FRC TEAM 1325 INVERSE PARADOX:

A GUIDE TO ROBOT DEVELOPMENT

Hi everybody, thanks for choosing to spend your morning with me! I have no idea why there are so many 1325 students here, guess you guys just really love me rambling about robotics? I will be taking the next 60(ish) minutes of your time to talk about how to develop a robot. This will be more of a talk format, I have some slides and have reserved the last 15 minutes for any questions you have about robot development or general questions about FRC.

I see many familiar faces but most of you are wondering who I am? My name is Bilal Qadar. I am a 4th year student at UofT studying computer science and math. I was the former lead design mentor and drive coach of FRC Team 1325. I am someone who has learned the very hard way the consequences of bad robot development. I have created this talk based on my experiences and what worked/didn't work for my team. I encourage everyone to take the principals of my talk and apply them to your own team!

I will be talking about _ things in the next 60 minutes.

1. How to set yourself up for success before the season even begins
2. How to evaluate the performance of your robot
3. A methodical process for upgrading a system
4. How to create effective tests for a mechanism
5. How to use data to make decisions about mechanisms
6. How to manage unbag time

So, before I delve into the competition season, we need to talk about the weeks leading up to build season and kickoff itself. Now yes, I know the title of my "talk" said COMPETITION SEASON. So why am I bringing kickoff up? Because this is the time where you get to decide how easy or hard you will make your life later.

Firstly, choosing your events. Ontario is a district system meaning you will get to compete at least 2 events. Choosing the weeks when you compete can make a huge difference to the success of your season. There are 2 main factors to consider:

1. The week number you are competing at
2. The level the game will be played at

So, I will start by explaining number 2. The game you play week 1 will not be the same game you play week 6. This is a consequence of drivers getting better, strategist getting more familiar with game flow and robots getting dialed in. The benefit of going to an early week is your team can capitalize on teams still finding their footing. Usually in week 1 if a robot is consistent and efficents at only 1

component of the game, that team can contend for a win. ie) 4039 2018 who ran this strategy perfectly. They nearly won there week 1 and week 3 events with a switch and exchange robot. So why compete at a week 6 at all? It's just harder!

Also, keep in mind the earlier the week the less time you will make to make changes to your robot should it not perform.

This ties into point number 1. You have more time to develop your robot, more teams have released their robots, so you have a better idea of modifications you can make and most importantly you have had the chance to watch many matches. You aren't 'going in blind'. For example you could reverse engineer the scale switch algorithm (well until first changed it IN WEEK 6) :'(Unfortunately, the consequence is the game is much more competitive.

Any questions about anything so far?

So, I am going to talk for a second to teams that have the ability to go to a third event. DO IT! Yes, you will not get any points from the event, BUT this is an event where you can test your robot before DCMP and it is risk free. You can try crazy things and have nothing to lose. Usually a good idea to make this event a very difficult one to see how your robot stacks up in a later week. Team 1325 did that last year, and it paid off big time. Everything that could have gone wrong did at that event, but this allowed us to find solutions to all these problems before DCMP. If you are more interested in my thoughts on a 3rd event speak to me after.

So, moving along to kickoff. So, once again 2 things to consider here that will make your life either easier or harder later in the season.

1. Your strategy
2. How you design the robot

So, I am not really going to talk about how to pick a strategy or how to choose a mechanism. If you are interested in that feel free to attend Malavya and Shaqueeb's talk later on today. So, with strategy I am going to put up the golden rule:

STAY WITHIN YOUR ABILITIES

Set very clear goals for your season. More specific then ie) win. If you set goals for yourself when you are making decisions about the direction you take the robot you have something to evaluate it against.

So, what was 1325's goals for the 2018 season? Yes, we wrote WIN A CHAMPIONSHIP very big on a whiteboard. But we also wrote:

1. Seed top 3 at a District event; with a **CONSISTENT** and EFFICIENT machine
2. Win a District event, not only being fastest on scale cycles but by making clean stacks on scale
3. Being top 3 best **SCALE** robots at DCMP

Also, on the whiteboard was many awards related goals, but that is a whole different talk.

