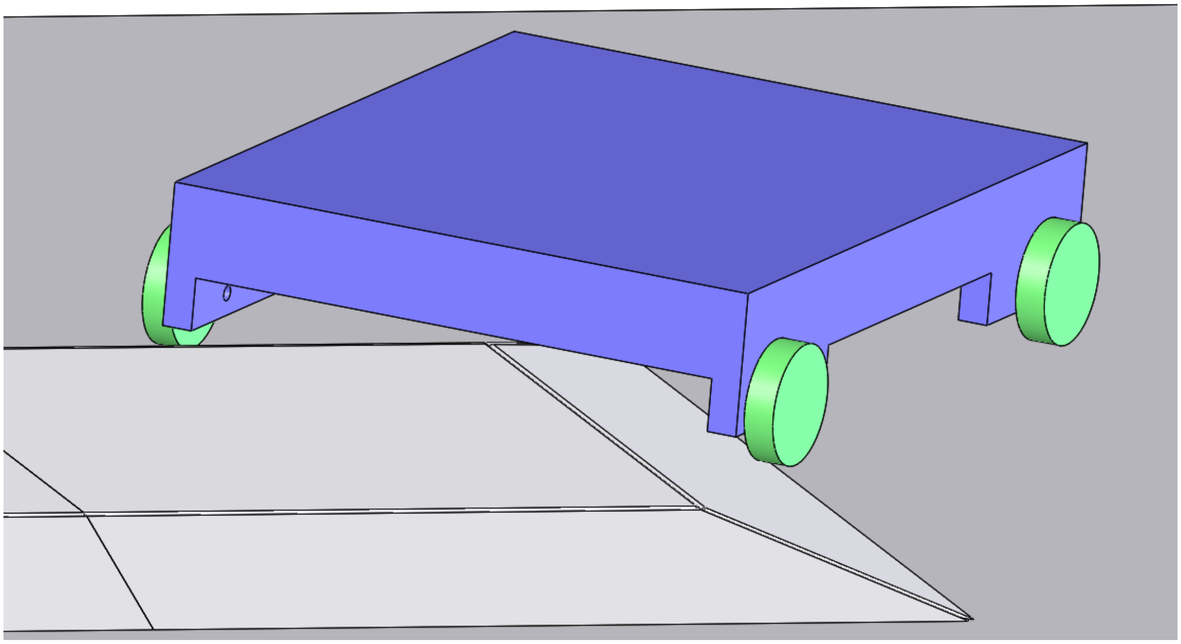
VEX PRO BUILD BLITZ



Drivetrain Design Guide 2015

Introduction

The 2015 FIRST Robotics Competition Game, Recycle Rush, is VERY different from previous challenges. There are several changes to the game & robot rules which impact the way teams should think about their drivetrain design. This section will summarize some of the new design considerations that the Build Blitz team feels are most important in 2015.

Divided Field Impact

Perhaps the most important design consideration is the divided playing field. Alliances are no longer playing "head-to-head" against opponent robots. As such, there should be almost no defensive play, and very little contact with opponents. Robots may be inadvertently "hit" by their partners, but this should be rare.

> **NOTE**: One side-effect of the nature of this game is that FIRST has ruled that bumpers are no longer required (and now count against a robot's overall size / weight restrictions). We recommend that teams do NOT use bumpers – they can spend that weight in other "more productive" ways.

This removal of contact in many ways removes the NEED for the "traditional" rigid robot chassis & drive base. Many teams may still opt to build their typical base, but the game doesn't require it

"*This is the type of game where you don't build your mechanism on top of your drivetrain, in this game you can just slap a few drive wheels onto the side of your mechanism.*"

Another way of saying that might be: let the design of the rest of your robot dictate the drivetrain design. That said, if a traditional chassis integrates well with your design, there are lots of great options or off-the-shelf choices for teams to use as inspiration.

One important consideration for teams to remember is that even if their robot probably won't get hit by another robot, it can still hit a wall. While in 2015 there is opportunity to save weight and build more delicate robots as compared with the aggressive gameplay of 2014, it is important to design your robots "tough enough" to survive an "accidental" full speed drive into the side of the field.

