

The Impact of Using Multiple Drive Teams on a FIRST Robotics Competition (FRC) Team During Competition

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Abstract

FIRST - For Inspiration and Recognition of Science and Technology – is a global program that inspires students to learn and love STEM. FIRST Robotics Competition (FRC) rallies students in grades 9-12 to design and build a robot according to the competition specifications revealed at kick-off; marking the start of build season which lasts a little over six weeks. The students then travel to competition events where a drive team of four students operates the robot; competing in numerous matches over a two or three day period to earn ranking points and ultimately qualifying for higher level (state or world) competitions.

The 2016 FIRST Robotics Competition (FRC) season was filled with excitement, a challenging competition design, FIRST Stronghold, and many talented youth, mentors, and leaders. Part of the excitement is the opportunity to drive the robot in competition. Unfortunately, this privilege is usually reserved for just a few students due to the nature of the competition. Different teams view the roles and responsibilities of the drive team through their own lens. Drive team composition is defined by the game rules each year. In 2016, the game called for four students to make up one drive team; each with their own roles. In 2017, the drive team required 5 students.

Many teams have 10-40 students (if not more)^{1,2} who spend many hours during build season designing, building, and testing the robot. It is a bit of a let down when they are not chosen as part of the drive team. However, FRC Team PyroTech, #3459 overcame this disappointment by creating and piloting a new model that implemented the use of multiple drive teams during the 2011 competition season. There were a total of 17 students on the team. Implementing two drive teams participating equally in each competition gave 8 of the 17 students the opportunity to participate in the matches. In subsequent years, the team has grown this practice to using three drive teams to maximize the number of team members who get the experience of using the mechanism they built in the pressure of competition; giving almost every team member a place on a drive team in 2017.

This paper documents the model created and used by Team PyroTech and the impact and success of this approach. FRC Team SUM #6003 also implemented a similar model during a recent exhibition competition. A survey was created to gauge the use of multiple drive teams by other teams.

Introduction

FIRST (For Inspiration and Recognition of Science and Technology) was founded in 1989 by Dean Kamen who partnered with Dr. Woodie Flowers, a former MIT professor of Mechanical Engineering and creator of the 2.70 design competition⁶. Thus, it is no coincidence that FIRST has many of the same flavors as the 2.70 contest. Dr. Flowers has coined the terms “Gracious Professionalism” and “Coopertition”; the former to teach respect for others and the latter to encourage innovation.²

The mission of FIRST is to inspire young people to be science and technology leaders, by engaging them in exciting Mentor-based programs that build science, engineering, and technology skills, that inspire innovation, and that foster well-rounded life capabilities including self-confidence, communication, and leadership.²

For Dean Kamen, “FIRST is more than robots. The robots are a vehicle for students to learn important life skills. Kids often come in not knowing what to expect – of the program nor of themselves. They leave, even after the first season, with a vision, with confidence, and with a sense that they can create their own future.”³

The 2016 FIRST Robotics Competition (FRC) season was filled with excitement, a challenging competition design, FIRST Stronghold, and many talented youth, mentors, and leaders. Part of the excitement is the opportunity to compete in matches. During each match, the robot operates autonomously for the first 15 seconds. For the remaining 2 minutes and 15 seconds, the robot is operated wirelessly by a driver or sometimes a pair of drivers using a console station equipped with one or more joysticks or controllers. This is referred to as the teleop period. The privilege of driving the robot is usually reserved for just one drive team consisting of four students. The common approach is to use one drive team in order to build their depth of experience and to make the team more attractive to scouts preparing for alliance selections for playoffs. For the 2016 Season, one drive team consisted of four students; each with their own roles. There is “the driver” who operates some of the robot controls, such as those used for navigating the field during teleop, “the coach” who helps maintain order and provide guidance for the driver, “the human player” who is given strategic duties to assist the driver during the match, and a “manipulator” who works with the driver to control the mechanisms of the robot. The manipulator is also commonly referred to as the programmer. The 2017 season, FIRST Steamworks, added a fifth player to the drive team. The roles consisted of a coach, a driver, a manipulator, a human player, and a pilot for the “airship”.