Notice we didn't say top 3 best robots. That wasn't our goal, we wanted to make sure our robot was the best **SCALE** robot it could be, and every change that went into offset was make it a better scale scorer

But also leave room to improve later on the season. Ensure your strategy has some flexibility built into it. As the game progresses ensure that your game strategy won't stop you from improving. Taking the 2018 game for example, if you make a switch and exchange robot leave the potential to do something later in the season. This is an element of the game that although you may not be the #1 concern for you, you can focus on later when your switch and exchange abilities are up to what you want, or in other words your upper limit. I want to stress though

ONLY DO THIS WHEN YOUR MAIN METHOD OF SCORING IS IN YOUR MIND PERFECT

As an example, 1325 in 2018 had intentionally left room on our 2018 robot to implement a fork/ramp buddy hang. (Our robot was a little heavy why it never happened) but it was a consideration that we had just in case we hit our "upper limit". Once again 4039 did something similar coming out with a scale add on just to put one cube on later in the season.

Okay, so a little bit about robot design that ties into what I just said above. Set clear goals for every mechanism on your robot just like you did for your season. Think about your season goals when making these goals. Malavya and Shaqueeb are

going to talk a lot more about this later on. But I think it's important to mention it twice. Have a **NEED**, **WANT** and **WISH.**

Need - What does this system need to do in order for you to achieve your season goals
Want - What would you like this system to do, but it's not the #1 priority when making the mechanism, but something you would like it to do.
Wish - What in a perfect world would you like this system to do? Usually more like a fantasy.

I will be using the example of a 2018 intake for most of this "talk". So, what was 1325's intake needs, want and wish?

Need - Have the cube enter the robot in a PREDICTABLE way every single time.
Want - Intake the cube in sub 1 sec from the time ANY spinning component comes into contact with the cube. Have the ability to reverse the intake and spit the cube back out.
Wish - Intake a cube in any dimension

Not only does this give you direction when creating a design, it more importantly will give criteria for you evaluate your robot's performance later on in the season.

Design your robot in a way that allows for modifications. Does anyone know what modularity means?

Modularity is the degree to which a system's components may be separated and recombined, often with the benefit of flexibility and variety in use.

say this very cautiously The second thing is, it's very hard to make 1 system do 2 things very well. Yes, there is exceptions like intake and outtakes last year or hangs but a robot that is very integrated can make robot development very hard. This is because later in the season if you want to make a change to one system you need to consider how it will affect the other mechanisms on the robot. This is like "putting all your eggs in one basket" if your multiple robot functions rely on one mechanism. If that mechanism has a flaw it will take out half your robot with it.

This means a system can easily be removed or changed without affecting the use of another system. A good example is an elevator gearbox. If when you design it into the robot in a way that to remove it requires entirely taking apart your elevator,

should you decide to let say change elevator speed it will be very difficult. The reason i used this as an example was because 1325s 2018 elevator gearbox was extremely difficult to remove, and we had to do it many times. I think any 1325 student in the room can attest to how hard it made our lives. Think about clearance holes so you can fit an allen key or a ratchet in a place. The 2 minutes it takes to drill a clearance hole for a tool during build season will save hours later on in the season.

Also, please, **ALWAYS PUT A PNEUMATIC SYSTEM ON THE ROBOT!** Pistons usually become saviours when making changes to a robot or developing new ideas. Think of it this way, it's much easier to remove one then add one later in the season.

Any questions thus far? Cool.

So, a note on practice bots. Show of hands how many teams make a practice bot? Does anyone not know what a practice bot is? Cool.

If you have the resources to make a practice bot, it is very worth it. But you can still successfully develop a robot without one. Since more people do/don't make one, ill focus on that. Those of you who make a practice bot. Ensure they are identical, down to the motor controllers if you can. A worst nightmare situation is when your practice bot behaves differently to your competition unit. Because it negates the point of having a practice bot if you can't test changes on it, knowing your bagged robot will behave differently.

To anyone who doesn't make a practice bot that is okay. But, to develop a robot you need a platform to test. A drivetrain, that is around the same speed and wheels as your competition robot is extremely useful. Also building a spare version of your main scoring mechanism is worth it. DO NOT BUILD AN ELEVATOR because there isn't much to improve upon, i mean it goes up and down. Do build for example a spare intake if you are able too. A spare intake mounted on a drivetrain is useful because 1. You can iterate your mechanism. 2. You can test and modify autonomous paths. 3. **Driver practice.** I could do a whole talk on Driver practice, I'll spare you all but a good driver and take a robot that's mediocre into one that wins.

So, we are all set to fast forward to after your first event. Your robot either did amazing or did not so great! Doesn't matter the process is still the same!

The day after the event there is one really important thing you need to do which is, write down every problem your robot had throughout the event, a good practice is to note them down during the event but let's be honest no one has time for that. Now, although time is precious in FRC usually taking a day or at least a few hours to not think about robotics is a good idea, obviously dependant on how much time you have before your next event.

