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Developing a Collegiate Robotics Competition Hosted by WPI

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Interactive Qualifying Project

Developing a Collegiate Robotics Competition Hosted by WPI

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Abstract

Although Worcester Polytechnic Institute (WPI) is considered a leader in robotics research and education, it has never specifically hosted a collegiate robotics competition. Through background research on other collegiate robotics competitions, discussions with both representatives from universities and robotics companies, and stakeholders at WPI we have developed a proposal for a collegiate robotics competition. This event would be hosted at WPI in collaboration with TouchTomorrow, a campus-wide event showcasing science and technology in early June. This event would consist of three separate challenges based on real-world problems. These challenges combined with a robotics career fair and networking opportunities would provide many long-term benefits to the school.

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Authorship

Initial drafting was primarily done by Andrew Nagal with editing and the final draft primarily done by Nathan Rosenberg with additional contributions by Rohit Unnam. The following is a breakdown of the authorship. Each is ordered from the most to least contributions:

Table 0.1: Authorship breakdown

Section	**Authors**	**Editors**
Abstract	Nathan Rosenberg	Nathan Rosenberg
Introduction	Andrew Nagal, Nathan Rosenberg	Nathan Rosenberg
Background	Andrew Nagal, Rohit Unnam	Nathan Rosenberg
Findings	Andrew Nagal, Nathan Rosenberg, Rohit Unnam	Nathan Rosenberg
Conclusions and Recommendations	Nathan Rosenberg	Nathan Rosenberg, Andrew Nagal
Appendix A, B, C	Andrew Nagal, Rohit Unnam	Andrew Nagal, Nathan Rosenberg

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1 Introduction

For decades society has acknowledged the importance and relevance of robotics as it continues to become a larger part of everyday life. In recent years, many educational institutions have begun to realize the importance robotics has in the world today and have started to integrate robotics programs into their curriculum. In 2007 our university, Worcester Polytechnic Institute, was the first ever to offer a Bachelor of Science in Robotics Engineering [1]. Through robotics programs and industry, the field continues to grow and develop, but these are not the only ways the field has advanced.

Another way the field has advanced over the years is through robotics competitions. Competitions cultivate a competitive and challenging environment that drive the innovation and creativity necessary to develop new technologies. While most robotics competitions have the intention of fostering creativity and innovation, particularly at the collegiate level, not all of them are successful and sustainable. Many collegiate robotics competitions have faced problems that have led to renewal delays or even cancellation. These problems in part come as a result of the rapid pace of technological advancement where challenges quickly become obsolete.

This Interactive Qualifying Project delivers a proposal for a successful and sustainable collegiate robotics competition hosted by Worcester Polytechnic Institute (WPI). We have studied the successes and failures of other competitions and have gathered information from potential participants, sponsors, and WPI stakeholders. We have developed this competition to increase opportunity for undergraduate involvement in cutting-edge innovation and to elevate WPI's peer-to-peer recognition amongst other institutions.

In the pursuit of our goals, we have researched and discussed a broad range of general questions and considerations. Each of these hurdles have been addressed during the course of our IQP:

- What do we define as a 'successful' collegiate robotics competition?
- What causes some collegiate robotics competitions to fail while others succeed?
- What do successful collegiate robotics competitions have in common?
- What do failed collegiate robotics competitions have in common?
- What do events outside of the academic world, or even outside of the world of technology, do to be successful? Are any of these design aspects transferable to the kind of event we are planning?
- How can we grow the scale of interest in this competition beyond people already active in similar ones?
- How do we get potential sponsors interested in our competition?
- What can we do to encourage concrete undergraduate involvement in this competition?
- How will our competition interest peer institutions?

- What resources will be required to host our competition at WPI?

By comprehensively answering these questions using effective methodology, and by learning from the triumphs and failures of others, we have created a presentable roadmap for a realistic, implementable, and impactful collegiate robotics competition hosted by WPI.

2 Background

In order to develop a successful and sustainable collegiate robotics competition at Worcester Polytechnic Institute (WPI) it is important to understand the background of the school, its Robotics Engineering Program, and other collegiate robotics competitions. It is also important to understand why a collegiate robotics competition hosted by WPI is relevant to the interests of the school, and the benefits that a collegiate robotics competition hosted by WPI can provide.

2.1 About Worcester Polytechnic Institute

Worcester Polytechnic Institute, founded in 1865, was established to provide the masses with an exceptional science and engineering education. It was not until the late 1960's that WPI adapted its signature "Plan," combining both theory and practice. Doing this arms each student with the ability to carry a wide range of theoretical knowledge mixed with industry experience [11]. WPI's curriculum structure is designed to foster teamwork rather than harbor competition. Part of this is WPI's innovative robotics engineering program which began in 2007 and was the first of its kind [1].

2.2 About WPI's Robotics Engineering Program

The robotics engineering program began in 2007, offering just two courses. Now it has grown to include more than twenty courses, combining the disciplines of computer science, electrical and computer engineering, and mechanical engineering. It awarded its four bachelor's degrees in 2009 to students who had switched majors into the program. In 2016 the program awarded 75 undergraduate degrees in Robotics Engineering, adding to the total 391 bachelor's degrees awarded to date. In recent years the program has also expanded to the graduate level and awarded 56 Master's degrees and 2 PhDs this past academic year [1].

2.3 Previous and Existing Collegiate Robotics Competitions

The following section conveys research into the most relevant collegiate robotics competitions today, providing insights into the resources needed for a collegiate robotics competition, the potential impacts of such an event, and the potential benefits. This section also discusses the factors that can attribute to a collegiate robotics competition's success and provides the groundwork for later sections where we use this information to present a solution to the problems asserted in the introduction.

2.3.1 FIRST

The FIRST Robotics Competition (FRC) began in 1992 when 28 teams from around New England came together for the first FRC season. Since then FRC has seen tremendous growth and today has 3,357 teams in 24 countries with over 83,000 students [20]. Although it is a high school competition, it is worth mentioning as it is the largest robotics competition in the world [19].

FRC tasks high school teams to design and build robots in six and a half weeks to play a field game. The rules and game change every year but still fall within certain parameters, allowing teams to reuse base robots each year and only requiring designing and building specific components.

2.3.2 VEXU

The VEX Robotics Competition started in 2007 by Innovation First International to help promote their STEM education product line [2]. Compared to the already existing FIRST Robotics Competition that was also available to high school students, the robots were much smaller and the rules varied considerably. For example, for the FIRST Robotics Competition robots could be a maximum of 120 lb and individual parts could be sourced from multiple suppliers as long as each individual part did not exceed $400 in cost [3, 4]. This differed from the VEX Competition rules where there was not a weight limit and robots could not be a larger than an 18x18x18 inch cube at the start of the match only using VEX brand parts. This new competition found a home with many high school students as it was far less expensive than FIRST but more sophisticated than FIRST Lego League. Unlike FIRST, the participants in VEX were not limited to a six-week build season, allowing them to spend more time working on their robot designs and going to competitions.

After the VEX Robotics Competition's first year the program continued to grow. A new non-profit organization, RECF or the Robotics Education and Competition Foundation, was created in order to help organize competitive events. This allowed for the competition to expand to middle school and internationally, with more than 10,000 teams from more than 30 countries competing in the various programs.

Starting in 2014, the VEXU division was formed out of the existing VEX competition. This new division was created specifically for college and university students with rules nearly identical to the high school and middle-school level VEX competitions, but with greater customization and flexibility. Additionally, this competition offered teams the ability to work on real-world problems and engineer robotic solutions.

Through our research, we have identified these factors that contribute to the success of the VEXU Competition:

- Compared to most competitions the VEXU Competition is less expensive to participate in since most teams spend a maximum of $1000 per robot their first year.
  - Since the parts can be reused the cost of participating each year can decrease.
- The competition grows every year with more teams and qualifying events from around the world. For example in the upcoming 2017-2018 there will be a new VEXU qualifying event in Singapore.
- The field is small (12x12ft) and easy to set up it makes running events simple.

Through our research we have also identified the following drawbacks to the VEXU competition:

- Unlike the high school and middle school VEX competitions, VEXU allows for sensors supplied by outside vendors and 3D printed parts which allow for some creativity, but teams are still limited to VEX brand parts for mechanical and structural components which puts a cap on what is possible by teams.
- The dynamics of the VEXU competition are generally similar to that of a sports match and have less relation to solving real-world problems.