There were 3,140 total FRC teams registered for the 2016 season with an estimated 44,549 spectators at the championships. Roughly 3,128 teams with approximately 75,000 students and 19,000 mentors from 24 countries worked during a six-week period to build game-playing robots that weighed up to 120 pounds (54 kg). Teams range anywhere in size from 2 members to over 100 members.⁵

ChiefDelphi.com is a portal to a wealth of knowledge regarding FRC teams and the number one place to ask a question and stay up to date in the FRC community. Chief Delphi was a team at one point, FRC Team 47, from 1996-2009 (<http://www.thebluealliance.com/team/47>). Their website evolved into this community forum which includes 130,439 threads, 1,568,964 posts, with 44,299 total members of which 9,053 are active.⁴

Motivation

Many teams have 10-40 students (if not more)^{1,2} who spend many hours during build season designing, building, and testing the robot. It is a bit of a let down when they are not chosen as part of the drive team. More than being a disappointment, it is a lost opportunity in terms of experience and leadership. However, FRC Team PyroTech #3459 overcame this disappointment by creating and piloting a new model that implemented the use of more than one drive team during their first competition season in 2011.

In 2011, the team chose to have two drive teams -- with no experience, and no practice robot, the first driving opportunity came on the field in competition for the students. The team had no experience with how to choose a drive team, and having two drive teams gave both team members who had experience driving a remote control car a chance to be on the field.

After the 2011 season, a student on the team remarked on how extraordinary an experience it had been to drive the robot in competition in front of crowds -- the robot that he had helped design and build, and know that it was both his skill in building the robot and his efforts on the field that resulted in the outcome.

In response to the question, "How do you think being on a drive team affected your post-school experience?" an alumna currently attending college, years after her drive team experience, had this to say,

“Being on a drive team helped me realize that I had an impact on the people around me very directly. I had an authority role and I saw how important it was to listen to the people who were doing the direct actions. It also taught me that you can always negotiate but to get other groups to work with you well, you need to know what you want and to be honest about it. I learned the reality of pressure and how perceptions of what has happened can be really warped by that pressure. You own how you act under pressure. It has made me more confident in asking for support in school and given me the confidence to work with my professors more directly to get support when needed.”

Even with two drive teams, only a few students ever have that opportunity of seeing engineering, programming and end-use come together. The coach and mentors decided to risk opening up three drive teams with equal status and equal access to increase the number of students obtaining this experience. To do this, the team committed to participating in an additional, out of state, competition so that there would be enough driving time for all three teams to be on the field.

The decision was quite controversial. In FRC events, teams compete in alliances. After qualifying matches are complete, one team will choose others to participate in following matches as an alliance. Each team comes to rely on alliance drivers and robots during playoffs rounds, sometimes known as “eliminations”.

Many parents and students were quite uncomfortable with the idea of so many drive teams. For the first three or four years, the team knocked bugs out of the process. Will the drive teams have enough practice to be skilled drivers? Who drives in eliminations if the team is a seed for the alliance? What happens if the team is “on the bubble” (becomes an on-call substitute for an alliance) and may only have two or three minutes between finding out they are playing on an alliance and being on the field? How will the alliance partners feel about seeing multiple different drive teams?

It took several years to find workable resolutions to these and other questions. During each competition throughout the early years, unexpected situations derailed assumptions and expectations, requiring the team to work together towards solutions.

Lessons learned:

- This approach requires team members to prioritize team success over team advancement, but must account for team members’ interest in personal achievement.
- Teams must go into the competition strong in terms of team dynamics and chances for drivers to have opportunities to drive the robot in the off-season.

- It is important to have a set of guidelines that resolve the foreseeable decision matrix for selecting which drive team drives under given circumstances. This provides transparency.
- There are *always* unforeseen circumstances that break that matrix. Have a person - coach, lead mentor, team captain, parent - who knows team member strengths and weaknesses well and is trusted by students and parents to have the good of the team and the good of each individual team member in mind to make “executive decisions” when something unforeseen happens.

In the team’s seventh year of intentionally using multiple (three) drive teams, each given equal opportunity to drive in competition, the process has become “normal” and accepted. Most of the team and the parents would be disappointed if it changed. There are other local teams who give supportive feedback to balance the opinions of the teams that suggest it is not a good idea.

Now other local teams are emulating this practice. Noticing that, the authors began to wonder if this was a unique approach (many local teams thought it was highly unusual) or if it was being used elsewhere.

This paper is an initial result of that inquiry.

