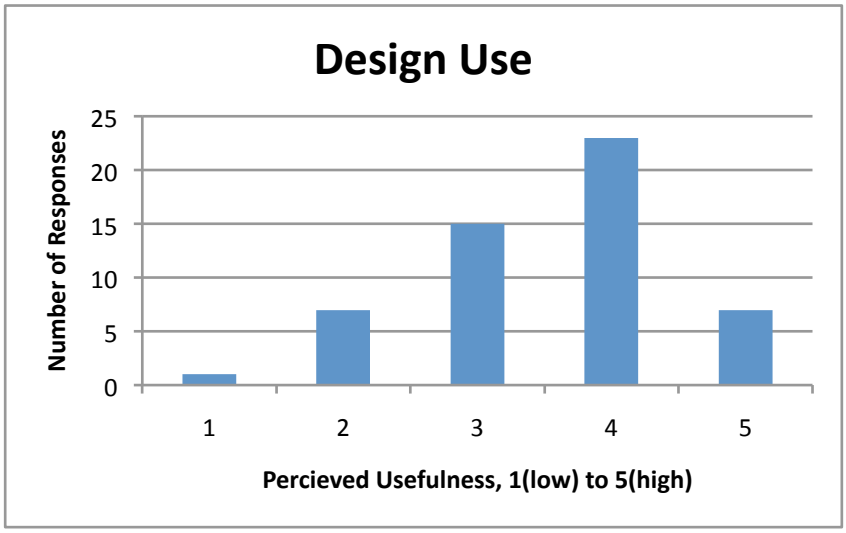


Figure 7 - Design Usefulness at Savage Soccer

The histogram for this question shows that the majority of people answered with a 3 or a 4, with as many

5s as there were 2s. This explains how the average stayed relatively constant, despite a change in the distribution of data regarding the idea.

The problems with using the simulator as a robot designer mostly had the weak physics engine and the lack of any major robot customization as their root cause:

- "It does not give any indication of how hard it is to build a design and how often/hard it will be to keep working"
- "The option to mix and match parts for a robot [would make it more useful]"
- "Cannot really convey how difficult different designs would be to be constructed"

These give a good summary of the qualitative data we received regarding the use of the simulation as a design tool. Nearly all of the feedback regarded the need for a robot creator/editor and physics upgrades to make the simulator useful.

The last vital question was intended to gauge the interest in using the 5th Gear Simulation as the basis of a competitive event. At this stage of the project we did not ask about any specific types of competitions, but we were just trying to get a general feel for the level of participation we would be likely to get.

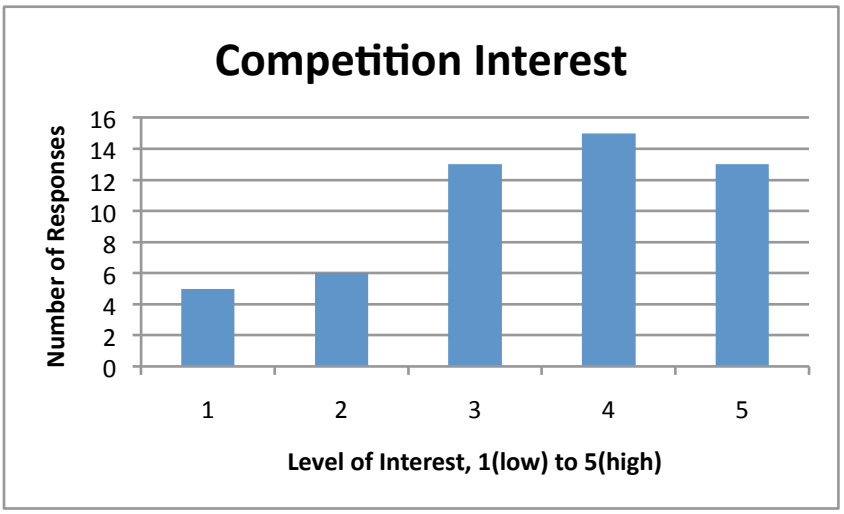


Figure 8 - Competition Interest at Savage Soccer

The average response for this question was 3.48/5.00, but the histogram (Figure 7) shows some interesting trends that are ignored by the mean. The responses were more

spread out than the others, with 11 participants answered 1 or 2, and 3, 4, and 5 were given with roughly equal frequency. While this does show a little less excitement over the idea than would be apparent from just the average, more than half of the responses were in the 4 or 5 range, so there is still a reasonable level of interest in a competition.

The remainder of the survey was given over to finding out details such as how much, if anything, people would be willing to pay to participate in a competition. The general consensus from this data was that the competition should be free, or at least very inexpensive once the simulation is improved. We also determined that people would be willing to travel for the event, but not very far. While these questions were open ended, they still allowed us to get some data to determine how to stage any potential competitions in the future.

4.2 Regional Surveys

After all of the *FIRST* Robotics Regional Events, we had collected 353 surveys from at least 6 regional events. The Manchester (NH), Boston (MA), Florida, Chesapeake (MD), and Connecticut events, as well as a collection of surveys from regionals where Lockheed Martin ran a 5thGear exhibit, gave us a geographic spread over much of the East Coast. The data (broken down by event) is available in Appendix E, and the survey given out is in Appendix D. The completed surveys are in Appendix F.

4.2.1 Overall Data

The first question on the regional survey regarded the participants' previous use of the simulator. The possible responses ranged from never having heard of it before, to having used it many times. These responses were then turned into quantitative responses, with 1 corresponding to never having heard of it before, and someone who answered 5 having a great deal of experience with it. The average response from all the events was a familiarity of 1.77/5.00. This quantified the average user

between never hearing of it and having knowing about it, but never seeing it. The histograms (Figure 8) of the number of responses also show this pattern, with the quantity of responses dropping off quickly from never hearing of it. There are also no apparent geographical anomalies in the responses, with the general shape of the graph constant for all regionals.