2.3.3 RoboMasters

The RoboMasters competition is one of the newest competitions we have researched, having only started in 2015 by DJI, a worldwide quadcopter company based out of China. For the first two years of the competition only Chinese universities could compete, but it was still a huge success, drawing in over 240 teams from more than 150 universities in its first year. Its rapid growth is largely due to DJI, who gave each team two kit-bots which was the minimum required to compete in the competition, lowering the barrier to entry [6]. The field is much larger (28x10 meters) than other robotics competitions and each team is able to field up to four robots and one quadcopter at a time. Another major difference with RoboMasters compared to most competitions is that each robot has a health bar and armor plates. If these armor plates are hit by the opposing teams pellets then the health of the robot can decrease and even disable it if the health of the robot is depleted. The structure of the competition makes its dynamic similar to that of an eSports event and brings in fairly large online audiences in the tens of thousands. Its international popularity has even produced a Japanese anime based on the competition.

Although the RoboMasters Competition is the newest we have researched, we consider it as one of the most successful for the following reasons:

- In its short run it has expanded from a Chinese National competition to an International Competition with more than 240 teams from more than than 10 countries. This shows the competition only continues to grow.
- DJI assistance through two free kit-bots and other various parts makes it easy for new teams to join RoboMasters.
- Its interesting competition structure and dynamic brings elements popularized in eSports to attract media attention.

Through our research we have also identified the following drawbacks to the RoboMasters Competition:

- RoboMasters Competition Events only occur in China which can make participation difficult for international teams.
- Besides the fully autonomous base-bot, the competition does not heavily focus on autonomous robots or real-world applications as part of the competition.
- Although DJI supports teams by supplying two kit-bots, most teams still spend upwards of $10,000 which can make participation in RoboMasters difficult for some organizations.

2.3.4 RoboCup

RoboCup is a non-profit organization led by a Board of Trustees, a President and Vice Presidents as well as a combination of committees designed to fill specific organizational needs. Robocup has hosted international robotics competitions annually since it was founded in 1997 [7]. RoboCup started as a competition for robots to play soccer against each other as a demonstration of artificial intelligence capabilities and to inspire innovation in the industry. Since then, it has evolved to include more advanced challenges such as search and rescue, open industrial challenges and humanoid assistant competitions.

It is clear that Robocup aims to promote innovation and research in artificial intelligence through five different levels of the competition: RoboCupSoccer, RoboCupRescue, Robocup@Home, RoboCupIndustrial and RoboCupJunior. Each league has a different target demographic allowing for RoboCup to draw in a larger audience from primary school students making dancing robots in the RoboCupJunior league to college students tackling research and industrial challenges. Within the RoboCupSoccer division there are further divisions: small, middle size, standard platform, humanoid, and simulation. This allows organizations that choose to compete in RoboCup divisions that fit with their resources and goals.

RoboCup also promotes innovation and research by providing a database of publications, presentations and research from leading scientific journals and conferences in artificial intelligence. Robocup currently indexes 277 research articles from 720 authors. This provides participants with accredited sources of information and research on which to base their designs and strategy. On their website they state that their database is “constantly updated and [they] estimate to reach about 1,000 papers” [7].

RoboCup also takes into consideration their public image via a “News” section on their website for the press. They hold databases of promotional newsletters, announcements, images and videos for public and press use in order to promote their brand. RoboCup also live-streams their events with commentary for international viewers that earn, on average, a few thousand views per stream [7].

Through our research we have identified the following factors for RoboCup’s success:

- RoboCup has developed many divisions of multiple levels and interests in order to make the competition available and appealing to a wide range of organizations.
- RoboCup events have been held annually since its inception in 1997 showing that the competition has been sustainable. It is also the longest running competition we researched.
- The competition has consistently had around 400 teams from over 40 countries over the course of the last decade.

Through our research we have identified the following the following drawbacks to the RoboCup competition:

- The RoboCupSoccer Competition does not change its rules often, making it possible for teams with successful designs to continue to achieve, while newer teams struggle to compete on the same level.

- Even RoboCupSoccer Small League requires a significant amount of resources to participate in. Many teams spend upwards of $10,000 for this division alone.

2.3.5 RoboNation

RoboNation is a robotics community founded by the Association for Unmanned Vehicle Systems International (AUVSI) that offers multiple educational competitions and programs [8]. Their mission is to allow middle school to graduate students to apply their STEM and robotics knowledge outside of the classroom through the various competitions they have to offer such as:

- **RoboSub** - Autonomous robotic submarines fully built by students must complete a difficult series of visual and acoustic-based tasks. These tasks simulate the work required of robotic subs in many facets of underwater activity [12]. In 2017 RoboSub saw significant participation at 44 registered teams [21].

- **RoboBoat** - Student teams design autonomous, robotic boats to navigate and race through an aquatic obstacle course. The behaviors demonstrated by these boats mimic tasks that are being developed for coastal surveillance, port security and other types of oceanographic operations [13].

- **Maritime RobotX Challenge** - This international competition is designed to evolve into a multi-platform competition that will include maritime, aerial and submersible tasks. Currently the competition is primarily focused on autonomous surface vehicle platforms and sensors [14].

- **The National SeaPerch Challenge** - A high school and middle school competition geared towards the construction and operation of remotely operated underwater vehicles to complete certain tasks. Most of these vehicles are actually constructed from kits as part of the educational program associated with the challenge [15].

- **IGVC (Intelligent Ground Vehicle Competition)** - For this competition undergraduate and graduate students compete to design, power,and construct an intelligent ground vehicle that can follow lanes, detect obstacles, and follow waypoint navigation [16].

- **SUAS (Student Unmanned Air Systems)** - Students research, design, integrate, and demonstrate an unmanned aerial system that is capable of autonomous flight and navigation, remote imaging and communication, and execution of a specific set of tasks. These tasks can include sensing, detecting, and avoiding obstacles [17].

- **IARC (International Aerial Robotics Competition)** - The longest-running collegiate aerial robotics challenge in the world, IARC advances autonomous aerial robotic behavior through competition. For IARC international teams must create fully autonomous flying robots that demonstrate behaviors never before demonstrated while completing missions with real world applications [18].

Each competition is held annually with the same technological focus, however they are given different objectives which allow teams to maintain similar designs from year to year. Each of the challenges mentioned have real world applications which holds relevance to the competitors and companies in the industry of that respective competition.

Based on our research we have identified feel the following reasons attribute to the success of RoboNation:

- RoboNation consists of multiple competitions which allow organizations to participate in the competitions that suit their interests.
- Since only the tasks/objectives change from year to year teams can use the same design for their robot every year. This also allows newer teams to draw inspiration from previous participating teams.
- All competitions have real world applications and are research based.

Through our research we have identified the following the following drawbacks to the RoboNation competitions:

- RoboNation as a whole has not grown as the number of teams competing in challenges has not increased in the last five years.
- Because of the scale and nature of the Maritime RobotX Challenge it happens every 2 years which is not ideal for many college organizations.

2.3.6 NASA Robotic Mining Competition

The NASA Robotic Mining Challenge began in 2009 as competition for undergraduate and graduate students to develop a mining robot designed to navigate and operate on the martian surface [9]. Since then the competition has been held annually at the Kennedy Science Center and has consistently hosted 45-50 teams.

Through our research we have found that the following factors can be attributed to the NASA Robotics Mining Competition's (RMC) success:

- The Robotics Mining Competition features both undergraduate and graduate level competitions.
- In its first year, RMC offered teams $5,000 need-based grants for travel expenses and supplies.
- Teams can win Judge's awards based on innovation and efficiency within their team and design [9].
- RMC maintains event-specific social media pages to promote their competition and draw in viewers.
- RMC live streams the events in order to reach a wide audience and potentially inspire other students to join.

Through our research we have also discovered the following drawbacks to the NASA Robotics Mining Challenge:

- The competition does not seem to have grown in size from year to year.
- Travel and material costs are high as teams are coming from around the country, making it difficult for lower budget colleges to enter.