There's still something to be said for "beefing up your drivetrain." Any weight spent on making the drivetrain more robust is also additional weight on the lower portion of your robot. In a game where many robots will be "reaching very high" with significant amounts of weight, any lowering influence on a robots CG is beneficial.

The additional time spent developing a custom solution may not prove feasible for many teams. The complexity of this year's challenge may warrant spending additional time developing high performing and robust mechanisms. To allow for this, for most designs, the traditional drivetrain style can be VERY appropriate for this game.

Robot Size Restrictions

Another major rule change which has BIG impact on drivetrain design (pun intended) are the new "size un-restrictions" (see <R3>). Teams can make their drivetrains expand to basically whatever size they want while on the field, as long as they FIT on the field and stay under 78" tall. When not on the field, the robot must fit inside a Transport Configuration which is 28" wide, 42" long, and 78" tall.

"*So what size do you make your robot? What size do you make your drivetrain?*

Simple – whatever size your design dictates."

There are many creative ways to utilize a "large" robot in this game, and these potential large robots might either require a larger drivetrain or diminish it to being a very minimal part of these large robots.

However, for most teams, the "traditional approach" is still a good one. If you assume the robot leaves the 78" dimension as its "height" your base should be designed to fit within a 28" wide x 42" footprint. This is actually more room than we've had in prior years! The previous rules since 1998 were 30" x 36", then 28" x 38", then most recently 112" total perimeter (the 2015 perimeter would be 140").

The Tote measures 17" wide x 27" long, so if your pickup is designed to pull one (or more) of these inside your frame perimeter, you should choose the drivetrain orientation accordingly.

> **NOTE:** "Long" robots are more front/back stable than "short" robots, and "wide" robots are more right/left stable than "narrow" robots. Wide robots also, as a rule, turn better. There will be more discussion on drivetrain turning later in this paper.

Traversing the Playing Field

When a designer works on a drivetrain, the first thing they should look at is what area it will be traversing. The 2015 game includes a few things to take into account.

Traction:

There are two field surfaces which drivetrains need to interact with, the carpet (which is the same low-pile stuff teams have been dealing with for years) and HDPE plastic on the scoring platforms. Designers should consider the traction that their wheels will get on both of these surfaces.

It turns out that most of the same types of wheels which have good grip on carpet also have good grip on HDPE. The only exceptions are those which are designed to "dig into" the carpet and interact with the carpet fibers. These wheels will have reduced traction in line with the "grippiness" of their material. For instance, wheels made of a hard & slippery material which interacts with the carpet to gain traction will have greatly reduced performance on the HDPE.

That said, designers will need to determine how much traction actually matters for their strategy. Since the field is divided, the traditional requirement for “pushing hard” may not exist: this opens things up quite a bit, wheel forward/backward grip may not be an important consideration, so other considerations would drive wheel selection.

Designers do need to consider how much force it takes to move the different game objects on the carpet. In particular, the Totes have “grippy” bottoms which resist sliding. It is important to test this performance before making decisions.

“Litter” Avoidance

In Recycle Rush, there could be 20 foam pool-noodles “littering” the field (pun intended) depending on how the match plays. These noodles are approximately 2.5” in diameter and 58” long. Designers should consider how their drivetrain will interact with the noodles. There are three main ways to deal with the pool noodles:

Noodle Management:

1. Tell your driver to never go near one.
2. Design your drivetrain to go right over them.
3. Design your drivetrain to plow them out of the way.

Some combination of these 3 methods may work for your team depending on other design tradeoffs you make. For instance, the low ground clearance to keep the noodles out from under your robot may have an undesirable impact on your ability to drive over the scoring platforms.

Crossing the Scoring Platforms

Some teams may choose that, as part of their strategy, they need to be able to cross the two scoring platforms on the field (either fully or partially).