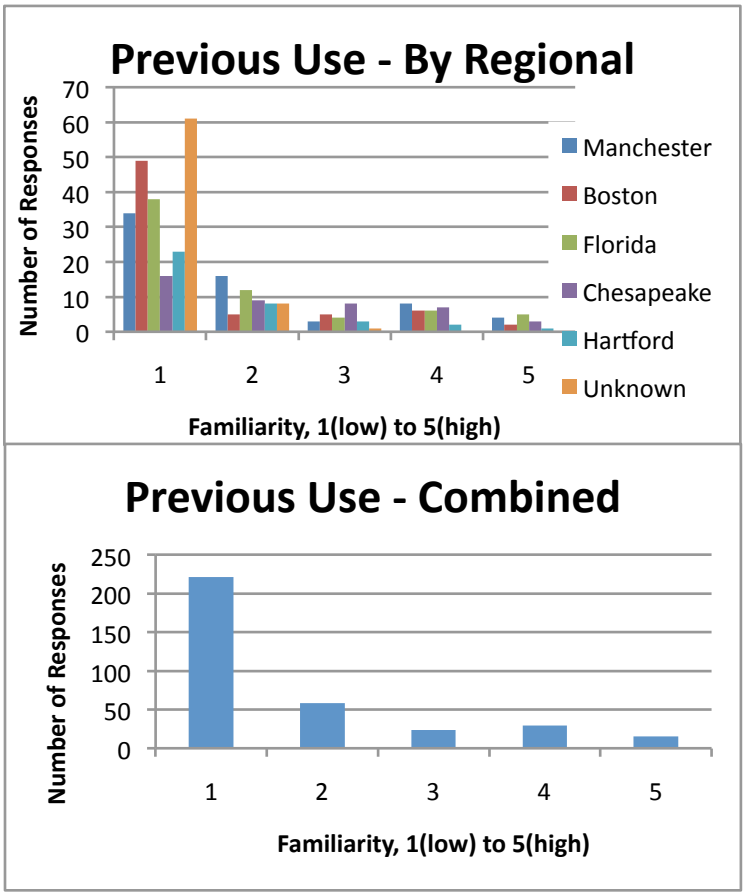


Figure 9 - Previous Use at Regionals (Upper: By Regional, Lower: Combined)

With the results from this question so low, we also decided to determine the percentages of people who had heard of the simulator at all, as well as the how many had actually tried it before. Fortunately, the qualitative options we gave on the survey made this relatively straightforward, as a response of 1 meant that they had never heard of it, and a 3, 2, or 1 signified that they had never used it before.

Figure 10 - Previous Knowledge at Regionals

These numbers showed that only 36% of participants had even heard of the 5th Gear Simulation before they tried the exhibit at the regional competition. And only 13% of the participants had actually used the simulation before.

We next tried to determine how accurate the participants thought the simulator was as a representation of *Lunacy*, the 2009 *FIRST* Robotics Challenge. Just like the Savage Soccer feedback, this was taken on a scale of 1 to 5. The average of this response over all regionals was a 3.67/5.00, about a tenth of a point higher than the average from the Savage Soccer surveys. The histogram (Figure 10) also shows that the most common answer has shifted from a 3 to a 4, signifying an slight increase in simulator quality from December to March/April.

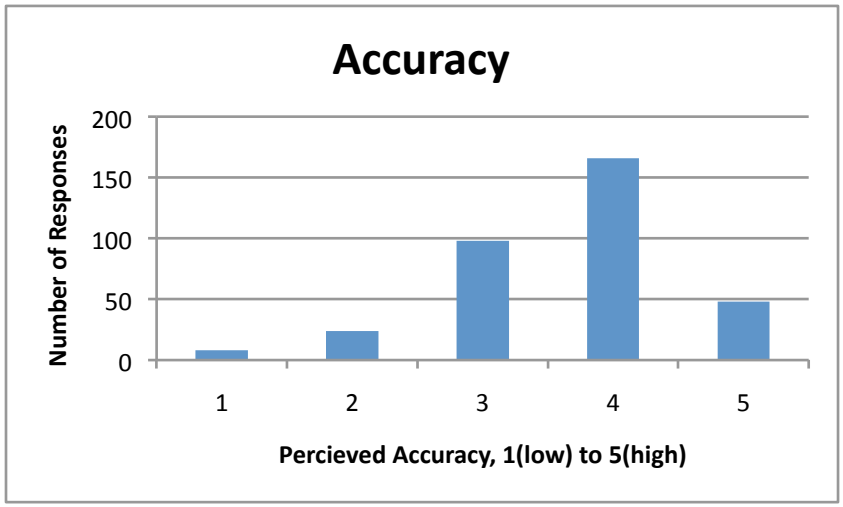


Figure 11 - Simulator Accuracy at Regionals

We also asked for participants to tell us how much they enjoyed participating in the 5th Gear exhibit, on the scale of 1 to 5. The results were extremely positive, with a mean of 4.01/5.00. The histogram also shows that the most common response was a 4, which is not surprising from the average. However, the histogram (Figure 11) also shows that there were more responses of 5 than there were of 3, which shows that the results had shifted much higher up the scale from those at Savage Soccer.