Methodology

A pilot questionnaire was created to gauge the number of FRC teams using multiple drive teams. The questionnaire can be found in the Appendix. Originally, the scope of the inquiry was limited to the teams in North Carolina but then was expanded to use Chief Delphi to reach a wider audience. The authors were unsure what degree of response might be obtained and were aware that there would be a significant issue of “self-selection” in the pool of participants who responded.

As a result, this survey barely touches the surface of this fertile line of inquiry. Many of the questions in the questionnaire were open-ended to determine what questions might better be asked in a follow up survey. The questionnaire used could best be considered a first test probe to be improved on and used for a larger, more carefully selected, set of survey participants.

The survey was published through a post on Chief Delphi asking how teams select and organize their drive teams. The questionnaire itself had 2 parts.

1. A simple “forum based” poll that any registered user could activate by simply clicking on one of several answers.

2. A Google Forms based online questionnaire that could be reached by following a hyperlink. This paper will look at what can be gleaned from the responses to this questionnaire.

Results

There were 61 responses to the survey from 59 different FRC Teams representing Alabama, California, Connecticut, Florida, Iowa, Illinois, Indiana, Kansas, Massachusetts, Maryland, Michigan, Minnesota, Missouri, North Carolina, New Jersey, New York, Oregon, Pennsylvania, Tennessee, Texas, Washington, Wisconsin, West Virginia, Canada and Israel.

Of the 61 participants, half (49.5 percent) were students, 29 percent were mentors and 21 percent were coaches (Figure 1). This suggests that much of the information cited in the survey was provided by more of the longer-term perspective of the adult coaches and mentors. A third of the participants (32.8 percent) had been a member of the FRC team for four seasons, with 27.9 percent on the team longer than that (Figure 2). Only one (1.6 percent) of the participants was responding from the first season on the team.