From the Recycle Rush game manual (found on www.usfirst.org):

2.1.3 SCORING PLATFORMS

Each ALLIANCE has two (2) SCORING PLATFORMS. Each SCORING PLATFORM is 1 ft. 8 in. wide, 2 in. tall, and 15 ft. 7 in. long. Each SCORING PLATFORM is a plywood base covered in White HDPE. Along both long edges of the SCORING PLATFORM there are Platform Ramps. The Platform Ramps are also made from White HDPE, but are not considered part of the SCORING PLATFORM. One edge of the Platform Ramp is mounted to the SCORING PLATFORM while the other is taped to the carpet using White or ALLIANCE-colored gaffers tape, depending on which edge is being secured. The result is a 16-degree, 7.125 in. incline. There is a shorter ramp on the short edge of the SCORING PLATFORM.

Figure 2-3: SCORING PLATFORM Size

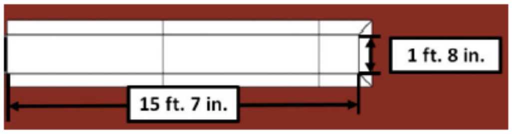
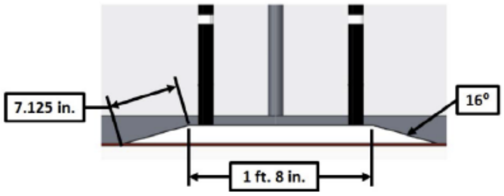


Figure 2-4: SCORING PLATFORM Geometry



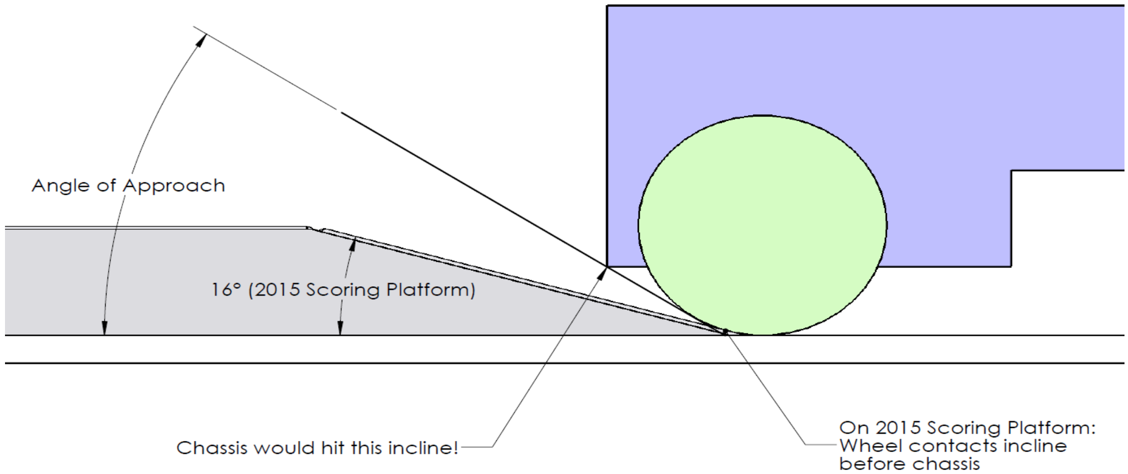
This is probably the most significant drivetrain challenge in the 2015 game. As discussed in "[Karthik's Strategic Analysis]," teams do **NOT** need to do this to be successful.

However, if your team wants to cross the scoring platforms, or climb the front of your robot up on a scoring platform from the side or end (maybe to drop off some Tote stacks) there are a few considerations to take into account.

The smoothest crossing will involve wheels solidly in contact at each stage without "rocking" from one set of wheels to another. We sometimes talk about the difference between a "smooth" crossing vs a "Dukes of Hazzard"-style crossing.