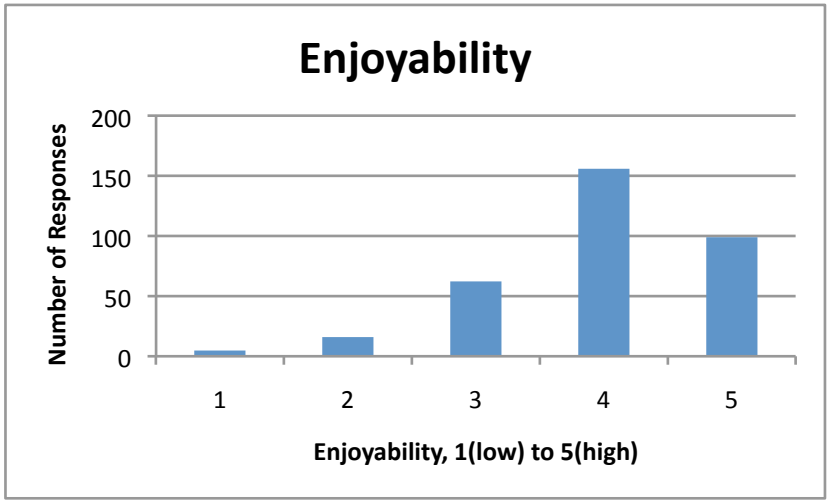


Figure 12 - Simulator Enjoyability at Regionals

The next section of the survey asked participants to rank four possible upgrades (a robot editor, autonomous mode, graphics improvement, and online play capabilities), as well as a write-in option, from 1 (most important) to 5(least important). The average rankings of these four gave the robot editor a 2.78, and all of the others were at approximately 3.03. There were no common write-in options. To try to increase the resolution of the combined rankings, we decided to try a weighted sum, where the total for each upgrade would be the sum of the reciprocals of the rankings. This would give higher rankings the most weight, and vice versa. In other words, for every ranking of 1, the sum would increase by 1; a ranking of 2 would increase the sum by ½, etc. This gave a total for the robot editor of 152.5.

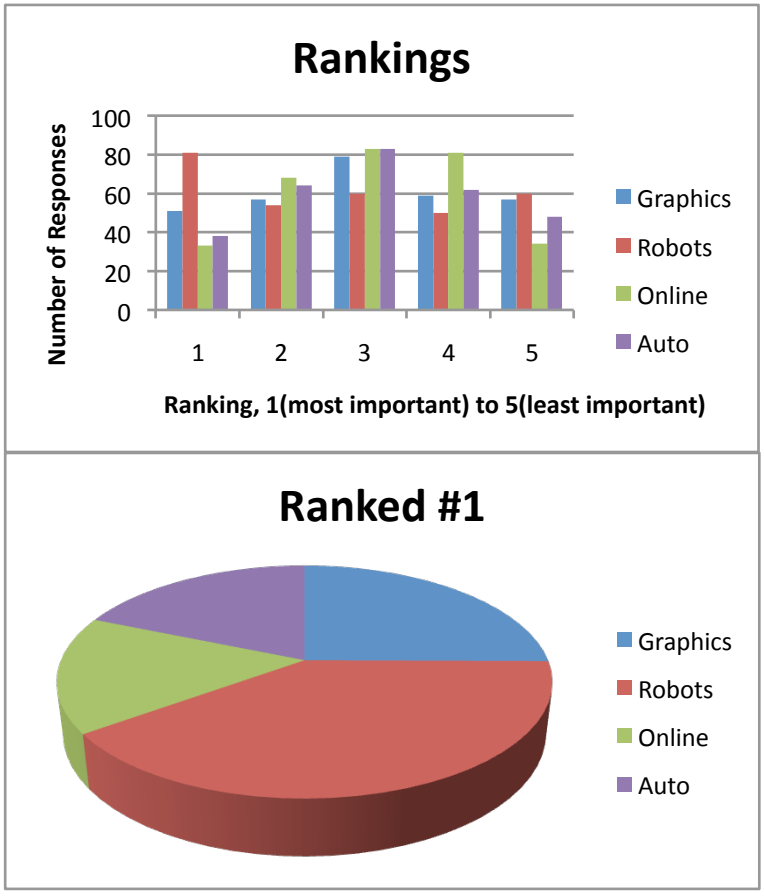


Figure 13 - Future Additions Rankings from Regionals

Improved graphics had a sum of just under 132, while the other two options were just about equal at 122.

There are also some interesting points that the graphs (Figure 12) of this data illustrate. The histogram gives a breakdown of how many times each option was ranked at a certain level. This shows the robot editor was ranked first almost twice as much as any other option, which is also illustrated by the pie graph, showing the breakdown of those ranked number one.

We also collected data on how likely people would be to use the 5th Gear Simulation in the future. We first asked people to respond on how much they would use the simulation next season using the scale of 1 to 5. The average response from all the regionals was 3.68/5.00. The histogram (Figure 13) also shows the overwhelmingly positive reaction after using the simulator, with 4 being the most common response, followed by 5, and then 3. We also asked if those who tried the simulator would participate in a future exhibit if given the chance, and 96% of those surveyed said that they would, illustrated in the pie graph (Figure 13).