Now, a common mistake made is to just start building and making changes to the robot. Yes, this can be successful, but a better way is to have a meeting with your team. You need to choose a direction to take the robot in. Here is what you need to do in this meeting.

1. Revisit your MECHANISM need, want and wishes. Now that you have played the game does your mechanism NEED to do something else? Would you like it to do something new? Re-evaluate these while remembering what your season goals were.
2. Evaluate how well your robot achieves the need, wants and wishes. Is your intake doing everything that it NEEDS to.
3. List any specific problems the robot had at the event. Was the set screw in a versa planetary coming lose? Was the cube jamming if you hit it off center?
4. Now work backwards to brainstorm solutions. Firstly, find solutions to fix the issues you had at the competitions. These can be robot mechanical changes, software changes or something as simple as “add to checklist”
5. Look at your revised need wants and wishes. If the mechanism doesn’t do everything it needs to what changes can you make it achieve that need. Look at other teams who have a similar need to you. What do they do differently? How can you adapt their solution to work on your robot? If the mechanisms complete all the needs to the degree you want, what can you do to better achieve the wants for your system.
6. Lastly, assign people who are responsible from each change and very important **ESTABLISH A TIME-LINE!** If you have 2 weeks before your next competition gives a week to implement the solution and reserve the second week for testing. Establishing clear deadlines for prototyping, design and build of a solution makes this process much smoother.

Now, your timeline doesn’t necessarily have to be before your next event. Redesigns or lengthy and difficult implementations can be carried out over a few weeks and not implemented right away. This gives you more time to develop a solution, while also letting you focus on more crucial issues or modifications.

Planning very far ahead is always encouraged. This was a picture of the blackboard 1325 had for the 2018 season. Not only does it say what needs to be done, it lists the priority based of when we need it completed.

Any questions thus far before I move on to when to give up on a subsystem? Cool. So, you at some point in your season might end up at a point where a subsystem on your robot refuses to cooperate. You face a question, keeping putting time and effort into getting the system up to where you want it, OR scrap it and start from scratch. You need to evaluate its potential, as usually it's much easier to fix a system them start over. Some things to consider:

- Is the issue fundamental? This means is the issue with the system a problem with its concept? This could be something like does the idea of a catapult just not work for the 2017 Steamworks game. It could be are you trying to intake the cube from the top face rather than the sides? Structural issues also usually require full redesigns, but efforts can be made to reinforce a system after the fact. If the answer to this question is yes, you should strongly consider starting it over.
- If the answer to the above question is no, ask yourself another question. Do you want to redesign the system because you either have an idea to achieve more wants or a wish? Did you see a concept that another team has and interested in implementing it? If the answer to these questions are yes, you should consider the redesign. But ensure you are getting something out of it!! Relate this back to your need, want and wish. If the new system will help you achieve something that isn't on your list, although it's a cool idea it may not be for you team.
- Remember your timelines. It is very close to impossible to redesign a full system in less than a week. If your turnaround is 3 days, it's better to just stick with what you have and focus on fixing a system you are familiar with.
- **Even though 1114 did it, doesn't mean it will work for you!** This doesn't mean you can't adopt the concept of what they did and make it work for you. **ALWAYS TEST AN IDEA YOURSELF BEFORE FULLY IMPLEMENTING IT!** No matter how simple a concept is, it's extremely important to fully understand how it works by testing it because more often than not there will be small considerations that you need to be aware of. Even if this means making a 1-hour wooden prototype that's perfect. Always know what you are getting yourself into!

This meeting allows you to have a game plan for the modifications to your robot. Time is a valuable resource and you don't want to waste it by making changes that have no direction and won't be beneficial to the robot.

So, you are designing solutions to your problems, you have criteria it needs to meet, and you have a timeline for when you need to have the change implemented. So, the next part is to create the solution. Some things to keep in mind when developing your solution:

- You have only a 30 lbs withholding allowance. So, whether you are modifying something or making a new mechanism the combined weight of everything going on the robot must be less than 30lbs.
- Remember you only have 6 hours to make a change to your competition spec robot. This is where the considerations you took at the beginning of the season will start to be seen. I will talk more about how to manage unbag time in a few minutes.
- Usually the simpler a solution the better, less things to go wrong and less things to modify.

Now, comes the most crucial part of developing a robot. Make a change, **TEST**, repeat until perfect (or you run out of time).