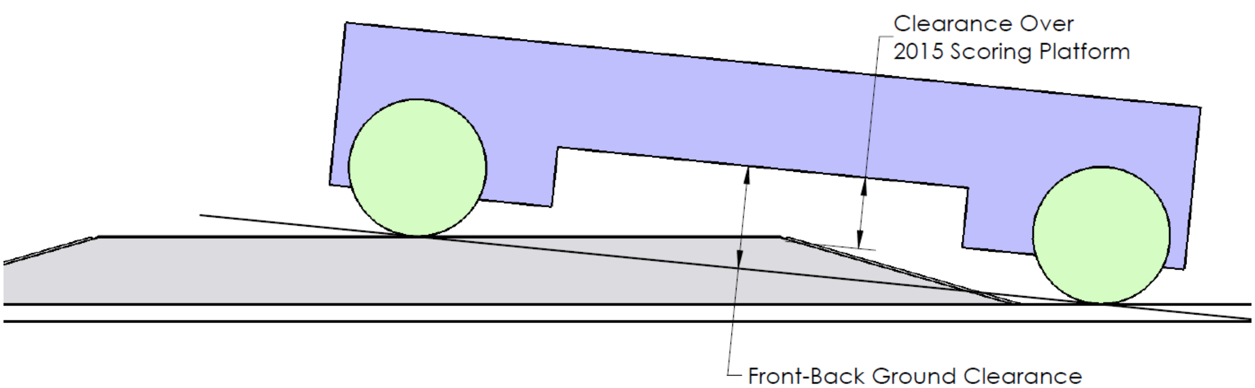
The first consideration for traversing a bump is the angle of approach and angle of departure of your robot:

The **angle of approach** is the steepest angle ramp your robot can drive up where the wheel still touches the ramp before the chassis. This is also the steepest incline your robot can drive off of without the front of the chassis scraping into the ground.

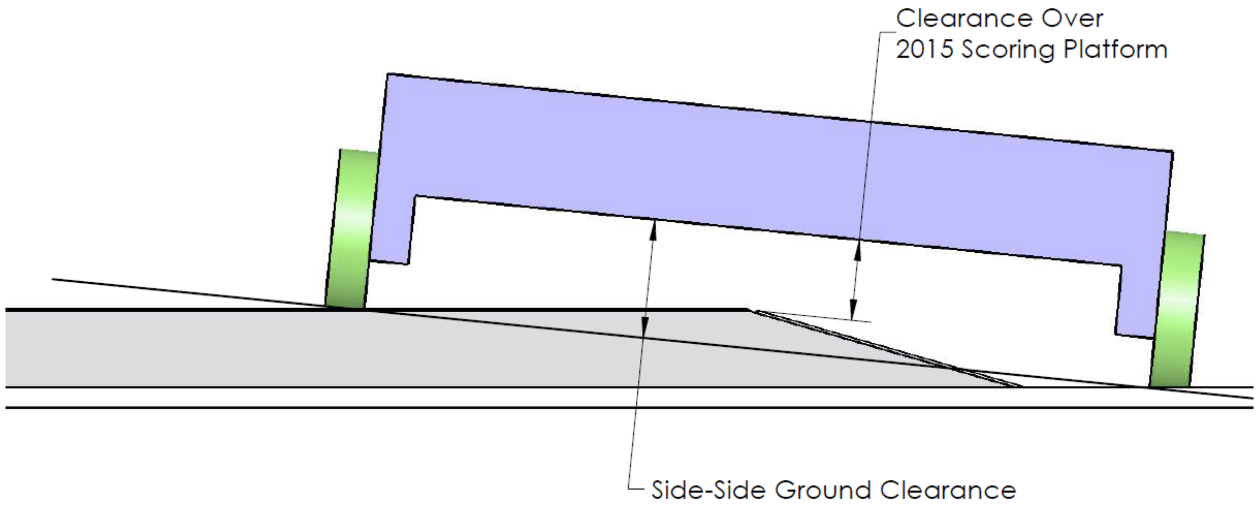


The **angle of departure** is similar. Usually, since FRC robot drivetrains are front-back symmetrical, the angle of departure is the same as the angle of approach. When the robot drives up a ramp the back end tilts closer and closer to the ground. The angle of departure is the steepest incline a robot can drive up where the “back end” clears the ground as it drives up. This is also the steepest incline your robot can drive off of onto level ground where its back end doesn’t hit the ramp behind it.