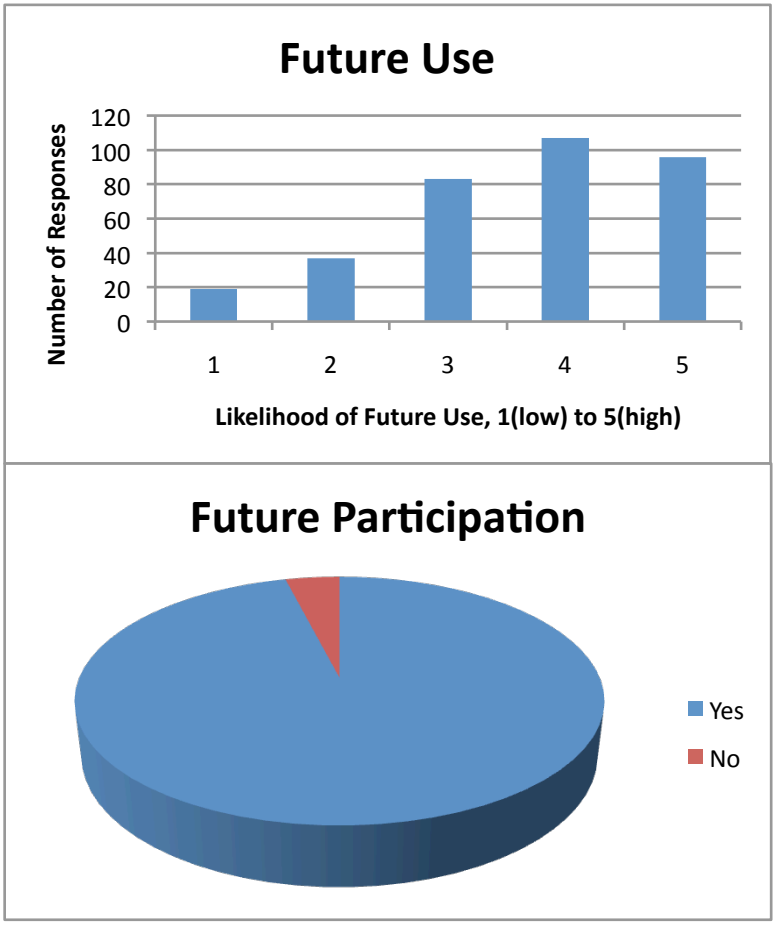


Figure 14 - Future Use/Participation at Regionals

4.2.2 Manchester

The results from the Manchester Regional were more or less average across the board, with enjoyability, future use, and participation slightly lower than the mean. Participants also ranked graphics as more important than any of the other improvements at this regional, but only marginally. None of these anomalies are substantial, however.

4.2.3 Boston

The Boston Regional had no noticeable deviations from the mean. We did, however, run a small FRC style tournament at the event. It was fairly well received, with all 6 surveyed participants rating the tournament a 4 or 5 out of 5. 4 of the 6 did say that they would participate in another, even if it was not located at a regional event; they did not seem as enthusiastic about an online tournament however, with several 3 out of 5 responses for how excited they would be to compete over the internet. All but one of the participants also said that it was easy to compete in the 5thGear tournament while fulfilling their team duties as well. One participant also noted that they enjoyed the FRC style format much more than they would have if it were a single elimination tournament.

4.2.4 Florida

The participants at the Florida Regional gave slightly higher than the mean for future use, enjoyability, and future participation. They also had a slightly higher than normal previous knowledge of the simulator, and found it slightly more accurate than the average.

4.2.5 Chesapeake

The Chesapeake Regional was unique in that it had by far the highest previous knowledge average (2.35/5.00 compared to the mean of 1.76/5.00). Interestingly, it also had above average numbers for accuracy, as well as the highest future participation, but few other anomalies. We also ran a brief single elimination tournament at the event, which was reasonably well received, with numbers close to those from the FRC competition at Boston. We did, however, get a comment from one participant that mentioned that the single elimination tournament was too brief, and recommended at least a best 2 out of 3 tournament structure instead.

4.2.6 Connecticut

The Connecticut Regional had no major differences from the averages.

4.2.7 Other

The surveys from Lockheed Martin regionals had several unusual results. They had, by far, the lowest previous knowledge, enjoyability, and future participation numbers. However, these numbers had little effect on the rankings or accuracy.

4.3 Championship Surveys

By the end of the Championship Event we had a total of 56 surveys on competition types: 22 were for a single elimination tournament, 19 were for a *FIRST* Robotics Competition structured event, and 15 were for a double elimination format. The survey itself is in Appendix G, the raw data is in Appendix H, and the completed surveys are in Appendix I. The first few questions on the survey regarded the participants' background at the event, both the *FIRST* organization they were there with (*FIRST* Robotics Competition, *FIRST* Tech Challenge, or *FIRST* Lego League), as well as their role on their team (if applicable). All but two of those who filled out surveys were from FRC, and the team roles were well spread out, with a high number of drive team members considering their busy event schedules.

We asked the competitors to give the structure that they participated in a rating from 1 to 5 according to whatever criteria they found important. Between all three of the structures, the average rating was a 4.30/5.00. The single elimination tournament rating was a 4.41/5.00, the double elimination was rated a 4.33/5.00, and the FRC structure was given a 4.16/5.00. All three structures had excellent ratings, and while the single