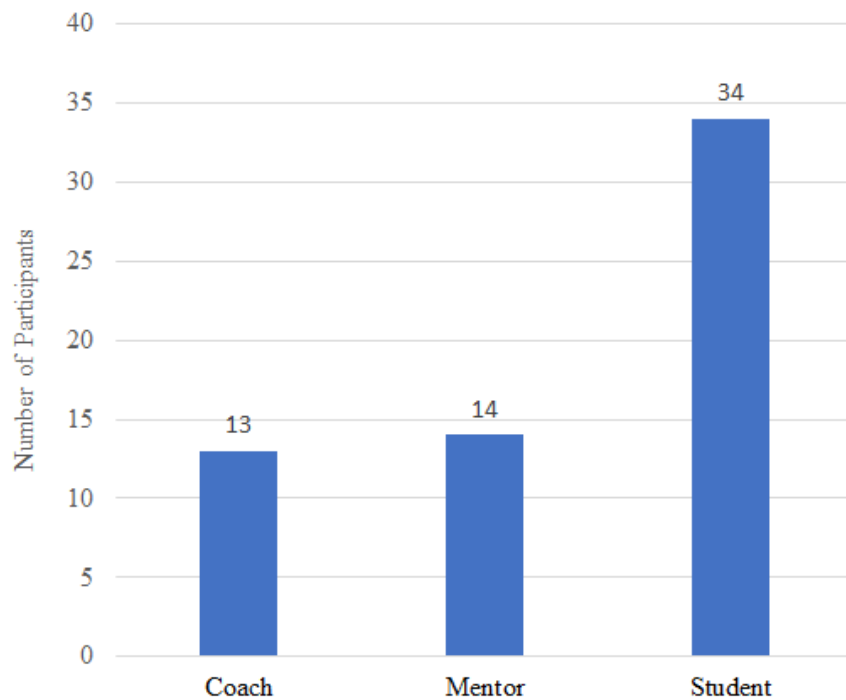


Figure 1: Participants' Roles on their Team

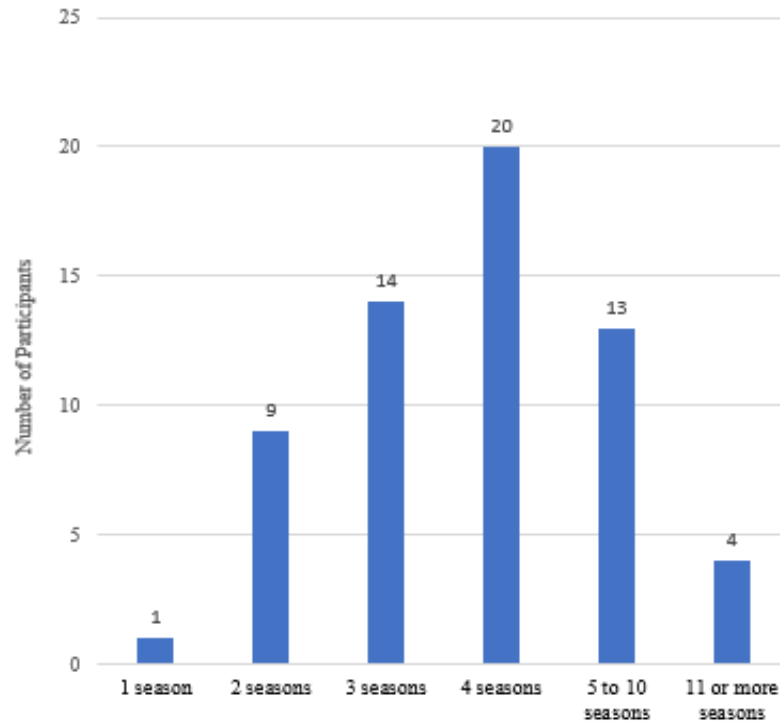


Figure 2: Length of Time Participants had been Involved with this Team

Notably, 86.7 percent of the survey participants (Figure 3) are associated with teams that have been in existence for four or more years. Established teams are likely more confident in articulating their approaches to team organization.

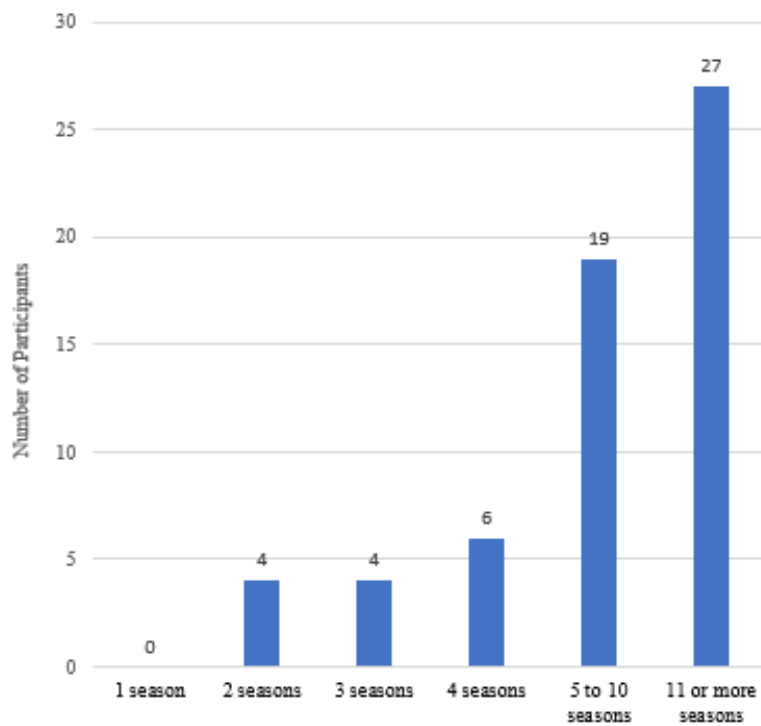


Figure 3: Time Team Has Been in Existence

Survey respondents' reported team size (Figure 4) conforms to expectations on overall team size of 10-40 team members, with outliers below 10 and above 100 members. Surprisingly, 30 percent of survey participants identified as being members of a team with between 41 and 75 members. This suggests that future surveys may provide information about the changing configurations of competitive robotics teams.