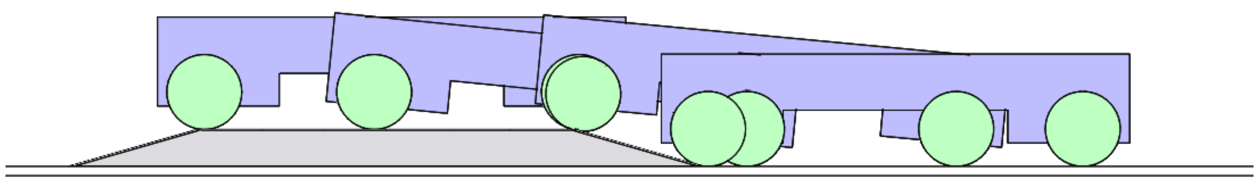
The next consideration for traversing a bump is the **front-back ground clearance**. When the robot is transitioning over the top of a bump, the bump moves up in between the wheels. The chassis must be designed so it does not scrape on the bump.

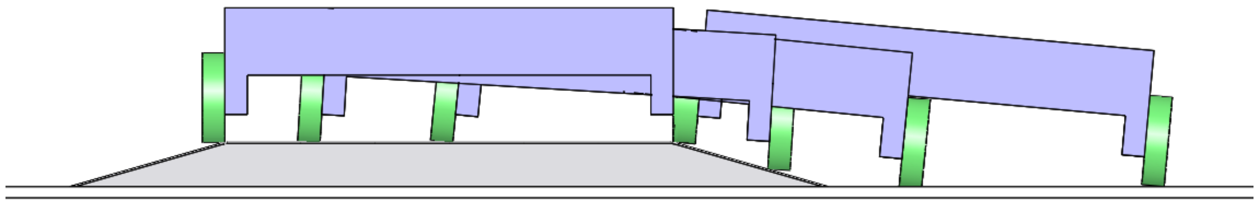


Similarly, if the robot ends up "straddling" the transition of the bump such that the right wheels are on top and the left wheels are on the ramp, the edge will end up in the middle of the robot. Designers need to take the **side-to-side ground clearance** into account.