2.3.7 SAE Collegiate Design Series

The SAE Collegiate Design Series is a set of college competitions held by the Society of Automotive Engineers. The competition is designed to provide participants with an opportunity to improve their engineering and project management skills outside of the classroom [10]. Students who participate have a chance to show their engineering skills to companies in the automotive industry, land internships and even earn scholarships. The most popular of these competitions are Formula SAE and Baja SAE.

- **Formula SAE** - For this competition, students are contracted by a fictional manufacturing company to develop a Formula-style race car. The cars are evaluated as a potential production item. The cars are targeted at non-professional weekend autocross racers. Each team is expected to design, build and test a prototype. Within the Formula Division, teams can choose to build various types of cars for different events. For example, teams have the option to build Combustion engine vehicles, electric vehicles, or hybrids and compete in the respective events for those divisions. The nature of the events can change from year to year, but the most consistent events include timed races and endurance races to test how long the vehicles can last [10].
- **Baja SAE** - Students are expected to build a single-seat off-road vehicle that will survive the harshness of rough terrain. All vehicles are powered by the same 10 HP engine from Briggs Stratton. The Baja competition is not as large as the Formula SAE competition, but it is able to draw a different crowd to SAE competitive events [10].

Through our research we have found that the following factors can be attributed to the success of the SAE Collegiate Design Series:

- Baja SAE gives each team an engine, allowing students to focus on the durability of the car as well as lowering the cost of entry.
- Event locations on both the east and west coast of the US as well as international events allow for more colleges to participate.

Through our research we have also discovered the following drawbacks to the SAE Collegiate Design Series:

- Due to the nature of automotive engineering, the cost of entry is very high, making it difficult for colleges with lower budgets to join.

- The space required for this event makes it one of the hardest logistically to hold of the competitions we have researched.
- Since teams work with car sized vehicles it can also be difficult to travel to competitive events with all of the ideal equipment needed to maintain their vehicles.

3 Methodology

This sections outlines the methodology used to complete this IQP. Each of these steps cover a specific area in the development of a robot competition to be hosted at WPI.

3.1 Background Research

As part of our development process we spent much of our time researching previous and existing collegiate robotics competitions. This research allowed us to better understand several key topics:

- The resources necessary to execute a collegiate robotics competition.
- What makes collegiate robotics competitions appealing to participants and sponsors.
- The benefits of a collegiate robotics competition for the host.
- The potential impact a collegiate robotics robotics competition hosted by WPI.
- The factors that attribute to successful and sustainable collegiate robotics competitions.

The background research on various collegiate robotics competitions can be found in section 2.3 of this report.

3.2 Interview and Discussions

In order to develop a successful and sustainable collegiate robotics competition at WPI it is important to have discussions with parties that would be involved in the event. These parties include WPI stakeholders, potential participants from other universities, and potential sponsors.

3.2.1 WPI Stakeholders

Before work began on designing a robotics competition to be held at WPI, interviews were conducted of key stakeholders at the school who would be instrumental in making it a reality. The main stakeholders would be those who would have direct involvement in running the competition and those who would benefit from the exposure. These stakeholders would be directly involved in the execution of the event:

- The Robotics Engineering Program
- The Robotics Resource Center
- Corporate Engagement
- TouchTomorrow

The stakeholders that would potentially benefit from the event would be:

- Admissions
- Marketing
- Pre-Collegiate Outreach
- TouchTomorrow

3.2.1.1 WPI Robotics Engineering Program

The Robotics Engineering Program is the most obvious benefactor and stakeholder of a collegiate robotics competition at WPI. The Robotics Engineering program faculty had valuable insight on hosting such a collegiate robotics competition and on which key individuals we should be speaking with.

3.2.1.2 WPI Robotics Resource Center

The Robotics Resource Center at WPI is responsible for running every competitive robotics event on campus such as FIRST Robotics Competitions and formerly the NASA Centennial Challenge. Their relevance to such events makes them a primary stakeholders for our proposed event, so it was critical for us to have discussions with them.

The Robotics Engineering Program would also have direct involvement in the event as they could serve as a source of funding and volunteers in the form of students and professors. The Robotics Resource Center and TouchTomorrow would be the primary organizer of the event and as such is a primary stakeholder.

3.2.1.3 WPI Admissions Office

The nature of the WPI Admissions Office is to review students and admit them into WPI, so we decided to meet with them as we felt they had relevant information pertaining to student statistics and interests.

3.2.1.4 WPI Office of Pre-Collegiate Outreach

Another benefactor of a robotics competition held at WPI would be Pre-Collegiate Outreach. Pre-Collegiate Outreach designs programs for middle school and high school students designed to help them explore the STEM field and to ultimately get them inspired to choose WPI when it's time to apply to colleges.

3.2.1.5 WPI Office of Corporate Engagement

It was very important to have a discussion with the Office of Corporate Relations as they are the point of contact for many WPI benefactors and they should have a relevant opinion on the subject of our IQP.

3.2.2 Potential Participants

A competition is not a competition without participants, which is why we conducted interviews with representatives from 18 universities in order to better understand their interests. We wanted to find out what they would want to get out of a robotics competition as well as how to make the competition as inclusive as possible. When finding interviewees from each university we made sure they were representatives of a relevant STEM organization or involved in STEM related activities on campus. Because of this, the representatives we interviewed had a deep understanding of the resources available to students at their university and a relevant opinion on the kind of robotics competition their university would be interested in participating in.

While developing our competition we wanted to both make it interesting to peer institutions with a reputation in robotics as well as universities that are new to the field. In order to gain diverse range of opinions on the subject we planned to contact and interview representatives from the following universities in relevant STEM organizations:

Table 3.1: University statistics

University	**Location**	**Undergraduate Student Population**	**Graduate Student Population**	**Known Robotics/STEM Organizations**
Massachusetts Institute of Technology	Cambridge, Massachusetts	4,524 in 2017	6,852 in 2017	MITERS Makerspace, Combat Robotics Team, SAE Electric Vehicle Team, and Solar Vehicle Team
Harvard University	Cambridge, Massachusetts	6,700 in 2014	14,500 in 2014	RoboCup Small League Team
Olin College	Needham, Massachusetts	350 in 2016	N/A, 0 Graduate Students	SAE Electric Vehicle Team, Robotics Sailing Team, and Human Powered Vehicles Team
Stanford University	Stanford, California	7,032 in 2017	9,304 in 2017	Solar Vehicle Team
Duke University	Durham, North Carolina	6,649 in 2016	8,383 in 2016	Robotics Organization, Amazon Robotics, Challenge Team, and Robocup Small League Team
Rice University	Houston, Texas	3,879 in 2015	2,744 in 2015	VEXU Team and Solar Vehicle Team

University of Pennsylvania	Philadelphia, Pennsylvania	10,406 in 2015	11,157 in 2015	Combat Robotics Team
University of Alabama	Tuscaloosa, Alabama	32,563 in 2015	5,100 in 2015	Regolith Team and Sample Return Challenge Team
Purdue University	West Lafayette, Indiana	30,043 in 2016	10,408 in 2016	VEXU Team
California State Polytechnic University	Pomona, California	23,731 in 2016	1,595 in 2016	VEXU Team, Formula SAE Team, Electric Baja Team, and Design, Build, Fly Team
Colorado School of Mines	Golden, Colorado	4,533 in 2016	1,261 in 2016	Formula SAE Team, SAE Baja Team, and Robotics Club
University of Texas at Austin	Austin, Texas	39,619 in 2015	11,331 in 2015	Student Robotics Organization, Design, Build, Fly Team, Rocketry Club, Formula SAE Combustion Team, Formula SAE Electric Team, Solar Vehicle Team, and VEXU
University of Texas at Dallas	Richardson, Texas	17,350 in 2016	9,433 in 2016	VEXU Team and Comets Makerspace
University of Houston	Houston, Texas	34,830 in 2016	7,874 in 2016	VEXU Team

When interviewing each of these universities we asked the following questions to gain a better understanding of the interests of potential participants and to help identify what types of competitions WPI could ultimately host:

- What is the member size of your organization?
- What is the annual budget of your organization?
- Does your organization have membership fees?
- Is competition travel covered by your school?
- Do students have access to fabrication resources? If yes, what kind?