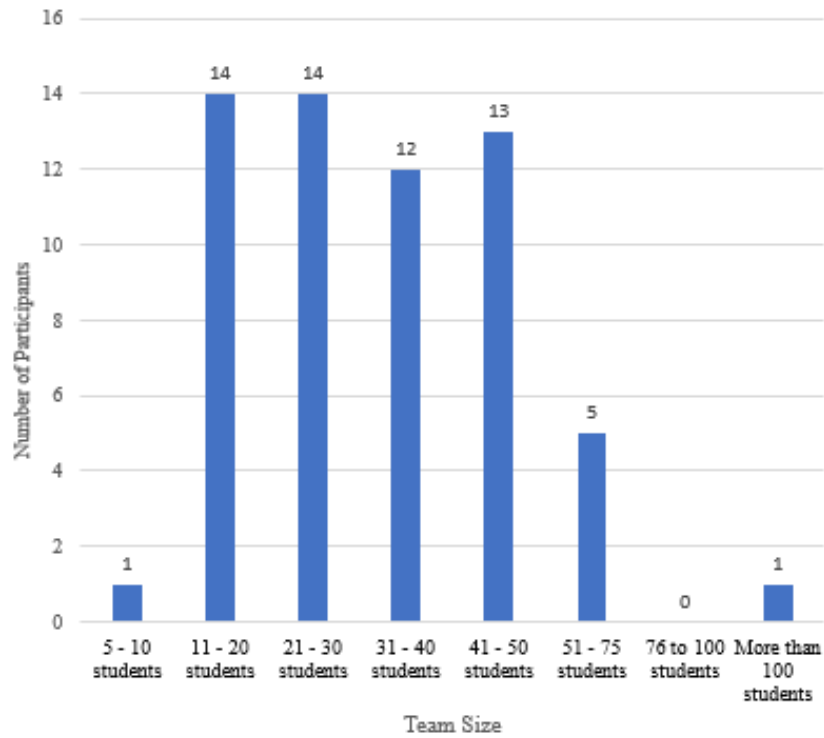


Figure 4: Team Size by Number of Students

Reported locations of teams responding to the survey show that most responding teams draw from suburban environments (Figure 5).

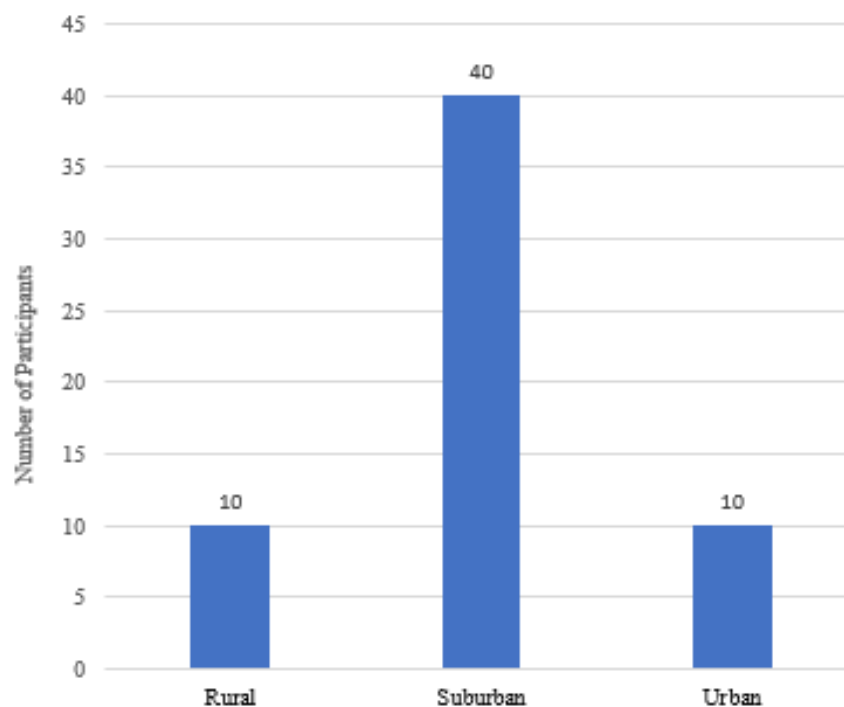


Figure 5: Location of the Team

Key Questions and Results

How common is it for FRC teams to implement multiple drive teams?

The response to the number of drive teams resulted in four main categories. (Figure 6) The most common category was simply that the team had one designated drive team that competed together throughout the season in every match. In the second most common category, the team had one main drive team with a backup team to take its place in an emergency. Four teams only utilized the third and fourth categories. The third category had two drive teams that they utilized equally; i.e. the drive teams would alternate matches throughout a competition. The fourth category had three drive teams that they utilized equally.