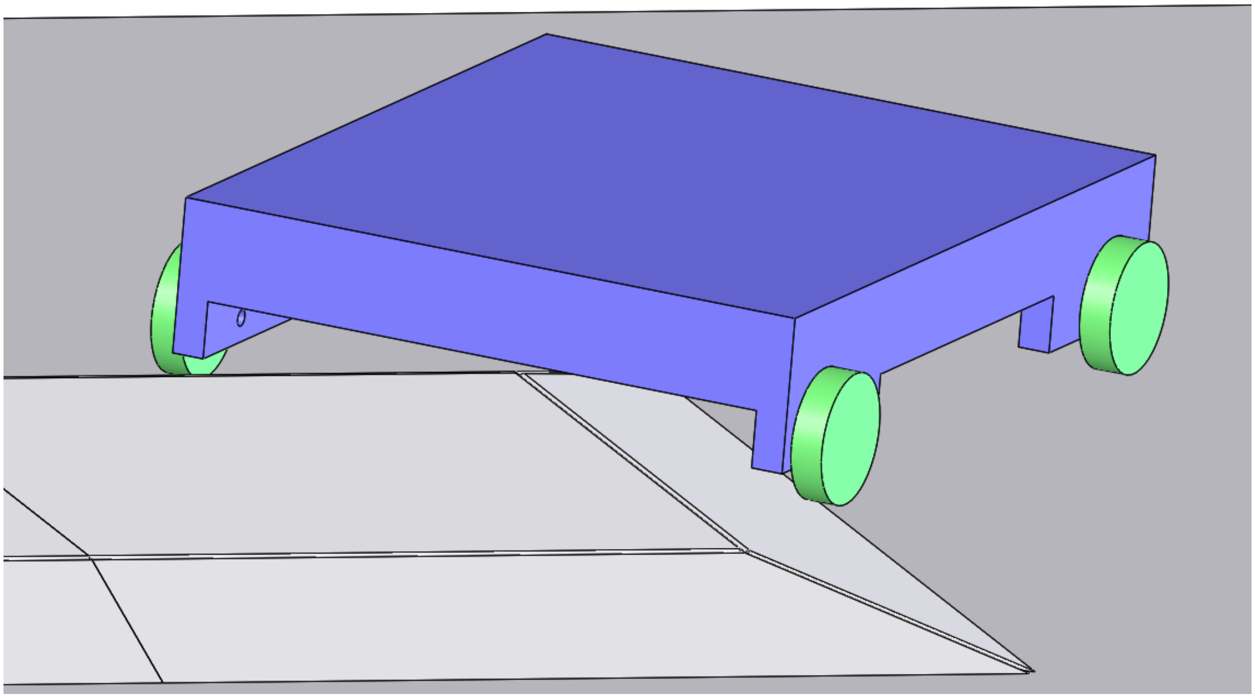


It is important to check the drivetrain as it transitions in each stage of crossing the bump.

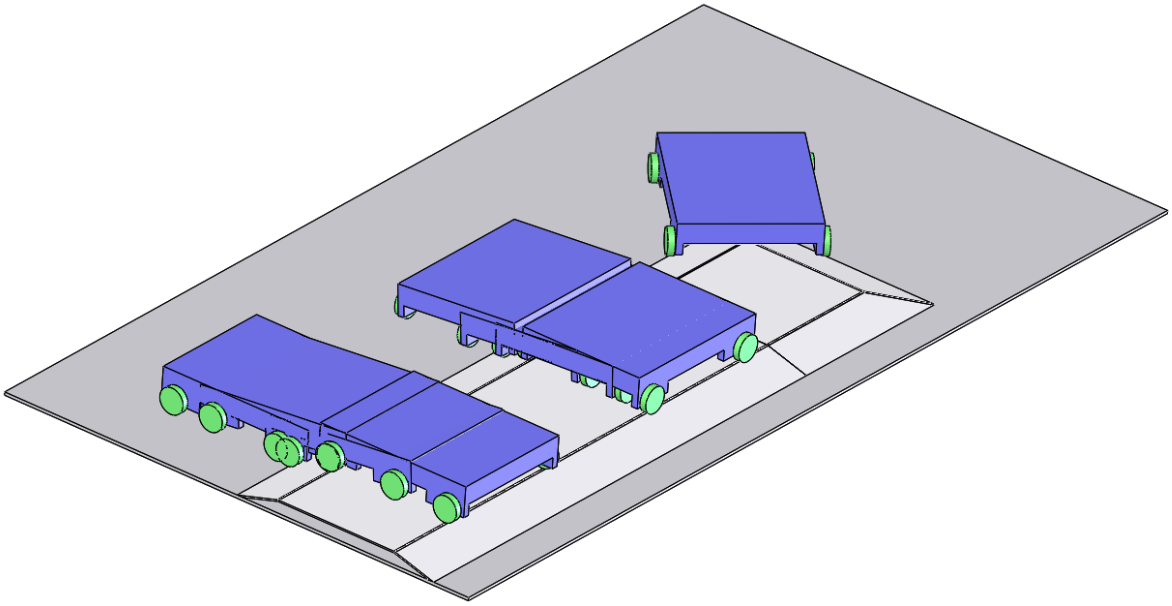




The scoring platform on the 2015 field adds further complication to the discussion since it has a "corner". You can see in the below image how the ground clearance & angle of approach changes in this orientation.



When we think about "testing", it is easy to be thinking about real-life drivetrains. As shown above, it is simple to test clearances in a 3D solid modeling program (or even with a 2D layout for some tests). We use a method we call "Crayola CAD" in which very crude CAD models are drawn to show the key dimensions and relations.



A Crayola CAD drivetrain is easy to “drag” over a virtual model of the field to see if it transitions properly.

So what happens if it doesn’t transition properly?

There are a few “easy” answers:

1. Increase the “ride height” by lowering the location of wheel axles in relation to the bottom of the chassis.
2. Use larger wheels.
3. Add more wheels to minimize gaps for interference.
4. Move wheels towards the front/back of the robot to improve angle of approach & departure.
5. Add “cut outs” in the chassis (as shown in the above “fake” example) to provide clearance.

Each of these solutions has pros and cons associated with it. Choose what works best depending on your specific strategy and design, play with it in Crayola CAD or build a mockup in real life and iterate until it goes over smoothly!