- What is your ideal frequency for the competition? (Annually, every 2 years, etc.)
- How often do you feel the rules should change?
- What is your ideal date for a competition to take place?
- Do you prefer an indoor or outdoor challenge?
- Should there be robot to robot interaction?
- Should there be a multi-robot aspect to the competition?
- If you answered yes, how many robots should there be?
- If you answered yes to a multi-robot competition then should those robots be different?
- Should there be any legged robots?
- Should there be any underwater robots?
- Should robots be fully autonomous or should there be an autonomous portion to the challenge?
- If you answered yes to a multi-robot competition then how many robots should be fully autonomous?
- Should there be alliances?

3.2.3 Potential Sponsors

Another important aspect of developing a collegiate robotics competition at WPI is contacting potential sponsors for the event. Through discussions with sponsors we gained an understanding of how to make our competition appealing to potential sponsors, how to form relationships, and eventually partnerships with them.

Throughout the course of the IQP we contacted the following companies in order to understand what should be included in our event to properly incentivize sponsors:

- iRobot
- Uber ATG
- Symbotic
- MASSrobotics
- New Stone Soup, LLC

3.3 Development and Drafting

Through our research, we developed a proposal and plan of action for a collegiate robotics competition hosted by WPI. We have developed severial documents for this IQP: this report, which contains our findings as well as conclusions on them, a rules handbook, targeted towards potential participants and includes details on each competition and a tentative schedule, and a logistics document, which contains details on the resources necessary to host this event.

In developing a proposal for this event we have identified several main decision and development points:

- Potential event dates
- Potential competition locations
- Proposed event schedule
- Logistics plan
- Sponsorship packages
- Proposed competitions
- Selected competitions

As part of this report we provide details for each of these points.

4 Findings

The following section describes the results of executing the methodology outlined in section three of this report. It begins with an overview of our discussions with WPI, potential participants, and potential sponsors. It then concludes with our work on a proposal for a collegiate robotics competition to be hosted by WPI.

4.1 Discussions and Information Gathering

This section summarizes the information gathered over the course of the IQP. It begins with details on discussions with WPI stakeholders, continues with details on discussions with potential participants, and concludes with details on discussions with potential sponsors.

4.1.1 Discussions with WPI Stakeholders

Before work began on designing a robotics competition to be held at WPI, interviews and discussions with key stakeholders at the school were conducted to identify event requirements. These stakeholders are the people and offices who would be directly involved in running the event and those who would need to give approval for it.

4.1.1.1 Robotics Engineering Program

Over the course of this IQP we had many discussions with key figures of WPI's robotics engineering program. Many of these discussions were with two of our advisors for this IQP, Professors Nicholas Bertozzi and Brad Miller during weekly meetings and outside discussions. They consistently provided valuable insight due to their knowledge of the industry and experience with mentoring competitive robotics teams. The competitive robotics teams they have mentored have participated in competitions such as the FIRST Robotics Competition and the VEX Robotics Competition. Because of their experience and position as robotics faculty, our frequent discussions with them were extremely helpful in drafting the competition. These discussions also kept the project on track by ensuring that the vision of the competition stayed in the best interest of all parties involved.

We also had several productive and insightful discussions with Professor David Cyganski, the interim director of WPI's robotics engineering program. Professor Cyganski had been involved with the program since its inception and had a good understanding of how to represent the WPI Robotics Program well. Professor Cyganski advised that cost would be a huge consideration when attempting to execute our event and that it would be best to couple the event with a large existing WPI event such as TouchTomorrow. This would prove advantageous as both events could enhance each other in a variety of ways if hosted in conjunction. He added that with since the NASA Sample Return Challenge has ended and is no longer a part of TouchTomorrow, adding a new competitive robotics event could be of benefit for all parties involved.

Professor Cyganski received the idea of having a collegiate robotics olympics with multiple events positively. Of his major opinions on the dynamic of the event was that he felt that we should stray from having events such as combat robotics if we wanted all events to be academic, but he did admit having those as one of the events had the potential of bringing a maker and hobbyist type of crowd. Professor Cyganski felt that having events that were directly related to real world applications would represent WPI well. Some examples of these events would include a legged robotics challenge, an underwater robotics challenge, and an item sorting challenge. He made it clear that if we were to have events like that there proper planning was necessary in order to make it feasible for an event like that to be executed successfully. The events would also have to be designed to be as accessible to other universities as possible, but should also remain fair to all potential participants. His concern was that if undergraduate, graduate, and PhD students were allowed to compete in this competition then undergraduate students might be at a disadvantage. This is because some graduate or PhD students may have developed technology associated with a certain event over the course of several years. His last major point in these discussions was that it would be of high interest to WPI to market this sort of event to peer U.S institutions in order to draw more domestic students into WPI's graduate programs.

4.1.1.2 Robotics Resource Center

Over the course of our IQP we had many discussions with Colleen Shaver, the Associate Director of the Robotics Resource Center and one of the advisors for our IQP. As the Associate Director of the Robotics Resource Center, Colleen is in charge of the planning and execution of many large robotics competitions hosted on WPI campus. Such robotics competitions include one of the FIRST Lego League Championships, an Annual FIRST Robotics District Event, BattleCry, and the NASA Sample Return Challenge. Throughout the IQP her knowledge and experience on running robotics events on WPI campus proved to be extremely valuable in reaching our goals for this IQP. She consistently gave valuable insights and feedback on the information we gathered and the competition proposal could not have been drafted without her.

4.1.1.3 WPI Admissions Office

As a benefactor of the potential outreach, admissions materials created in the form of pictures and videos, and the increased attention given to WPI from any robotics competition held, admissions was an important stakeholder in the event. We met with Ashley Johnson and Katie Phung, both Assistant Directors of Admissions. Ashley specializes in robotics applicants and Katie specializes in minority outreach.

During the meeting, various strategies were discussed on what what interests potential high school applicants when it comes to robotics. Due to the complicated and visual nature of the subject, videos were brought up as being an important tool. They allow high schoolers to get excited when they see it for themselves. They saw a robotics competition held at WPI as a great way of generating content for these videos as well as a mechanism for outreach to potential domestic graduate students. They mentioned that the admissions office in general would love a spectator element combined with interactive parts for potential high school applicants.

4.1.1.4 WPI Office of Corporate Engagement

Our main discussions with the Office of Corporate Relations were with Rachel Leblanc, the Vice President of Corporate Engagement. As mentioned in section 3.2.1.5, we thought it was very important to meet with this office as they are the point of contact to many of the companies and organizations associated with WPI. Rachel Leblanc also sits on the New England Board of the Association for Unmanned Vehicle Systems International (AUVSI). AUVSI is an entity that heavily supports the advancement of robotic technologies and hosts several robotics competitions and conferences. Similar to David Cyganski, Rachel felt that AUVSI and other potential sponsors would be heavily interested in a robotics competition hosted at WPI. A robotics competition with different focused events would have the potential of drawing in specific sponsors for each event. For example Bluefin Robotics, an underwater drone company, may be interested in sponsoring an underwater drone challenge. Hosting challenges with real world applications would provide WPI with a good amount of peer to peer recognition with similar universities.

Overall, our discussions with Rachel proved productive in connecting with potential sponsors for our event and she felt that at a high level our proposed event was executable and would provide many benefits for all parties involved.

4.1.1.5 WPI Office of Pre-Collegiate Outreach

Discussions primarily took place with Sue Sontgerath who guided us through the three main avenues in place to direct middle school and high school students towards the school:

- Through parents
- Through educators
- Direct contact with students

In general the first two were far more effective than the third for off-campus outreach. She stressed that using "multiple touchpoints" is important because it brings pre-collegiate students to the campus and WPI-hosted events as often as possible so that they associate the the school with college when it comes time for them to apply. The event TouchTomorrow is one of the largest examples of this. The event brings thousands of students, as young as 10, from around New England to the campus and gets them introduced to the school and the types of things undergraduates get to do.

Discussions also circulated around female inclusion in the event and the types of things that work for that. Sue mentioned that most of the research surrounding this says that women have heavy interest in helping and improving people's lives.