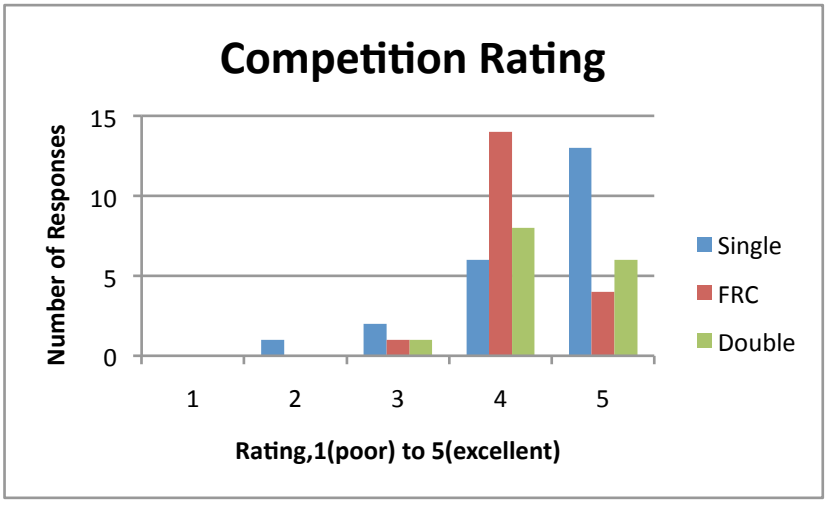
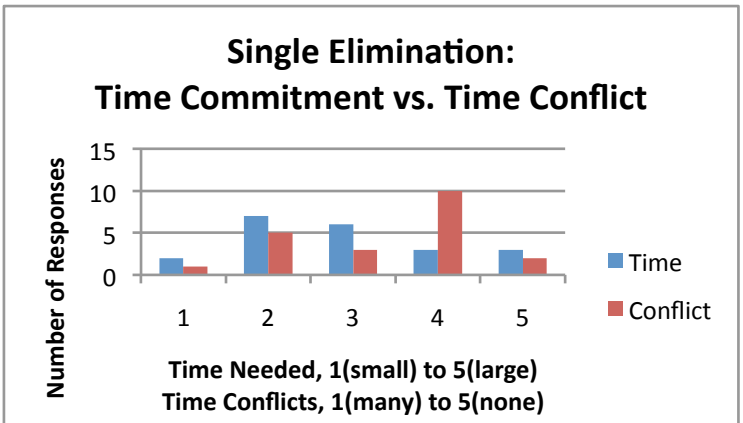
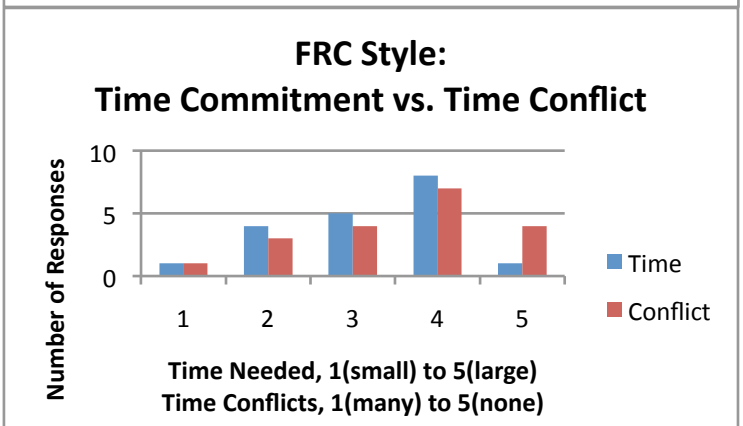
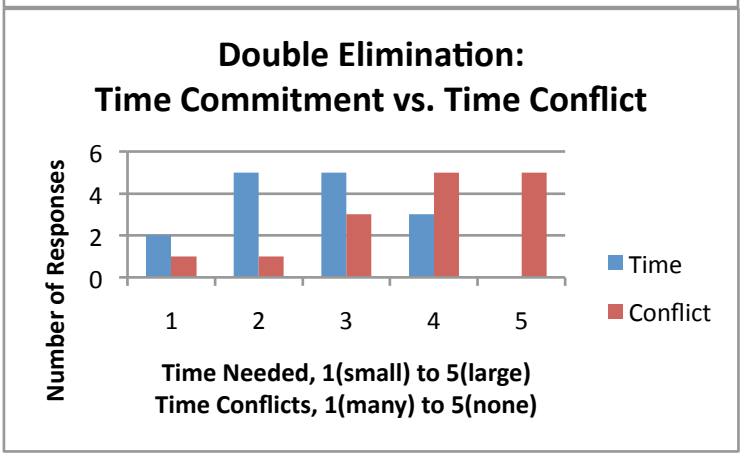


Figure 15 - Competition Structure Rating at Championships

elimination was rated highest by a slight margin, the averaged ratings on their own are too close to each other to use to make a decision. The histogram (Figure 14) also shows no convincing trends, considering the small sample size.







We also asked the team members how much of a time commitment it was to compete in the 5th Gear tournament on a scale of 1 to 5, 1 being a small commitment, and 5 being a large one. The mean results for time commitment were: 2.91/5.00 for all, 2.90/5.00 for single elimination, 3.21/5.00 for FRC style, and 2.60/5.00 for a double elimination tournament. While these results more or less match the time needed to run each tournament, each one actually ran for between an hour and an hour and a half. With such a small range in the run times, as well as in the responses, none of the structures are a clear success or failure from the numbers.

On that same note, we also asked how much the tournaments interfered with their participation with their *FIRST* team. This was also on a scale of 1 to 5, with 1 implying that it was very difficult for them to do their job with their team, and a 5 meaning that no problems arose. The average responses to this ranged from 3.33/5.00 for the single elimination, to 3.80/5.00 for the double elimination. FRC style had an average response of 3.52/5.00, and the mean of all three competitions was 3.55/5.00. The unusual part of these results is shown in the histograms. While the double elimination graph (Figure 15) shows approximately the expected relationship, with conflicts increasing with time commitment, the single elimination graph shows less correlation, and the FRC style graph shows the exact opposite pattern.

Because of these rather unusual responses (and small spread in mean), we decided to use these questions to obtain a general feel for the amount of time needed for any of the competitions and not use this data to differentiate between the structures.