- Out of 60 teams who filled out the survey, only Team 3459 uses three drive teams who have equal drive time; three other teams use two drive teams and have them drive equally. This includes two teams who learned from Team 3459 (Team 4828 and Team 6003) and Team 3547 located in Michigan with a similar philosophy to driving to Team 3459.
- 29 teams (48 percent) used one drive team. 27 (45 percent) had one drive team and a backup.

- Three teams had two drive teams that had equal driving time.
- One team had three drive teams with equal driving time.

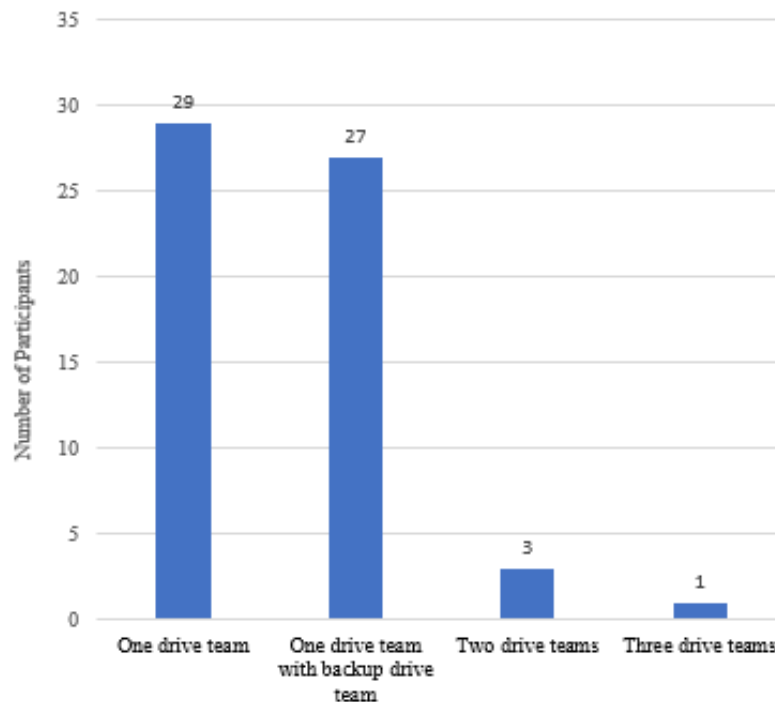


Figure 6: Number of Drive Teams

- Of the four teams who gave equal drive time to multiple drive teams:
 - Three teams fall in the 11-20 student size and the fourth falls in the 21-30 student size.
 - Three teams are five to ten years old and one is a rookie-plus-one-year.
 - Two are rural and two are suburban.
 - All four teams have five to ten adult mentors on a regular basis
- One team from North Carolina commented that
 - “Wanted to let you know that your team having multiple drive teams is a pretty big inspiration to us. While we decided against it for the drive team, we try use a similar system wherever we can, even if it means making a worse robot but better people. Having multiple drive teams is apart of your team identity, don't change it

just cause we or other teams work differently. See you at Wake County, I'll be the guy in the bowler hat! :D”

What are the expressed motivations in favor of multiple drive teams?

- **Reason for having two teams with equal time:**
 - (MI) “This is our first year trying two drive teams. We have done a lot of recruiting, and we now have a larger team with many freshmen and sophomores. There are no returning drivers. We view FRC as an exercise in building student leaders and future STEM professionals more than a robot contest to win, so we are trying additional ways to get students leadership experience. Two drive teams will give twice the students this experience. We build and practice a lot, so they will have plenty of practice.”
 - (NC) “To have more opportunity and to switch off whenever needed.”

- **What are the expressed motivations in favor of a single drive team?**
 - Having a single or primary drive team was perceived to be the best chance to win with more driving practice.
 - (NY) “One drive team allows for your drivers to get more practice and reach their full potential. Also allows you to keep a consistent level of play.”
 - (MI) “To have the most cohesive set of students out on the field so they can feed off each other and basically get to the point of not even needing to communicate they just know what each other is going to do.”
 - (IA) FRC is about more than being a driver. Having a better chance at getting to champs benefits more people than putting a few more kids into matches. Putting unprepared kids out there compromises the product on the field. I think the fair move for the team as a whole is to pick the drivers that give the team the best chance to advance to elimination rounds and further competitions, and give these drivers as much practice time as possible.
 - Those who had a back up did so because:
 - (IN) “Attendance issues prevent all our students from being able to attend all our events due to them being over spring break. Having backup drivers allow us to be covered if the primary team can't make it to the event.”
 - Back ups could fill in if there was an emergency
 - It was training for next generation of drivers

- **Are there team attributes surveyed for that show a clear correlation with single or multiple drive team preferences?**

- There were not enough multiple drive teams to say for sure.