4.1.2 Discussions with Potential Participants

Through our efforts we were able to interview 20 student representatives from 18 universities, including the ones we originally planned to interview listed in section 3.2.2. During these interviews we made sure to answer similar questions in order to produce metrics that would simplify drawing conclusions. The following universities were interviewed:

- Massachusetts Institute of Technology
- Harvard University
- Olin College
- Stanford University
- Duke University
- Rice University
- University of Pennsylvania
- Pennsylvania State University
- Purdue University
- California State Polytechnic University
- Colorado School of Mines
- Southern Methodist University
- University of Texas at Austin
- University of Texas at Dallas
- Texas AM
- University of Houston
- University of Alabama
- University of Auckland

The gain a better understanding of the resources available to students at each university we asked representatives the following questions:

Table 4.1: Potential participant university statistics

Question	**Response Summary**
What is the member size of your organization?	The average membership size was 21.625 members.
What is the annual budget of your organization?	The average annual budget was $18,895.
Does your organization have membership fees?	Only two of the 18 universities interviewed had membership fees. These were both for VEXU and at UT Austin and UT Dallas.
Is competition travel covered by your school?	Responses ranged from "no" to "sometimes" with 25% of the answers being the latter.

Do students have access to fabrication resources? If yes, what kind?	Most universities have access to fabrication resources. These range from small makerspaces to full-fledged machine shops. Only 25% of the universities interviewed do not have access.

Since these representatives would be potential participants of our competitive event we felt it was important to ask their opinions on how the competition should be structured. The questions we asked every representative and a summary of those question responses can be found in the table below:

Table 4.2: Potential participant opinions

Question	**Response Summary**
What is your ideal frequency for the competition? (Annually, every 2 years, etc.)	All interviewed representatives preferred annual frequency. This is because students are only in college program for four years so an annual competition would keep students engaged in the competition.
How often do you feel the rules should change?	Every representative felt that the rules of the competition should change annually in order to keep the competition interesting and engaging.
What is your ideal date for a competition to take place?	All representatives felt a date during the summer would be the best timing. Most had a preference for the beginning of the summer(Late May/Early June)
Do you prefer an indoor or outdoor challenge?	All representatives felt that an indoor competition was preferable. Some felt that an outdoor competition is interesting, but did not like that it would be reliant on the weather.
Should there be robot to robot interaction?	With the exception of a few representatives, most felt that robot to robot interaction should be a part of the competition.
Should there be a multi-robot aspect to the competition?	About 80% of representatives felt that there should be a multi-robot aspect to the competition.
If you answered yes, how many robots should there be?	About 87% of representatives felt that 3 robots would be a good number to a multi-robot competitions. The other 13% felt fewer or more robots was ideal.
If you answered yes to a multi-robot competition then should those robots be different?	All representatives that felt there should be a multi-robot competition said that the robots should be different types.
Should there be any legged robots?	About 67% of representatives were interested in seeing a legged robot competition.
Should there be any underwater robots?	All representatives were interested in an underwater robotics challenge.

Should robots be fully autonomous or should there be an autonomous portion to the challenge?	About 75% of representatives felt that there should be an autonomous portion of the challenge rather than fully autonomous robots.
If you answered yes to a multi-robot competition then how many robots should be fully autonomous?	About 60% of representatives who were interested in a fully autonomous robot thought all robots should be autonomous while 40% felt only at least one robot should be autonomous.
Should there be alliances?	Only about 21% of representatives were interested in a competition with alliances. Most felt that if there were alliances in the competitions it should not be multi-robot.

The full interviews of each representative(including representative details) can be found in the Appendix section of this report.

Based on the interviews we have made several conclusions that are fully outlined in the section 4.2 of the report. These representative interviews were extremely helpful in understanding the capabilities of most universities and how to design the competition in a way that will attract competitors and satisfy their interests.

4.1.3 Discussions with Potential Sponsors

Over the course of our IQP we attempted to contact all the companies and organizations we listed in section 3.2.3. We were not able to establish communication with all of these groups, but the following section outline the discussions we had with the groups we were able to properly contact.

4.1.3.1 Uber ATG

One of the potential sponsors we were able to contact was the Uber Advanced Technologies Group. Uber ATG is the autonomous vehicle development division of Uber, based out of Pittsburgh, Pennsylvania. Because of their mission to advance autonomous vehicle technology we felt it was important to contact them about potentially sponsoring our event. We were able to contact Alan Nuttle, a senior engineer at Uber ATG. Allan had previous experience partnering with the FIRST Robotics Competition and was heavily interested in the prospect of sponsoring a collegiate robotics event. We felt that it would be best if Uber was a title sponsor for an autonomous navigation challenge and Alan agreed. Uber would be interested in sponsoring a specific event and providing volunteers support in the form of judges.

4.1.3.2 iRobot

We were able to reach out to Lisa Freed, a public relations representative from iRobot. Through our communications with Lisa we discovered that iRobot does not sponsor competitive events monetarily. According to Lisa, iRobot is focused more on participants rather than the actual competition. If they were to assist in a competition at WPI they would provide volunteers that would mentor or judge competitors of the competition. iRobot feels that as long as the competition is giving students the opportunity to find their passion, be it building, coding, team leadership or some other area of the STEM fields, it would be of value to them. One last way iRobot might participate in our event that Lisa mentioned would be by having a booth in an exhibition area for recruiting purposes.

4.1.3.3 MASSrobotics

MASSrobotics is a robotics startup accelerator in the Boston Seaport District that was founded less than two years ago. Despite being so young, MASSrobotics has made a large impact in the robotics community and has more than a dozen different robotics companies residing in their offices. Because of their nature we felt that it was important to talk with them and the companies they house as these parties could be potential sponsors of our event. Most of our communications were with Joyce Sidopoulos, one of the directors of MASSrobotics, mainly in charge of their community programs. As a parent, Joyce was interested in the prospect of a competition that would be in collaboration of TouchTomorrow and felt that the timing of the competition would be ideal for many. As an organization MASSrobotics would be interested in having exhibition space for their multiple companies and providing judges for the event. Joyce also gave helpful competition design suggestions such as gearing an underwater robotics challenge towards aquaculture, a challenge their company Hydroswarm is trying to tackle. One of MASSrobotics's residents is American Robotics, an agriculture robotics company that utilizes drones to actively track crops. Joyce brought up the idea of this event to them and they were interested in seeing an outdoor autonomous drone challenge that utilized computer vision to actively track some sort of target.

4.1.3.4 Rita Vasquez Torres

Over the course of this IQP, we had several discussions with Rita Vasquez Torres, CEO of engineering consulting company, New Stone Soup. Rita's background and experience provided a lot of insight while developing our competition. Since Rita had partnered with the army and research institutions such as Natick Labs on many occasions she was confident that our intent to have competitive events with real world applications was the best approach. Overall she was satisfied with the initial proposal for our event and felt it would be successful, but she wanted our event to emphasize more than the technical aspect of things. In her experience she felt that many bright engineers she had worked with lacked fundamental non-technical skills that are just as important as technical ones. She felt that it was important to foster a business and entrepreneurial mindset in engineers so she suggested adding an entrepreneurial aspect to our event. This event should emphasize real technology rules and regulations currently set in place so that students will understand how to properly bring technology to market and how to commercialize it.

4.1.3.5 Symbotic, LLC

Symbotic, LLC is a warehouse robotics company based in Wilmington, MA. As of Fall 2017, this company started a small collegiate competition of their own. This competition is structured to be more like an engineering project, but has increased their interest in working with universities for future competitions. To discuss this topic we met with Maggie Weeks, Symbotic's Marketing Communications Specialist, and Taylor Smith, one of Symbotic's Corporate Recruiters. Through this discussion, we learned that Symbotic would be interested in sponsoring a robotics competition of any kind and that they would most likely be available to provide both monetary and volunteer support, but more specific details about the final event will be required. If Symbotic were to sponsor an event they would like for the event to focus on engineering undergraduate students and for students to have opportunities to develop mechanical engineering, hardware engineering, and software engineering skills. From a recruiting standpoint they see it as an opportunity to groom potential employees and see what those potential employees have to offer. From a marketing standpoint they simply feel that by being involved it would be a good opportunity, especially since Symbotic is starting to become more public.

4.2 Competition Development

Through our information gathering and discussions with stakeholders at the school, potential sponsors, and participants we developed a proposal for a robotics competition to be held at WPI. This section outlines this proposal and includes:

- Potential dates
- Potential locations
- A proposed schedule
- General logistics requirements
- Sponsorship
- Initially proposed challenges

This section ends with a decision matrix to determine which proposed challenges should be hosted in the first year of the event.