We also checked to see how much people enjoyed competing in the 5thGear tournament. This used the same scale as all of the enjoyability questions in the past, with 1 to 5, 5 being the most enjoyable. The mean response was 4.60/5.00, with the single elimination being rated 4.67/5.00, double elimination had an average of 4.60/5.00, and the FRC style was rated 4.52/5.00. Once again, these numbers are too close to the overall mean to be of much use

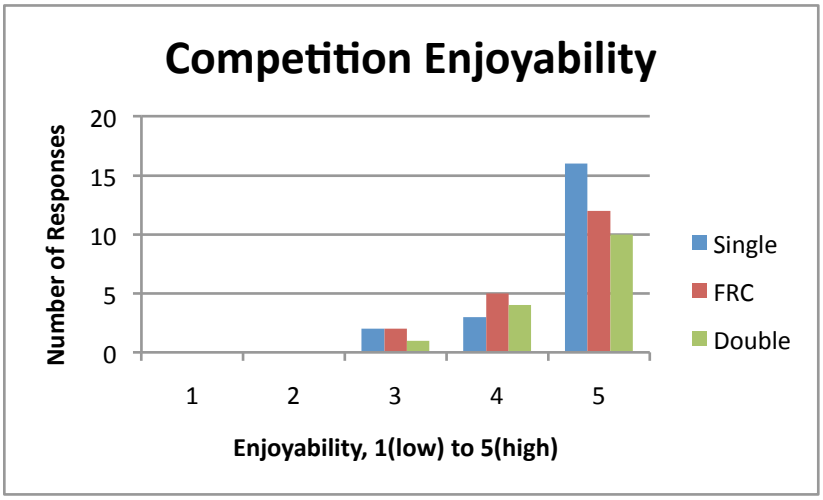


Figure 17 - Competition Enjoyability at Championships

to us; however it does tell us that all competition types were well received. This conclusion is emphasized by the histogram (Figure 16) of the responses, which shows a dramatic trend, with no ones or twos, and five being the most common response by far.

The last direct question on the survey asked the participants if they felt that a simulation competition should be held at an existing *FIRST* competition, or at an event run only for the 5thGear tournament. 90.2% of the participants felt that the tournaments should be held at existing competitions.

At the very end of the survey, we left some space for the participants to leave any comments they had that did not fall directly under the questions we had asked. We found that many of these were much more useful than any of the quantitative feedback we obtained at the Championship Event. Regarding the single elimination tournament:

- “Was fun, nice break from everything else at the competition”
- “Good for pilot, scheduled matches would be appreciated”
- “Single elimination can be disappointing”
- "Single elimination is too harsh of a structure, no chance to warm up, one mistake and you're out"

The FRC style tournament had the following feedback:

- “Great experience, lot of fun”
- “Tense and overall enjoyable”
- “Very well put together tournament”

These comments were on the double elimination structure:

- “It's awesome, I like the double elimination better [previous tournament unspecified]”

- “Great competition”
- “Fun and enjoyable”
- “Anything that promotes robotics is good for all of robotics”

These various qualitative comments very useful for our project, as most directly describe the problems with or advantages of the competition structure. This provides much more direct feedback to relate the different tournament styles than the quantitative responses we had collected, which were frequently too similar to be able to safely draw conclusions from such a small sample size.

5. Conclusions

Using the results acquired from the Regional, Championship, and WPI events, there appears to be enough data to make recommendations about how *FIRST* should continue with 5thGear. There are two types of recommendations: for use as a tool and for use as a competition. The use as a tool section include desired changes to the program, and the ability of the program to be used to improve robot design, strategy, outreach, training, and use as a tool for *FIRST*. The competition section is about the recommended tournament style and how to implement it.

5.1 Features to add

While 5thGear is a useful tool right now, users had many suggestions for improvements. The most requested feature is a robot design tool. Whether these designs come from integration with CAD software or a built-in robot editor did not seem to be important. Players simply want more control over the type of robot they drive, and some want to drive something closer to their actual FRC robot. Online play, autonomous mode, and better graphics were also requested, but none of these are seen as being as important as robot design.

5.2 Use for robot design

A long-term goal of the 5thGear simulator would be to act as a virtual design tool, to aid in the development of various robot ideas for the *FIRST* Robotics Competition, and possibly the *FIRST* Tech Challenge. The concept of a virtual design assistant is based around the idea that a team could develop a virtualized model of their robot, which could then be loaded into the simulator, and tested in the virtual playing field.

The concept behind the implementation this feature would consist of one of two design methods. The more complicated method, but completely open ended, would be to design a robot in a 3D CAD modeling package, such as Autodesk Inventor, SolidWorks, or PRO-Engineer. From here, the model could then be exported into a file format readable by the simulator. The other option is to have a built-in library of sub mechanisms and modifiable robot parameters, which teams could then drag and drop onto a robot model and built it from the ground up. While easier to implement, this method would limit the potential creativity of robot designs to those that could be designed using the available sub assemblies or components built into the simulator.

5.3 Use as a strategy tool

While the simulator is not ready to be used as a design tool, it definitely has potential as a strategy tool. Our data from several surveys also show that most hold the opinion that the simulator is sufficiently accurate to the real game to be useful. The simulator would be more useful if included in the FRC kit of parts or was released shortly after the kickoff of a new game. As teams played and got better at the game, they began discussing strategies with their partners. When we listened to them strategize, it was quite similar to listening to actual teams go over strategy. In both the Lunacy and Overdrive versions of 5thGear, most of the matches played out like actual matches. If teams had taken the opportunity to use the simulator during the build season, they might have realized how the game was going to be played, and used that to their advantage.

5.4 Use as an outreach tool

Another long-term goal of the 5thGear simulator in the *FIRST* Virtual Challenge was to ascertain a way in which the simulator could be used to further the goals of *FIRST* into a market yet to be tapped by either the *FIRST* Robotics Competition or the *FIRST* Tech Challenge. This would be achievable through the free and open nature of the 5thGear executable binaries being used to spread a *FIRST*-branded

program into any client with a computer. The intent of the simulator for outreach, therefore, is to inspire students about robotics in schools that lack a current *FIRST* presence.

The advantage behind this is the low barrier of entry for individuals attending a school not yet interested or involved with either of the *FIRST* high school competition models. Due to the ubiquitous nature of computers in modern society, coupled with the increasing share of users with broadband connections and the free availability of 5thGear, the growth potential of the simulator is quite large. What this means for *FIRST* is that the potential exists not only for these students to become inspired through the use of the simulator as is, but also to lead an effort for their school to participate in either the *FIRST* Virtual Challenge, or even FRC or FTC. Thus the simulator, available as a free download on the Internet, is essentially a marketing strategy, with the costs involved with hosting a Web server and the donated time of the Lockheed Martin software engineers.

