# Drivetrain Philosophy for Competition Robotics

*"The best drivetrain is the one that gets you where you need to go when you need to be there"*

## Intro:

Hello, my name is Bryan Culver. I began my FIRST career in 6th grade continued through 8th growing my passion for engineering in FLL. I then joined team #33 the Killer Bees where I eventually advanced in my knowledge far enough to become the primary student designer, student mechanical lead, and robot operator in the 2012 Rebound Rumble season. At the time this paper is being written I am attending Kettering University for ME and IE degrees. This paper is basically a summation of my thoughts on what is important when choosing/designing/ building a drivetrain – my "drivetrain philosophy." My hope is that others will find it valuable when developing or deciding what drivetrain to use in future seasons.

## The Basic Question:

The general idea is very simple. What are you trying to accomplish with your drivetrain? Then only implement features that contribute to solving the problem. Unfortunately, these types of questions are not commonly asked so simple the answer often seems. Because they are so simple it is common that teams overcomplicate their drivetrain by placing value on unjustifiable attributes. Many do not get to the root of the question setting parameters without completely understanding why. By examining the core problem and justifying choices solving the decided upon question you can ensure a first-rate final product. My drivetrain mantra is the above and will be repeated throughout the paper; *the best drivetrain is the one that gets you where you need to go when you need to be there*.

## Getting Where You Need To Go:

Getting to your point of interest on the field of play is always the primary objective with the drive system. No matter if it is to drive over and pick up a game object, getting to a goal to score on, or moving to an otherwise strategic place to be on the field. In order to do any of these the basic robot functionality must be moving forwards, backwards, and some method of turning. Anything less than this and it is extremely unlikely that robot will *be able to get where it needs to go.* It is also very important to note that reliability plays an enormous factor in the problem. If the drive system only works 2/3's of the time then you are only solving the drivetrain problem 2/3's of the time.

### Reliability:

Extremely important are the concepts of durability, robust design, simplicity, and ease of maintenance all of which factor into reliability. Reliability is the single most important aspect of the drivetrain as you are not getting to where you want to be if you can't move or can only limp along. The solution one chooses to solve the drivetrain problem must be repeatable match after match. If it is not, then it is simply not a good solution.

-The easiest way to make a drivetrain reliable is to make it simple. Simplicity means fewer parts that could potentially break and that need to be maintained.

-Going hand in hand, durability and robust design are what is keeping the robot working even after it takes a beating the match before. A durable robot with a robust design will have very few failures during competition and allow for more time playing, practicing, and preparing for the next match.

-Ease of maintenance is often overlooked because it does not directly contribute to how good your robot is. However, proactively designing in maintenance holes, tool access points, and ways to easily remove and/or replace damaged parts turns a robot failure from a major disaster into a minor setback.

*-An excellent example of a "reliable" drivetrain is a 6wd. 6 wheel drives are known for their ability to drive in straight line quickly and turn about their respective center. However, their popularity truly stems from these traits in conjunction with their simplicity allowing for more freedom in other design aspects.*

Center of Gravity:

-This is an aspect of drivetrains which is often underappreciated or ignored. However, often the difference between a good and poorly preforming drivetrain is where the Center of Gravity of the robot is. This is even more relevant with the popular skid steer drive systems. (6 and 8 wheel drives) These drive systems will turn very differently based on height and for-aft position of the robot's center of gravity – lower is better.

Turning:

-In most cases the average robot will have no problems going straight. It is when they attempt to turn that differences are obvious. Robots that can turn upon command allow the driver to quickly get where they want to go while robots that don't turn well will hinder the process greatly.

Chassis Stiffness:

-A vital but overlooked aspect of drivetrains is Torsional stiffness (the amount the frame can twist.) 6 and 8wd's require a very high level of torsional stiffness because they need to maintain their slight wheel drop in order to turn. A Mecanum or Holonomic drivetrain requires a lack of torsional stiffness because it relies on having all of its wheels touching the ground in order to function properly. If a drivetrain has the opposite of what it's supposed to (ex: a 6wd with little torsional stiffness.) Then it is likely to perform poorly even if everything else about it is well executed.

## When You Need To Be There:

The answer to this question is usually “Right Now!” with few exceptions (team 71: 2002 comes to mind.) Getting around the field quickly is nearly always advantageous, and all other things being equal if you can get around the field more quickly than the opponent then you’ll tend to win. Optimally, the robot would just pop in and out of existence going where the drivers want it to be. Unfortunately, we have to settle for traveling in vectors.

Assuming that we have the ability to turn upon command there are several main factors which control how fast we can get somewhere.

Path to Point of Interest:

-How long it takes to get somewhere is directly related to how far away it is. A properly driven Swerve or Mecanum drive should nearly always be able to drive in a straight line to wherever the drivers want to be while a non-omnidirectional robot may have to turn to get from the same point A to B.

-A commonality in competitive robotics is terrain which the robot usually has the option of crossing. An example of this is FRC 2010’s Breakaway. Splitting the field into thirds were large bumps and a single tunnel. Any robot needing to get around the field had to choose between one of these two obstacles. In general, the bumps were superior to the tunnels because they allowed a much more linear path to wherever the drivers wanted to go.

Top Speed:

-The fastest speed the robot can move is a major limiting factor in how fast the robot can get somewhere. If the robots top speed is only 6fps then you won’t be going anywhere faster than 6fps – simple as that.