4.2.1 Potential Dates

Choosing a potential date for a robotics competition hosted at WPI was challenging as there are a lot of factors to take into account. First, the school year for WPI goes from April 24th to May 1st, with commencement on the 12th. Any event in the summer would need to happen after this date as the whole campus is reserved to that event. Additional factors include the dates that participating colleges adjourn for the summer and students start internships. Internships typically start at the beginning of June and go until mid August.

Through talking with potential participants and WPI stakeholders we concluded that the ideal date for the competition would be late May to early June with the event starting Friday morning and ending Saturday evening. This would make the event accessible to participants with internships, even by those traveling from outside of New England, as it would allow them to take Thursday and Friday off and return on Sunday.

Late May to early June is also ideal for WPI as it would be after commencement and the quad would no longer be in use. After we determined this time frame was the ideal date, we realized that having an event in conjunction would TouchTomorrow would be ideal as it typically takes place in early June and was originally created to be hosted in collaboration with NASA's Centennial Challenge in 2012 and still has a strong theme of robotics even now that the challenge is over.

4.2.2 Potential Locations

If this competition were to be in collaboration with TouchTomorrow then the following locations that would be available for use:

- Harrington Auditorium
- Recreation Center Robot Pits
- Recreation Center Swimming Pool
- Riley Commons
- WPI Football Field
- WPI Rooftop Field
- Institute Park

We had discussions with Meredith Merchant, the Assistant Recreation Director and Facilities Director, to determine if use of facilities, such as the swimming pool in the recreation center, for a competitive robotics event would be possible. Meredith was open to the idea as long as the Varsity Swimming Coach approved as well.

Institute Park would also be available for the event. For example, the NASA Centennial Challenge was held there and the entire park was fenced off. In order to organize this, the Worcester Parks and Recreation Center would need to be contacted in order to make sure that the park was available for our desired event dates. The fees associated with renting the park were fairly low and the it would be possible to fence it off.

4.2.3 Proposed Competition Schedule

Through discussions with potential sponsors, participants, and WPI stakeholders we gathered information on what should be included in a robotics competition schedule. We also determined that this event would be executed best if it occurred over the course of two days to provide enough time to execute everything that should occur in such an event.In this schedule there are several important parts that differ from most collegiate robotics competitions. First, we decided it was important to include networking events for participants. These events would be an opportunity for college students studying engineering with experience in robotics to gain connections within industry. These connections would be especially helpful for rising seniors when seeking out jobs during the coming school year. Second, there will be keynote speakers at the provided lunches. These speakers will be experts from industry discussing a relevant topic in the field of robotics. The following is our proposed schedule:

Table 4.3: Thursday schedule

Time	**Activity**	**Location**
5:00 PM	Early Team Check-In & Equipment Drop-Off *Note: Practice Fields will be open until venues close	Harrington Auditorium
7:00 PM	Team and Volunteer Networking Dinner	The Odeum
8:30 PM	Venues Close *Note: that you will not be able to have access to the event venue overnight so please do not leave anything you might need when the venue closes*	

Table 4.4: Friday schedule

Time	**Activity**	**Location**
8:00 AM	Opening Ceremonies	Harrington Auditorium or WPI Football Field *Rain Location is Harrington Auditorium*
9:00 AM	Practice Fields Open and Open Q&A with Judges	See Competition Logistics section for field locations
10:00 AM	Challenge Events Begin	See Competition Logistics section for field locations
12:00 PM	Lunch Break *Events will be closed from 12:00PM-1:00PM. Teams will have an opportunity to practice.* There will be a keynote speaker for lunch in the Odeum.	Odeum
1:00 PM	Challenge Events Resume	See Competition Logistics section for field locations
2:00 PM	Project Poster Judging Begins	Robot Pits in Sports and Recreation Center
6:00 PM	Challenge Events Suspended *Note: Challenge Fields will be open for practice until closing. This is with the exception of Institute Park.	See Competition Logistics section for field locations

8:30 PM	Venues Close *Note: that you will not be able to have access to the event venue overnight so please do not leave anything you might need when the venue closes*	

Table 4.5: Saturday schedule (TouchTomorrow)

Time	**Activity**	**Location**
8:00 AM	Opening Ceremonies	Harrington Auditorium or WPI Football Field *Rain Location is Harrington Auditorium*
9:00 AM	Practice Fields Open and Open Q&A with Judges	See Competition Logistics section for field locations
10:00 AM	Challenge Events Resume	See Competition Logistics section for field locations
12:00 PM	Lunch Break *Events will be closed from 12:00PM-1:00PM. Teams will have an opportunity to practice. * There will be a keynote speaker for lunch in the Odeum.	Higgins House
1:00 PM	Challenge Events Finals	See Competition Logistics section for field locations
2:00 PM	Project Poster Judging Closes *Note: Any remaining poster judging will be carried starting at 10:00AM	Robot Pits in Sports and Recreation Center
5:00 PM	Challenge Event Finals End *Note: Challenge Fields will be open for practice until closing. This is with the exception of Institute Park.	See Competition Logistics section for field locations
6:00 PM	Closing Ceremonies Begin	Harrington Auditorium or WPI Football Field *Rain Location is Harrington Auditorium*

4.2.4 General Logistics Requirements

Behind every successful event lies extensive organizational planning. We decided to create a logistical plan to outline where, when and how the events would be run in conjunction with TouchTomorrow. We first identified the required resources to run this competition:

- Volunteers
- Event space
- Event materials
- Audio and video

The competition will require a wide variety of volunteers to operate smoothly. Each challenge will follow the same volunteer structure. The volunteer structure outlines the expected tasks for each position and is as follows:

- **Standard Volunteers**
  - **Misc.** - Volunteer Positions that are to be determined to help with event flow.
  - **A/V Crew** - In charge of lighting and audio/video for challenge venues and would be provided by LNL (WPI's A/V club).
  - **Challenge Reset** - Assists in challenge venue maintenance.
  - **Queuing** - Maintains time flow of each challenge by directing teams to necessary destinations.
  - **Referee** - Assists in upholding event challenge rules.
  - **Challenge Admin** - Who teams check-in to and an informational guide for the event.
- **Judges**
  - **Robot/Safety Inspector** - Inspects robots and confirms if they comply to event/challenge standards, makes sure that event is up to safety standards, and able to restrict teams from competing if they are in violation of safety standards.
  - **Technical Judge** - Scores posters and the designs of team's robots and evaluates robot performance.
  - **Scoring Judge** - Maintains scoring of challenges.
- **Key Volunteers**
  - **Head Referee** - Oversees all the referees for all challenges.
  - **Head Inspector** - Oversees all the inspectors for all challenges.
  - **Head Judge** - Oversees all technical judging for all challenges.
  - **Emcee** - Master of ceremonies and narrator of challenges.
  - **Field Supervisor** - In charge of field maintenance.
  - **Volunteer Coordinator** - Organizes and oversees volunteers for a challenge.
  - **Challenge Coordinator** - Also organizes and oversees volunteers for a challenge.

The majority of the potential sponsors we contacted expressed intent to provide volunteers to help run the event. Between our sponsors as well as volunteers from the WPI volunteers we anticipate to have enough sponsors to staff our selected challenges.

One of the most important resources required would be funding. The main costs for running the event would be materials for field construction as well as audio and video production for the event. All of the fields will be constructed out of basic materials such as cardboard and plywood. Below are the materials costs for the selected challenges:

- **Indoor Drone Challenge** - $1,000
- **Warehouse Swarm Challenge** - $1,000
- **Miniature Fire Fighting Challenge** - $1,500

Audio and video production will be provided by the student run club, Lens and Lights (LNL). They have provided price estimates for each challenge location:

- **Harrington Auditorium** - $3,500
- **Riley Commons** - $500
- **Robot Pits** - $200

Based on our positive feedback from potential sponsors, we believe that we can generate the funds needed solely through sponsorship. This would allow the event to be cost neutral to the school.