As discussed above, the scoring platforms are made from HDPE. When designing a drivetrain to cross the scoring platform, designers need to make sure they’ll have enough traction to get over. To simplify things, the ramps are only 7.125” long, which means a robot will probably still have wheels touching “grippier” carpet while it is climbing the “slippery” HDPE sides.

BOTTOM LINE: In reality, climbing these bumps shouldn’t be much of a problem as long as your robot doesn’t scrape too badly or beach itself.

One last point to make, when you’re firing up your drivetrain for the first time, and you’re testing to see how it transitions over the bump, remember one thing: center of gravity & weight play BIG roles in the way it will perform. Test your robot in “real life” configuration. Fully loaded, including any game objects it might be carrying.

This field has one other obstacle designers need to consider: PARTNER ROBOTS. This is especially important if you’re not crossing the scoring platforms. Make sure you think about traffic flow before you build an “aircraft carrier” robot and expect to drive it around with impunity – you have two partners who may also have aircraft carriers!

Turning Design & Holonomic Drives

As discussed above, this year's game has very limited interaction between "opposing" alliances, which results in a lack of defensive play. As such, robots don't have many of the same "needs" concerning pushing and holding position. The removal of this "requirement" allows teams to use a few drivetrain configurations which they previously would have ignored. In particular, configurations utilizing omni-directional wheels, mecanum wheels, and even casters can be viable depending on a team's specific requirements.

For more information on holonomic drivetrains, refer to Ian Mackenzie's great paper found here:

http://www.simbotics.org/files/pdf/omnidirectional.pdf

For details on drivetrain turning physics, check out these resources:

"Drivetrain Geometry & Turning" from the VEX EDR Curriculum

http://curriculum.vexrobotics.com/curriculum/drivetrain-design/drivetrain-terminology-and-turning

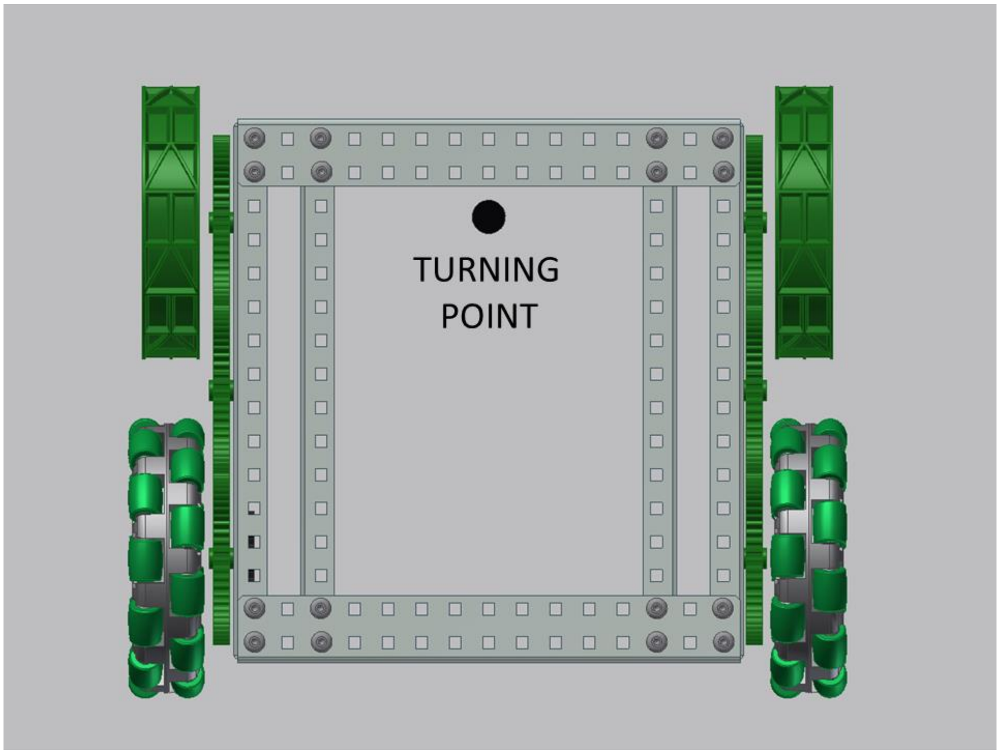
(Basic conceptual explanation)

Chris Hibner's "Drive Train Basics"

http://www.chiefdelphi.com/media/papers/1443

(Explanation of the formulas at play)

Lots of teams struggle with making their drivetrains turn the way they want. As seen in the above resources, adding omni-directional wheels to a skid-steer (skid-steer drivetrains turn like tanks) removes turning scrub and provides MUCH better handling.