Discussion

When the authors embarked on the mission to investigate how common it was to use multiple drive teams, they did not expect these results. Having three drive teams on Team 3459 is unique relative to all the teams in North Carolina and 91 percent of the participating FRC teams responding used the traditional format of one drive team or one drive team plus a backup. We were surprised to see that another team in Michigan has considered this option and will try it this season.

This was just a pilot study, and we observed potential issues with survey participant selection.

- Only teams with representation in Chief Delphi were invited to participate
- Because the invitation was in the form of a forum post, only teams that have spent time reflecting on the question of drive team organization are likely to engage. 160 poll entries were observed but only about 60 survey responses were obtained. This shows an uncontrolled selection process having impact.
- Looking at various data collected and analyzing information that is publicly available, a number of possible self-selection factors that may have impacted results were detected. For example, teams and individuals with many years of experience responded in greater numbers than did rookie and low experience teams and individuals. This may show skewed participation since many participants leave the FRC program upon high school graduation and teams often fold after a few years. While this and other metrics of selection skew have not been fully examined for validity, further study of participant selection may be necessary.

Moving forward, we intend to revisit the survey and incorporate more questions regarding gender, socioeconomic status, and demographics. Specifically to our domain, we would also like to investigate:

- Core values of the team (how important learning was vs. competition)
- How many regionals/districts did they compete in (so number of matches)
- Motivations behind team organizational structure
- Other organizational structures that have been tried or considered
- For student and mentor questions, find out if they are involved in “robot” or “other”
- Professional background of coach or lead mentor (educator, scientist, engineer, fields of expertise)

There are additional dimensions that merit further investigation.

Questions to be answered

- What is the longer-term impact of being on a drive team to the students' eventual educational and professional performance?
- How does this compare to non-driver participation on a competitive robotics team?
- How does this compare to participation on a competitive robotics team in a role that is not related to the robot or driving in the competition?
- Does participating on a drive team, that is one of many, change the experience compared to participating as a member of a single drive team?
- Are there differences in the attitudes about collaboration and skill in collaboration created by having multiple drive teams?
- Does organizing to have multiple drive teams maximize the number of students obtaining the greatest benefit from participation on a competitive robotics team?

Data collection

- Develop instruments to collect and compare attitudes, achievements and degree of fulfillment of students who were
 - On a drive team
 - Not on a drive team
 - On a drive team that was one of many drive teams

Of interest will be testimonials, self-reporting of attitudes/achievements and, if possible, peer reporting of attitudes. Longitudinal data collection about drive teams is possible for the first two categories today (25 years of drive teams in competitive robotics). For the third category "On a drive team that was one of many drive teams," the participant pool available to survey remains limited and has not progressed beyond collegiate achievements, because the practice of multiple drive teams is relatively new (seven years).

Understanding the long term impact of organizing to support multiple drive teams on a single competitive robotics team will inform how future teams may best be configured to provide the best outcomes to participants.

Acknowledgements:

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References:

1. Dolenc, N., & Tai, R. H. (2013). Taking Different Paths: A Comparative Study of Mentoring Models Among Robotics Competition Teams. *120th ASEE Annual Conference and Proceedings Paper Publications*, Paper ID#7871.
2. Fagan, T. J., & Holt, G. D. (2011). Providing Opportunities for High School Competition Teams: US FIRST Robotic Competition Initiative for Home Schooled Students. *118th ASEE Annual Conference and Proceedings Paper Publications*, Paper ID#808.
3. FIRST Robotics Competition. (2017). Retrieved from <http://www.firstinspires.org/robotics/frc>
4. FRC Team 47. (2000). Chief Delphi. Retrieved from <https://www.chiefdelphi.com/forums/portal.php>
5. Merrick, F. (2016, May 13). The 2016 Season, by the Numbers. Retrieved from <https://www.firstinspires.org/robotics/frc/blog/2016-by-the-numbers>
6. MIT Museum. (2011). 2.70/2.007 MIT's Most Famous Class, 1970–Present. Retrieved from <http://museum.mit.edu/150/40>

Appendix: Questionnaire Form

Approaches to Drive Teams Survey

Hi! If you have found this survey, and you are part of an FRC team, we'd love your input. This is a survey about how teams choose and implement drive teams. Each team has its own way of doing this. Help us learn about how your team takes on this critical challenge. We also ask for some background about your team and how things work on your team to see if there are any patterns that we can find in the data we get. Thanks for participating!