4.2.5 Sponsorship

In order to host a successful event it is vital to recruit sponsors that can provide resources that will enhance the event. Sponsors can provide support in the form of both monetary and volunteer capacities. Therefore, in order to entice sponsors of different sizes we developed sponsorship tiers based on what a sponsor provides for the event. These tiers were developed in collaboration with Colleen Shaver, one of our IQP advisors. A sponsor is considered within a sponsorship tier if they provide at least one of the bullets under the following sponsorship tiers:

- **Standard**
  - Donation of $1,000
  - 10 standard volunteers provided
  - 5 judges provided
  - 2 key volunteers provided
- **Bronze**
  - Donation of $2,500
  - 20 standard volunteers provided
  - 10 judges provided
  - 5 key volunteers provided
- **Silver**
  - Donation of $5,000
  - 25 standard volunteers provided

  - 15 judges provided
  - 10 key volunteers provided

- **Gold**
  - Donation of $10,000

- **Platinum**
  - Donation of $20,000

In order to incentivize potential sponsors we developed a benefits matrix based on the sponsorship tiers. This benefits matrix outlines what we felt was appropriate to provide sponsors based on what they provided to the competition:

Table 4.6: Sponsorship benefits matrix

Description	**Standard**	**Bronze**	**Silver**	**Gold**	**Platinum**
Admittance to Stakeholders Dinner in Odeum (Up to 4 Organization Members)					
Name/Logo on Event Website (Will State Level of Sponsorship on Website)					
Name/Logo on Event Banners and Handouts					
Reserved 10x10ft Exhibition Space					
Name/Logo on For-Sale Event T-Shirts					
Name/Logo on all Event T-Shirts (Including Volunteer Shirts)					
Option for Larger Exhibition Space					
Specific Challenge Named After Sponsor (Ex. Redbull Aquaculture Challenge)					

Organize Custom Challenge *See Later Section for more details*					

4.2.6 Proposed Challenges

Through discussions with potential participants we learned several key things about what types of competitions they were interested in. First, we learned that different schools with were interested in different types of competitions of varying sizes. Because of this, we decided that instead of designing one specific robotics competition we would propose designing and hosting multiple. That way, universities with different interests and resources could choose which events they would want to compete in and still participate in the event as a whole. This would also allow us to ask potential contributors to sponsor a specific event relevant to them. For example, Symbotic, a warehouse automation company, could sponsor an item sorting challenge and could be entitled the “Symbotic Item Sorting Challenge”. Another important item we learned was that both potential participants and sponsors were interested in competitions based on real-world problems. They felt that working on solutions to these would provide students with relevant experience and make it easier to get sponsors.

Taking all of what we learned into consideration we went back to potential participants and sponsors with numerous ideas for competitions and asked for their opinions. The following is list of the competitions that stood out:

- Underwater robotics challenge
- All-terrain robotics challenge
- Item-sorting challenge
- Indoor drone challenge
- Fire Fighting challenge
- Autonomous vehicle challenge
- Warehouse swarm robotics challenge

Each of these competitions are based on current real-world problems that sponsors we have been in contact with are currently working on.

4.2.6.1 Underwater Robotics Challenge

With the increasing demand for fish and the reduction of fish populations around the world, the aquaculture industry has grown to account for half of the world’s seafood. Despite its large success, the aquaculture industry still face many problems today.

For coastal aquaculture farms, nets require constant inspection as they have a tendency to break, causing thousands of fish, often non-indigenous, to escape into local waters. This causes both substantial losses to the farm and untold ecological problems. Every aquaculture farm also faces the problem of diseased fish. Since there are no current systems to identify and separate diseased populations, farms have suffered heavy losses.

This challenge was created in order to foster the development of technologies that solve these problems as well as create a competition for universities interested in underwater robotics. Teams are tasked with building a robot to autonomously find and identify items underwater. These items could be waste or escaped fish. Robots could also be tasked with finding tears in a fish farm net. Specific details on this challenge can be found in the rules handbook.

4.2.6.2 All-Terrain Robotics Challenge

For this challenge, teams must build robots that are capable of traversing a variety of terrain. This is meant to simulate real life exploration and navigation problems as well as foster technology geared for disaster relief. Points will be rewarded based on how far each robot travels. Robots will not be required to complete each terrain track, but an additional bonus will be awarded. There will also be an additional assessment task conducted by each robot. Specific details on this challenge can be found in the rules handbook.

4.2.6.3 Item Sorting Challenge

To accommodate the growth of ecommerce and demand for more efficient sorting and distribution, warehouse automation has grown to be one of the largest industries in the world. With the advancement of automated technologies it only continues to grow. For this challenge teams must build and design robots that will be able to pick and sort different objects that might be found in a typical warehouse such as boxes and containers. Specific details on this challenge can be found in the rules handbook.

4.2.6.4 Miniature Fire Fighting Challenge

Fire fighting is one one of the most dangerous professions today. In order to foster the development of technology that can complete fire-fighting tasks without a human individual, this challenge was created. For this challenge teams must construct robots that autonomously navigate an "indoor maze" and extinguish a candle that is somewhere in the arena. The rules for this challenge drew inspiration from the Trinity Firefighting Challenge and specific details on these rules can be found in the rules handbook.

4.2.6.5 Autonomous Vehicle Challenge

Due to recent advancements, the autonomous vehicle industry is currently experiencing rapid growth and as such the demand for engineers in this field is growing. For this challenge, teams will build vehicles that will autonomously complete a small track and avoid obstacles. Specific details on this challenge can be found in the rules handbook.

4.2.6.6 Warehouse Swarm Challenge

Swarm robotics is an active area of research in the field of robotics and artificial intelligence. It is based on the principle of emergent behavior seen in social insects, such as ants and bees, were the actions of each individual are heavily influenced by those around them. Swarms in nature make use of many redundant separate entities to accomplish tasks that would have been difficult to complete alone. This challenge will give college students the opportunity to develop multi-robot systems on a hardware and software level as well as specific software skills such as computer vision and environment navigation. Details on the competition are in the rules handbook.

4.2.6.7 Indoor Drone Challenge

The market for Unmanned Aerial Vehicles (UAVs) is rapidly growing. Companies like Amazon, who is working on UAVs to deliver packages from warehouses directly to consumers in minutes, and Uber, who is working on UAVs to transport people from place to place on demand, are spending millions of dollars on development [23, 24]. This challenge tasks teams to build a miniature autonomous drone to navigate within a mock city and transport packages from a pickup location to a destination. Specific details on the competition can be found in the rules handbook.

4.2.6.8 Existing Competitions

Based on feedback, to augment the new robotics competitions we are proposing, we decided to add an already existing competition. This would allow participants of these competitions to enter their already-built robot a second time for another chance to compete. The following are competitions we have considered:

- Trinity Fire Fighting Robotics Challenge
- Sparkfun Autonomous Vehicle Challenge
- Drone Racing
- VEX Robotics Competition
- Smart Mouse Maze Competition

4.2.7 Engineering Design Judging

For each event we decided there should be a judging section to augment the performance of the robot in the competition. For this, teams will have the opportunity to present their engineering design process and their overall approach to the challenge they competed in. We outlined the following topics for teams to demonstrate for this judging:

- **Understanding** - Define the problem
- **Define** - Determine solution specifications

- **Ideas** - Generate concept solutions
- **Prototype** - Learn how your concepts work
- **Choose** - Determine a final concept
- **Refine** - Improved design
- **Implement** - Implement the detailed solution
- **Test** - Does the solution work?
- **Iterate** - Are there changes between iterations?

Based off our research of other competitions and discussions with relevant parties we decide that the best way for teams to demonstrate the factors listed above would be in the form of a technical paper and a poster that would be reviewed before and during the event respectively. Additional details are available in the rules handbook.