Besides the potential of the simulator as a marketing tool for *FIRST*, the potential also exists for teams to use the 5thGear simulator as a marketing tool for their own teams. These teams may elect to set up anywhere from a single computer to a full scale seven computer setup at open houses or public demonstrations, as well as invite other schools and potential students to use the simulator to get an instantaneous "feel" for what a robotics competition match is like. Alternately, they might distribute links to download the software to potential students or team sponsors, so they themselves could get a more intimate understanding of what a match in the *FIRST* Robotics Competition is like. While this alone may not fully convince someone to participate in any of the *FIRST* programs, the potential exists for it to help persuade an individual to get involved as a means of interactively showing them what a typical *FIRST* Robotics Competition match is like.

Since the current simulator does not allow for play over wide-area networks, such as across the Internet, the simulator as it stands is designed around being used on local area networks exclusively.

Thus use of the simulator is limited to a classroom in a school. Features would have to be added to the simulator to make the game more suitable for play over the Internet, but the technology required to make this happen exists. Thus using the 5thGear simulator for outreach partially exists (for local networks), with a clear path defined to achieve full functionality.

5.5 Use as a training tool

The potential use of the 5thGear simulator for testing and evaluating the skill of various students at controlling a robot by their respective FRC or FTC team was another early goal of the *FIRST* Virtual Challenge. This skill, which is incredibly important in the *FIRST* Robotics Competition and *FIRST* Tech Challenge (due to the majority of their match time being spent with students tele-operating the robots instead of them acting autonomously), is easy to evaluate with the 5thGear simulator. The fact that the space, money, and resources needed to accurately build a significant portion of a FRC or FTC playing field can be high only helps reinforce the use of the 5thGear simulator as a method or training potential robot drivers.

Since the simulator also has the ability to run a single robot to all six robots in any given match, this gives teams the ability to train drivers in a variety of environments of varying difficulty, depending on the number of computers and participants available. Use of this along with the ability of the simulator to record all matches, and allow playback of all previous matches gives these teams the ability to thoroughly analyze driver performance and strategy in a given match. By giving teams an easier method of analyzing driver performance, this also gives FRC teams lacking the funds to build a practice robot a chance to competitively reach similar levels of experience prior to a competition for a fraction of the cost. The simulator as it stands right now can be used for this goal.

5.6 Use at *FIRST*

Since the simulator is completed before the actual FRC game is released, we have been looking into ways that *FIRST* could use the simulator as part of the game design process. For example, the engineers at Lockheed Martin could be given the field plans while the Game Design Committee is creating the game. The GDC could design the robots, and test out how the game would be played without having to construct the field or any physical robots. Another idea has involved using 5thGear to assist in the making of the FRC game animation. While the simulated environment does not look as good as the game animation, it would take less time to make, and be easier to use. The robots could be programmed to do whatever the animator would like them to do. Since the simulator includes a game recorder, the animator would not need to render the animation anymore. He would simply need to control the camera angles.

5.7 Use as a Competition

We spent most of our time testing how the simulator would work as part of a *FIRST* competition. People who played in a tournament were especially positive about 5thGear tournaments continuing. From the feedback we received, we think *FIRST* should run a pilot 5thGear tournament for at least a year before making a full competition. One of the problems we ran into this year involved people not knowing what 5thGear is. There was certainly a relationship between how well 5thGear was advertised and how many people were familiar with it. For the 2010 season, we think it would be a good idea to invite a relatively small group of teams that are very familiar with 5thGear to compete.

Most of the feedback we received indicated that *FIRST* should hold 5thGear tournaments alongside FRC Regional and Championship events. Instead of making this tournament completely independent, like the *FIRST* Tech Challenge and *FIRST* LEGO League events, it would be a part of an existing competition. This would most likely happen during the Thursday practice rounds, as teams tend

to have less to do, and are not as constrained by matches. At times when the tournament is not being run, the exhibit would be open for anyone to play, in order to continue advertising 5thGear. Teams registered for the FRC competition would be able to send three representatives to the tournament location, which would likely be in a high traffic location near the pit or field. These representatives would likely not be from an FRC drive team, so that they do not need to concentrate on two competitions at once. Instead, they would be from another part of the team, like the Chairman's Award representatives.

When teams arrive at the tournament location, they would sign in, and a match schedule would be made. Depending on the evolution of 5thGear, these teams might import robots that they had designed before the event. Since it was one of the most popular styles, and does not require the number of teams to be a power of two, teams would be playing the FRC style tournament. They would play a number of elimination matches, and the top teams would compete against each other. We hope that the winners, and maybe finalists or high-scorers, of this event would be given the Simulation Award, similar to the Autodesk Animation Award. In a few years, if the game is a success, it might be possible to make the competition a separate event from the regional, like FTC and FLL, but still take place at a regional event. It would be important to keep the simulation event in close proximity to physical robots, as to not take away from the engineering aspects of *FIRST*, and so that people unfamiliar with the program understand there is more to *FIRST* than just a simulation.

In addition, the challenge played in the simulation does not necessarily have to follow the FRC game. Because of the nature of simulations, almost any environment or type of challenge would be possible. Instead of driving on plastic called regolith and throwing balls the simulator could be a challenge on a simulated moon or other extreme environment unavailable to other *FIRST* competitions.

Appendix A: Savage Soccer Survey

Robot Simulation Survey

Now that you have used the 5th Gear Simulator for the 2008 FRC game, we invite you to answer this survey on your own experience with *FIRST* and the simulation itself. The information collected in this survey will be used to help improve and add features to the simulator and help determine its best use in the future.