Does anyone know what a bias is?
A bias is prejudice in favor of or against one thing, person, or group compared with another, usually in a way considered to be unfair.

Everyone has them, whether it be because you devoted a lot of time into a system, or the preconceived notion that an idea won't work. IDK you have something against compliant wheels. When testing a system every effort to eliminate biases should be done. Small things can be done to do this, 1 having multiple people testing a system, some of which are COMPLETELY neutral. 2. When taking data on a system take the largest data set possible. If that means intake a cube 100 times, by all means do it. Lastly you want to ensure all data is quantitative not qualitative. You want to use numbers to decide not your feelings.

I have said it many times you want to remember your need, want and wish. You want to design tests that will give numbers to compare to your control (the system that was on the robot before). If you make a change to your intake for example to achieve a want, is it important to test the need again? Why?

Yes! This is because any modification, no matter how minor can have unintended consequences. An example was 1325 changed how we hold a cube in our outtake but had the unintended consequence of making it harder for us to intake cubes against the switch. Now you don't need to retest everything extensively but be sure to check. See this is where not having a super integrated robot makes life easier.

Thinking back to my intake example, what would be some good tests for this?

1. Timing how long it takes to intake a cube from the moment it is touching a wheel.
2. Using a set of 20 cubes, send them into the intake in changing the angle of orientation 10 degrees every time and see how many jam?

These are very simple things to do and can really help you evaluate whether a change was beneficial or worse. Follow this process with anything from a mechanical to a software change.

So, time to see if anyone was listening.

I would like everyone to try and design 2 tests for a 2016 robot's flywheel. (shooting dodge balls into a goal). Here is the Need, Want and wish - Need - shoot a ball into the high goal regardless of ball 'wear/degradation'. Want - Score a ball from anywhere +/- 3 feet from batter. Wish - Score a ball from defenses. So, you added an articulating hood, so you could score from defenses and the batter. What are some tests that we can use to test this modification.

1. Shoot 10 balls from very stiff to not stiff starting from -3 feet from the batter.
2. Repeat test above in 1 or half foot increments back from the batter until +3 feet from batter
3. Repeat above test from the defenses right in front of the goal.

Very good, but oh no! You found that 6/10 balls went in from the batter and 3/10 from defenses. Compared to before it was 10/10 from batter and 0/10 from defenses. Is this change worth it? Why?

Hm, using the wonderful technology that is a smartphone using slow motion you notice that the piston actuating the hood isn't strong enough causing it to flex on the shot. Have a meeting with your team and discuss potential solutions.

(Larger bore cylinders, more cylinders, **INCREASE LEVERAGE**, locking mechanism).

What do you do after you have implemented your solutions?

TEST!

You found that you are at 9/10 from batter and 8/10 from defenses. Is the change worth it now?

So, the last part of my talk before questions will be how to manage unbag time. You and your team have done it! You have many modifications you want to make to your robot and your 6 hours is about to start. What are some things you can do to make this process smoother? HAVE A PLAN OF ATTACK. Every moment of your unbag should be planned. Everything that is needed to complete the unbag whether it be tools, people, materials, or new mechanisms should be prepped and ready. Having a document entailing exactly who will be doing what, what changes can be going on simultaneously and a clear list of what is to be done. You never want your unbag to fully be utilized making changes. Always remember to leave time to test the robot and time to inspect the robot for wear. Unbag time is the perfect time to do some maintenance. ie) Grease Gearboxes, ensure all sensors are plugged in, check fasteners are tight.

Another thing is you don't need to do all 6 hours in one day. Doing smaller increments of 2 hours over 3 days can give you time to re-evaluate what need to be done or think through any issue that arises. Unbag time should be organized chaos :P

And there we are your second competition and the robot are all ready to go! Before we go into questions, this process doesn't have to be reserved for competition season. I did this talk in the context of it being between 2 competitions, but this process can be used when making changes to prototypes in week 1, evaluating your performance after watching a week 0 event. I can't stress this enough, planning out your movements can save many headaches later in the season. Also, always stay within your means, when you start to get overly ambition is when things can go very wrong.

So, this is a link to my ramblings. I wrote "blog" style entries after every one of 1325's events in the 2018 season outlining what the changes we needed to make

and solutions. If you are interested in reading about 1325's 2018 development journey feel free too. One thing to note, I am not funny, but tried to make it fun to read. Soooo you have been warned.

Does anyone have any questions about anything FRC?

Thanks for coming, this is my contact info should you have a question for me even if it's through the season feel free to email. Studying gets boring so I like answering robotics questions.