4.2.8 Competition Survey Results

As mentioned before, our research and initial discussions with teams led us to discover there was interest in a variety of competitions. In order to accommodate these interests we decided to create proposals for each. However, if this event were ever to be hosted it would be unrealistic to host all of the challenges we created in the first year, so we decided to choose only three of them. This decision was made with our advisors and was intended to focus our proposal for a competitive robotics olympics. In order to determine which three of the competitions we should focus on we created a rubric that compared each of the challenges we created. This rubric considered the following factors:

- Potential cost to competitors
- Interest of potential participants
- Resources required to host event

Table 4.7: Decision matrix key

Reference Letter	**Competition**
A	All- Terrain Robotics Challenge
B	Underwater Aquaculture Challenge
C	Item Sorting Challenge
D	Autonomous Vehicle Challenge
E	Mini Firefighting Challenge
F	Warehouse Swarm Robotics Challenge
G	Indoor Drone Challenge

Table 4.8: Challenge decision matrix

Metric	**A**	**B**	**C**	**D**	**E**	**F**	**G**
On a Scale of 1-10 how interested are you in competing in this competition? (Averages based off survey results)	5	7.33	3.83	5.3	5.5	6.67	7.17
On a scale of 1-10 how likely is it that your university will participate in this competition? (Averages based off survey results)	4.7	5.67	5	4.2	7.33	7.2	7
Estimated cost range of this competition for teams	$4,000 -12,000	7,000-12,000	1,000-5,000	3,000-10,000	100-1,000	1,000-7,500	500-5,000

Table 4.8: Challenge decision matrix

Metric	A	B	C	D	E	F	G
Examples of Mechanical Engineering Skills that may be used	Computer Aided Design, Mechanical Suspension, Mechanical Transmissions	Computer Aided Design, Underwater Propulsion, Water Proofed Internals	Computer Aided Design, Mechanical Manipulators	Computer Aided Design, Mechanical Suspension	Computer Aided Design	Computer Aided Design, Mechanical Manipulators	Computer Aided Design, Impact Resistant Systems
Examples of electrical engineering Skills that may be used	Power Systems, Potential for PCB Design	Water Proofed Electrical Systems	Potential for PCB Design	Potential for PCB Design	Potential for PCB Design	Potential for PCB Design	Potential for PCB Design
Examples of software engineering Skills that may be used	Autonomous Navigation	Computer Vision, Obstacle Avoidance, Autonomous Navigation	Computer Vision	Computer Vision, Obstacle Avoidance, Autonomous Navigation	Computer Vision, Obstacle Avoidance, Autonomous Navigation	Computer Vision, Obstacle Avoidance, Autonomous Navigation, Swarm Logic	Computer Vision, Obstacle Avoidance, Autonomous Navigation
Estimated number of students on participating teams	4-10	4-10	4-6	4-10	4-6	4-8	4-6

Table 4.8: Challenge decision matrix

Metric	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Type of space necessary to host	200x100 ft Indoor Space Minimum, 100x100 ft Outdoor space minimum	Swimming Pool	Up to 100x100 ft Indoor Space	200x200 ft Outdoor Space Minimum	Up to 100x100 ft Indoor Space	Up to 100x100 ft Indoor Space	Up to 100x100 ft Indoor Space

5 Conclusions and Recommendations

This section outlines the conclusions and findings of this IQP. It begins with an overview of our conclusions based off the background research on other collegiate robotics competitions, discussions with potential participants and sponsors, and interviews with key stakeholders at WPI. Next we will give an overview of our selected competitions based off feedback from interviews and survey results on drafted competitions. We conclude by explaining how this proposal fits within the greater WPI ecosystem and recommendations for future work.

5.1 What We Discovered

Through background research on popular collegiate robotics competitions, discussions with potential participants and corporate sponsors, and stakeholders at WPI we discovered several key points about hosting a robotics competition:

- Based on our research we identified that successful competitions typically have been around for many years, are audience friendly, and are based on real-world problems.
- Our initial interviews showed that potential participants had a wide range of interests prompting us to develop proposals for several competitions in the context of hosting them at WPI.
- After developing these proposals and discussions with WPI stakeholders, such as the Robotics Resource Center, we decided it was unrealistic to host all seven of the challenges we initially proposed.
- Surveying potential participants on each of these proposed events helped to determine which were both the most popular and feasible, for both the competing university, students, and sponsors.
- With these survey results we chose three challenges that struck a balance between the required resources for WPI to host, popularity, cost for participants to enter, and sponsor interest.

5.2 Selected Challenges

As mentioned in the previous section, through survey results and the decision matrix outlined in section 4.2.8, we discovered that potential participants had a wide range of interests. As such, three of the seven proposed challenges in section 4.2.3 were selected:

- Indoor drone challenge
- Warehouse swarm challenge
- Miniature fire fighting challenge

These challenges provide a good balance between feasibility and the resources required for WPI to host, potential participant interest, and the resources required to enter. They also help develop skills that are highly relevant in the robotics industry, and experience with them would put participants at an advantage when seeking a job.

5.2.1 Indoor Drone Challenge

The first of the selected challenges is the indoor drone challenge. This challenge would task participating teams to build a miniature autonomous drone to transport packages from a pickup location to a destination. This is designed to simulate tasks that companies like Uber and Amazon are building full-sized drones for. This miniature scale of this competition is important because it means that:

- **Low cost to host** - One of the largest benefits of an indoor drone challenge is the low cost to host. The resources required to host this competition are as follows: a 100 by 100 by 50 foot indoor netted space, cardboard boxes to be used as obstacles, and a grid on the floor made from tape and plywood.
- **Low cost of entry** - For those looking to enter this challenge, the cost to entry is relatively low due to the high availability of parts. It is estimated that teams would have to spend between $500 and $5,000 on hardware, depending on the size of the drone, the compute modules chosen, and selected sensors.
- **Marketable skills** - For this challenge, the skills developed are mostly software-based. These skills include computer vision, obstacle avoidance, and advanced autonomous navigation. Mechanical skills are also developed, such as designing impact-resistant systems and with general computer aided design.
- **Spectator value** - Highest among all selected challenges is the spectator value of drones. For example, drone racing has grown to become highly popular in the last few years with it expected to keep growing as companies such as ESPN beginning to broadcast it [25].

5.2.2 Warehouse Swarm Challenge

The warehouse swarm challenge would task participating teams to create both a hardware and software platform for five robots to interact with a miniature warehouse and pick up and deliver packages from and to specified locations. This challenge was chosen because:

- **Low cost to host** - As with the indoor drone challenge, the warehouse swarm challenge also has a low cost to host. The resources need are as follows: up to 100 by 100 foot indoor space and several boards with miniature packages and shelves to simulate the warehouse.
- **Low cost of entry** - Again like the indoor drone challenge, this challenge has a low cost of entry for participating teams. The hardware required are all fairly simple, with components readily available. It is estimated that teams would have to spend between $1,000 and $7,500 on hardware, depending on the complexity of mechanisms, sensors, and compute modules.
- **Multi-robot challenge** - This challenge satisfies the interest we had for a multi-robot competition with the potential of collaboration with other teams possible.

- **Marketable skills** - Skills developed through participation in this challenge are both mechanical and software based. Software skills, such as computer vision, obstacle avoidance, autonomous navigation, and swarm algorithms, are developed with mechanical skills, such as computer aided design and the design of mechanical manipulators.

5.2.3 Miniature Fire Fighting Challenge

The miniature fire fighting challenge would task participating teams with creating robots to seek out and extinguish a flame on a small table-top field. It was primarily chosen because it would allow existing participants of the Trinity Fire Fighting Competition have their robots compete for a second time. This challenge would also have the following benefits:

- **Low cost to host** - As with the other two proposed challenges, the miniature fire fighting challenge has a low cost to host. The resources required to host this competition are as follows: a 100 by 100 foot indoor space and several boards with the layouts described in the rules handbook.

- **Low cost of entry** - this challenge has a low cost of entry for participating teams. The hardware required are all fairly simple, with components readily available. It is estimated that teams would have to spend between $100 and $1,000 on hardware, depending on the complexity of mechanisms, sensors, and compute modules.

- **Low difficulty** - This challenge was originally targeted at high school students, so the expected technical difficulty is low.

- **Marketable skills** - Skills developed through participation in this challenge are both mechanical and software based. Software skills, such as computer vision, autonomous navigation, and obstacle avoidance, would be developed as well as basic mechanical skills, such as computer aided design.

5.3 Future Work and Implementation

This IQP identified three robotics challenges that WPI could feasibly host in a first iteration of a collegiate robotics competition, when and where it could take place on campus, and how it could be funded. The actual execution of our proposed competition was not in the scope of this IQP so an actual committee should be formed to execute the event for the first time. This committee would ideally include key members from offices of TouchTomorrow, Corporate Engagement, the Events Office, and the Robotics Resource Center as well as professors from the robotics program who are experts in the technical and educational aspects robotics.

The earliest this event could happen would be during TouchTomorrow 2019, with the rules and competition being announced no later than June of 2018. This would give universities enough time to form teams, get funding, and build a competing robot.

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