1. How long have you been involved with the *FIRST* Robotics Competition (FRC)?

   ___ Not Involved
   ___ < 1 year
   ___ 1-2 years
   ___ 3-5 years
   ___ 6+ years

2. How familiar are you with the 2008 FRC Game *Overdrive*? (1 being very unfamiliar with *Overdrive*and 5 being very familiar with *Overdrive)*

   1 2 3 4 5

3. Do you think this simulation is an accurate representation of *Overdrive*? (1 being very inaccurate and 5 being very accurate. N/A being that you are too unfamiliar with *Overdrive* to make an assessment)

   1 2 3 4 5 N/A

   Why is/Why isn't this an accurate representation?

   _____

   _____

   _____

4. How useful do you think this simulator would be in determining a strategy of play for the game *Overdrive?* (1 being not useful at all 5 being very useful.)

   1 2 3 4 5

   What, if anything, makes this simulator useful in determining strategy?

_____

_____

What would make this simulator more useful in determining strategy?

_____

_____

5. How useful do you think this simulator would be in picking a general robot concept for the game *Overdrive*? (1 being not useful at all 5 being very useful.)

   1 2 3 4 5

   What, it anything, makes this simulator useful in determining robot concept?

   _____

   _____

   What would make this simulator more useful in determining a robot concept?

   _____

   _____

If this were to be a competitive simulated league:

6. Would you be interested in participating in the competition? (1 being uninterested and 5 being very interested)

   1 2 3 4 5

7. What would be the best time of year to have the competitions? (e.g.: During build season, concurrent with the FRC competition season, after the season is over)

   _____

   _____

8. How much would you be willing to pay to compete in a simulation league?

   _____

9. How far would you travel to compete in a simulation league?

   ___ Would not travel

   ___ Travel in state

___ Travel to neighboring state

___ Travel across country

Appendix D: Regional Competition Survey

5th Gear Simulation Survey

Now that you have used the 5th Gear Simulator for the 2009 FRC game, we invite you to answer this survey on your experience. The information collected in this survey will be used to help improve and add features to the simulator and help determine its best use in the future.

5thGear Simulation Technical Questions:

What was your experience with the simulator before using it at the event today?

___ Never heard of it before today

___ Heard of it, but never saw it

___ Seen it being used, but never used it myself

___ Used the simulator a few times before

___ Used the simulator several times before

Now that you have used the simulator and have seen the competition on the field, on a scale of 1-5, do you think this simulation is an accurate representation of *Lunacy*?

Inaccurate 1 2 3 4 5 Accurate

Assigning each feature a value of 1 to 5, please number the following 5th Gear upgrades from most (1) to least (5) important.

___Improved Graphics

___Robot editor/creator

___Online/Multiplayer

___ Autonomous mode

___Other: _____

After seeing it in use, how likely would you be to use it during the 2010 FRC Build Season?

Unlikely 1 2 3 4 5 Likely

5thGear Simulation Exhibit:

On a scale of 1-5, was the *5thGear Simulation* exhibit run professionally?

Unprofessional 1 2 3 4 5 Professional

Additional Comments:

_____

_____

On a scale of 1-5, how enjoyable would you rate the *5thGear Simulation* exhibit?

Boring 1 2 3 4 5 Enjoyable

Would you participate in an exhibit again?

Yes No

From here on, only answer if the *5thGear Simulation* exhibit was run as a competition:

On a scale of 1-5, in general how would you rate the competition structure?

Poor 1 2 3 4 5 Excellent

What would you change to make the *5thGear Simulation* competition structure better?

_____

_____

On a scale of 1-5, how would you rate the difficulty of spending time competing in both the *FIRST* Robotics Competition and the *5thGear Simulation* at the same event?

Difficult 1 2 3 4 5 Easy

If a *5thGear Simulation* competition was not held at a *FIRST* Robotics Competition event, would you go out of your way to compete?

Yes No

On a scale of 1-5, how likely is it that you would compete in a *5thGear Simulation* competition held over the Internet (high speed Internet access would be necessary)

…If the competition was a single day-long tournament?

Unlikely 1 2 3 4 5 Likely

…If the competition was a recurring event held for several hours a day over several days?

Unlikely 1 2 3 4 5 Likely

General Comments:

_____

_____

_____

_____

_____

Appendix G: Championship Event Survey

5th Gear Simulation Survey

Now that you have used the 5th Gear Simulator for the 2009 FRC game, we invite you to answer this survey on your experience. The information collected in this survey will be used to help improve and add features to the simulator and help determine its best use in the future.

1. **Which tournament structure did you compete in?**

A B C D

2. **What other *FIRST* program are you connected with at the Championship Event?**

___ FIRST Robotics Competition (FRC)

___ FIRST Tech Challenge (FTC)

___ FIRST Lego League (FLL)

3. **What would you describe as your role on your FRC/FTC/FLL team here at the Championship Event in Atlanta?**

_____

4. **On a scale of 1-5, how would you rate this competition structure?**

Poor 1 2 3 4 5 Excellent

5. **On a scale of 1-5, how much of a time commitment was competing in a 5thGear tournament?**

Little Commitment 1 2 3 4 5 Large Commitment

6. **On a scale of 1-5, how difficult was it to compete in a 5thGear tournament and fulfill your commitment to your other team?**

Difficult 1 2 3 4 5 Easy

7. **On a scale of 1-5, how enjoyable was the 5thGear tournament to compete in?**

Boring 1 2 3 4 5 Enjoyable

8. **Would you want see a 5thGear tournament as part of an existing *FIRST* competition or as a standalone event?**

Standalone Event At competition

General Comments: _____

_____