In many games, teams will shy away from omni-directional wheels since they have the stigma of being "easy to push around" – that is not a concern this year.

Designers working on skid-steer drivetrains should STRONGLY consider omni-directional wheels as part of their design.

In addition, there are some aspects of this game for which holonomic motion is desirable. When stacking totes on top of existing stacks it takes time if a robot needs to "parallel park" to get in position. Swerve drives, mecanum drives, holonomic drives using omni-direction wheels, and H-drives are all very useful in this game, if they fit a team's strategy. Designers should be aware of how omni-directional handling can change as CG shifts (i.e. picking up 3 boxes on the front of the robot) or because a wheel was lifted off the ground (i.e. one wheel rolls up the scoring platform ramp before the others).

It is MOST important that teams pick the simplest drive which will accomplish their goals and which they can execute effectively. Drivetrain is NOT a subsystem where teams should "reach" beyond their capabilities.

Drivetrain Speed, Gearing & Power

As mentioned above, 2015 game's divided field and lack of defense reduce the need for robots to push in this year's game. In addition, robots will most likely be working in localized areas, not traversing over long distances; this greatly reduces the need for high top speed. Since robots will likely be required to do some precision maneuvering as part of their match strategy, it may be beneficial for drivetrains to be geared slower so they're inherently less "twitchy." (Software can be used to smooth things out for the driver, but there might be strategic reasons to mechanically help things out also.)

A reasonable top-speed for this game might be somewhere between 7 ft/sec and 11 ft/sec (free speed). This is much slower than many teams have geared in recent years.

Without high top speed needed, teams can gear slower. If they gear slower, they won't need as much motor power for "good" acceleration. For this game, the traditional 4-CIM motor drivetrain is almost more power than you need. Four Mini CIM motors or two CIM motors would provide enough power to achieve great performance, and would be lighter weight.

For quick reference, each Mini CIM motor can be considered about 2/3 of a CIM motor.

For more detailed analysis, refer to Paul Copioli's calculator here:

http://www.fightingpi.org/Resources/Business/MSC%20Seminars/2013%20Files/Useful%20Calculations.xlsm

Also see John V-Neun's design calculator here:

http://www.chiefdelphi.com/media/papers/2755

For more information on drivetrain gearing, refer to this section of the VEX EDR Curriculum:

http://curriculum.vexrobotics.com/curriculum/drivetrain-design/geartrain-design

Drivetrains for Recycle Rush – Final Thoughts

As discussed above, there are a lot of factors which need to be considered when designing a drivetrain for the 2015 game. Refreshingly, a few of the "historical" constraints have been removed. In addition several aspects of the game may shift a team's traditional design requirements. This is cool because it forces designers to discount their pre-conceived notions and it provides a fun thought exercise. We love fun thought exercises!

Lots of people ask "what do you recommend for this year's game?" The answer is always: the simplest drive that does everything dictated by your strategy. (See Karthik's Strategic Analysis). In our minds this probably means the following for most teams:

- Moving sideways is very helpful when trying to align & stack Totes
- Stick to a "traditional size" base – just because the rules allow for giant robots doesn't mean it is a good decision
- If you're gearing faster than 10 ft/sec free-speed, you're probably going too fast
- You should try to find a configuration which crosses the scoring platforms; using 6" diameter wheels is a simple way of accomplishing this
- Focus on reliability – you need to maximize every match, not just "escape with the win".

Whatever you choose to do, focus on that last point. Consistency is critical in 2015. Good luck to all teams! Send any comments or questions to prosupport@vex.com for more help.