If you have questions, let us know.

* Required

About you...

1. Which FRC team are you associated with? -- team number(s) *

2. What state / country are you located in?

3. Are you a ... *

Check all that apply

Check all that apply.

- Student on the team
- Mentor
- Parent
- Coach
- Other: _____

4. How long have you been associated with this team?

Mark only one oval.

- This season (FIRST STEAMworks)
- 2 seasons (FIRST Stronghold and FIRST STEAMworks)
- 3 seasons (including Recycle Rush)
- 4 seasons (including Aerial Assist)
- 5 to 10 seasons (Ultimate Ascent, Rebound Rumble, Logomotion, Breakaway, Lunacy)
- 11 or more seasons (prior to Lunacy)
- Other: _____

5. What role/s do you take on the team?

Drive Teams

Questions about how drive teams are organized on your team

6. How are drive team members selected on your team?

Select all that apply

Check all that apply.

- By lot (random drawing)
- By driving skills test
- By degree of participation in build season
- By seniority on team
- By essay contest
- By how they represent the team
- By vote
- By coach/mentors
- Other: _____

7. Do drive team members stay on the drive team year over year until they graduate?

Mark only one oval.

- Yes
- No
- Sometimes
- Other: _____

8. Explain more about the selection and role of drive teams on your team

9. How many drive teams will your team have this year (2017)?

Mark only one oval.

- One drive team
- Two drive teams
- Three drive teams
- more than three drive teams
- Other: _____

10. If your team will have more than one drive team planned for 2017, how will they be scheduled at competition?

Mark only one oval.

- Primary team and backup team if primary team not available
- All teams all get a a similar degree of driving at competition
- Varsity and Jr Varsity
- Other: _____

11. Why does your team choose the number of teams it does? Pros/cons?

Team Organization

Questions about how your team organizes into groups or roles to get work done

12. Where do students work on the team during build season?

Check all that apply.

- Everyone does everything - robot building, marketing, Chairman's, etc.
- Students are primarily in different subgroups for build season
- Subgroups are fluid throughout build season with students moving from group to group
- Other: _____

13. What type of subgroups does your team have?

14. How does your team organize itself?

Check all that apply.

- Hierarchical reporting structure with team leads, area coordinators and a team captain over it all
- Senior students lay out a plan, junior students follow plan
- General discussion among all students to make decisions
- Students and mentors decide a plan together and make it work
- Mentors have a large say in the plan, students follow it
- Other: _____

About Your Team

15. How long has your team been competing/participating in FRC?

Check all that apply...

Mark only one oval.

- This season (FIRST STEAMworks)
- 2 seasons (FIRST Stronghold and FIRST STEAMworks)
- 3 seasons (including Recycle Rush)
- 4 seasons (including Aerial Assist)
- 5 to 10 seasons (Ultimate Ascent, Rebound Rumble, Logomotion, Breakaway, Lunacy)
- 11 or more seasons (prior to Lunacy)
- Other: _____

16. Is your team primarily:

Check all that apply.

- School-based
- Community-based
- University-based
- Corporation-based
- Church-based
- Other: _____

17. How big is your team this year?

Mark only one oval.

- 5 - 10 students
- 11 - 20 students
- 21 - 30 students
- 31 - 40 students
- 41 - 50 students
- 51 - 75 students
- 76 - 100 students
- More than 100 students
- Other: _____

18. How many adults work with your team at a typical team meeting during build season?

Mark only one oval.

- 1 to 2 adults
- 3 to 4 adults
- 5 to 7 adults
- 8 to 10 adults
- 11 to 15 adults
- 16 to 20 adults
- 21 to 25 adults
- Other: _____

19. Is your team primarily

Mark only one oval.

- Rural
- Suburban
- Urban
- Other: _____

20. Gender - Approximate percentage of student team members who are male

21. Gender - Approximate percentage of regular adult mentors who are male

Thank you!

22. Any other thoughts or comments about drive teams and team organization?