Acceleration:

-The robot’s sprint distance acceleration time is probably a much more important number than the top speed. Because most games require the robot to repeatedly stop, start, and change direction the acceleration of the robot up to “driving speed” is very important. If the robot’s top speed is geared too high the resulting slow acceleration will never allow the robot to get up to speed and the robot will be overall slower than if it were geared lower. The optimum balance between top speed and acceleration for a drivetrain is dependent upon the game.

Once a robot can reliably move to generally any place on the field it has become a threat to the opponent and very well may encounter defense. This is where -- *when you need to be there* -- becomes complicated beyond how fast you accelerate, what your top speed is, and how quickly you can turn. It is also where most unjustified design decisions are made. It’s important to remember no one is going to have to stop you if you can’t get there yourself. The aspects of getting where you want to go are always

more important than how fast you get there. With this said, the best drivetrains always have integrated solutions that seamlessly fulfill both criteria.

There are many solutions to getting to where you want to be where defense is concerned:

Many teams like their drivetrain to have a high amount of torque.

Q: Why does the drivetrain need a lot of torque?

A: We want to be able to push other robots.

Q: Why do you want to be able to push other robots?

A: In case they are in our way.

Q: Why would they be in your way?

A: Because they want to stop us from going where we want to be.

Alternatively for speed:

Q: Why does the drivetrain need to go fast?

A: Because we want to be able to outrace other robots.

Q: Why do you want to be able to outrace other robots?

A: Because they might want to be where we want to be.

Q: Why would they want to be where you want to be?

A: Because they want to stop us from going where we want to be.

Here we have two completely opposite solutions to the same fundamental problem. In the torque example the team was addressing the basic question by making it difficult for others to stop them from going where they wanted to be. The speed example addressed the basic question by being there before anyone could stop them. A team could choose to implement both solutions, but at the cost of weight and complexity. It is very important to keep an open mind during this process and ask as many questions as possible, remember that there is more than one correct solution, complementing solutions, and conflicting solutions. Ideally one would want to identify and implement as many ways as possible to help solve the root problem. In general, complementing solutions boost a drivetrain above the sum of its parts.

Example: *Team 469; 2010 Breakaway*

*This team had a unique ball redirector which redirected balls right back into the goals. The drawback, however, was that they needed to in an exact position under the tower on the field for it to work.*

*Problem: Get to the tunnel/ tower to implement redirection device as soon as possible.*

*They wanted to ideally get to the tower before anyone could stop them. However, in case of opposition they also wanted to make themselves difficult to stop.*

*Solutions:*

*-A lot of torque:*

*-very low "low gear" in 2 speed transmission*

*-A high coefficient of friction:*

*-pneumatic wheels*

*-weigh as much as possible*

*-already be there*

*- get there in auto mode*

*- make opponents want to be somewhere else*

*-still be able to still actively play the game from elsewhere*

## The Drivetrain is only 50%:

This gets its own category because no matter how great one's drivetrain is in most competitive robotics competitions you can't score very many points (if any at all) with your drivetrain alone. In this sense the drivetrain is more of a vessel for the rest of the robot which allows you to score points and hopefully win.

Construction Time:

-How long does the drivetrain take to make? The FRC season has a time limit of 6 weeks during which the entire robot must be built and tested. Every hour that is spent designing, developing, or building a drivetrain is an hour that is not being spent designing, developing, or building the parts of the robot that actually score points. It is for this reason that the modern FRC Kitbot is superior to so many other more time consuming designs even though it might not perform as well in any of the above criteria. It is also for this reason that most very successful teams have a drivetrain(s) that they reuse each year with minor changes.

-By using the offseason to develop drivetrains (AND arms, elevators, ball sorters/conveyors, shooters, claws, hanging mechanisms, etc.) one can populate a design shelf of proven ideas which only need minor modifications in season before they can be used.

Driving Practice and Confidence:

-The robot drivers are just as important as the robot itself. Similarly to any other motor skill it takes over 100 hours on the sticks for the drivers to really begin to master the robot, each actual competition attended is at best around 1 hour of actual driving on the field. By finishing the robot early and/or building a practice robot the drivers can get the experience they need to drive the robot at its full potential. (The best way to get through defense is to have drivers that have trained with defense.)

-The drivers need to have confidence in the robot or they will never use it to its fullest potential. They need reliability in the robot in order to obtain repeatability while driving. Once the drivers are used to compensating for something it takes a lot of time for them to fully adjust back even after that something is fixed.

Robot Interface:

-This is also extremely important; if the drivers are not comfortable with the user interface then they won't drive the robot to its fullest potential. Drivetrain controls should be thought out and practiced with in the offseason. All other robot controls need to be decided upon based on the drivers' input.

## Summary:

-Reliability is always the top priority.

    -durability, simplicity, robust design, and ease of maintenance are primary factors in reliability.

-Everything else being equal getting where you want to be faster is better.

    -traveling distance, top speed, and acceleration are primary factors in minimizing travel time.

-Accommodating Defense

    -there are many ways to get around defense. The solution varies with the method.

-The Drivetrain's only 50%

    -the drivetrain usually can't score many (any) points by itself.

    -having trained confident drivers is extremely important.

Hope this was helpful.

Regards, Bryan