Effective *FIRST* Strategies for Design & Competition

April 16, 2025

FIRST Championship

Karthik Kanagasabapathy
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About Me

- 26 years of *FIRST* experience
- Lead Mentor for Team 1114, 2004-2016, Team Advisor 2017-present
  - 56 Blue Banners
  - 2008 World Champions, 2010 & 2014 World Finalists
  - 2012 Championship Chairman's Award
- 2005 Waterloo Regional Woodie Flowers Finalist Award
- TEDx Speaker - http://youtu.be/MfC3JdkEVgQ
- Host of past ESPN & CBS High Robotics Specials
- Lead Designer or Design Team Member of 21 large scale competitive robotics games played by over 600,000 students globally
- Current – Director of Programs & Strategy – *FIRST* Canada

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FIRST CANADA

Then & Now – 20 Years

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Outline

What are we talking about?

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Outline

- Strategic Design
  - Game Analysis
  - Golden Rules
  - Trade Offs
- Scouting
  - Case Study on Data
  - Match Scouting
  - Alliance Selection
- Match Strategies
  - Match Plans
  - Coaching a Match
  - During a Match
  - Elimination Rounds

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Quotes

That make me think and feel things

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Quotes

Enthusiasm is one of the most powerful engines of success. When you do a thing, do it with all your might. Put your whole soul into it. Stamp it with your own personality. Be active, be energetic, be enthusiastic and faithful and you will accomplish your object. Nothing great was ever achieved without enthusiasm

— Ralph Waldo Emerson

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Quotes

[Folks], we are going to relentlessly chase perfection, knowing full well we will not catch it, because nothing is perfect. But we are going to relentlessly chase it, because in the process we will catch excellence. I am not remotely interested in just being good.

— Vince Lombardi

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Quotes

There are two ways to compete in this world. You can drag your opponent down, or you can rise above them; which is better for society in the long run?

— John Abele

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Quotes

Limits, like fears, are often just an illusion

— Michael Jordan

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Strategic Design

Where it all begins

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Strategic Design

- Designing and building a cool robot is a lot of fun
  - Designing and building a cool robot that does well in competition is even more fun
- Very hard to go through the build process without a concrete aim
  - The clear choice is success in competition
  - Lots of other (secondary) objectives: aesthetics, design elegance, coolness factor, etc.
- Beware of the “cool factor”
  - It can be fun, but sacrificing effectiveness hurts your partners

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Game Analysis

- Read the rules!
- Examine every possible way to score points, no matter how obscure
  - Full Court Shooting (2013), Jumping Robots (2022), Passing (2024), Fans (2024)
- Examine every possible way to prevent your opponents from scoring
  - Capping robots (2004), Giant Walls (2013 & 2025)
- Understand the ranking system
  - e.g. Win-loss-tie, loser's score, own score plus double the loser's score, Coop, no winning, etc.
    - Paradigm shift!!! (2015)
    - Designing for RPs – 6 vs 4
- Consider possible strategies
  - Leads into overall robot designs

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Chokehold Strategies

- A strategy which, when executed, guarantees victory, independent of any action by your opponents
- Determining if one exists should be the first step in game analysis
- *FIRST* tries to design games with no reasonable chokehold strategy
  - Possession limits make chokeholds nearly impossible
- If one exists, it will be very difficult to perform
  - Pulling three goals - Team 71, Beatty & Hammond (2002), Deflecting Balls? (2010)
- Try to find one single, finite task that overwhelms all other possible ways of scoring

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Cost-Benefit Analysis

- For each task you must compare the difficulty of accomplishment to the reward for doing so
  - Laps vs Hurdles (2008)
  - High Grid vs Low Grid (2023)
  - Trap is a trap? (2024)
    - This is where the strategic value vs. coolness factor decision often pops up
- The best tasks to perform are those which are relatively easy, yet provide big points
  - Links are points!
- Remember denying your opponents 10 points is just as good as scoring 10 points (at least in terms of win/loss)
  - Descoring/defending often much easier than scoring (2003, 2013)

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Priority Lists

- Two separate lists
  - Desired robot qualities
    - Things like speed, power, agility, centre of gravity
  - Desired robot functionality
    - The things you want your robot to be able to do
      - Shoot balls, climb bridges, traverse field
- At this point you can merge the two lists, and decide on a drive system and functionalities
  - Swerve? Should you do it
    - Yes
- This list determines all direction of design for the season

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Priority Lists

- What should be #1?
- What should be #2?
- What should be #3?

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Priority Lists

- What should be #1?
  - Move
- What should be #2?
  - Acquire/Release
- What should be #3?
  - Score

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Simplicity & The Golden Rules

- Golden Rule #1: Always build within your team's limits
  - Evaluate your abilities and resources honestly and realistically
  - Limits are defined by people power, budget, experience, time
    - These are real!
  - Avoid building unnecessarily complex functions
  - On the other hand, as you get more experienced, start cautiously pushing a few boundaries

- Golden Rule #2: If a team has 30 units of robot and functions have maximum of 10 units, better to have 3 functions at 10/10 instead of 5 at 6/10
  - Define what a 10/10 function is!
    - "Do the thing fast", minimal lineup, in and out, automation

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Tradeoffs

- The key to deciding upon a design is to evaluate the tradeoffs
  - e.g. Speed vs. Power, Complexity vs. Durability, High CoG with more scoring vs. Low CoG with less scoring, Wide vs. Long, Swerve vs. Tank
- Making the right choices based on your analysis will determine the fate of your season
  - Make sure tradeoffs are consistent (hard to do when the design is always changing!)
- Remember the Golden Rules – Teams who try to do more than they're capable of tend to fail
  - There's no shame in building a simple robot!

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Tradeoffs

- Try to maximize functionality with simple additions or modifications to mechanisms
  - Score out of an intake, instead of a intake loading a scorer
  - Intake as a device to line up your robot
  - Be careful – hard to change one part without affecting the other
- When making tradeoffs, remember your initial priorities!
  - Let your strategic priorities dictate design

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Other Strategic Design Tips

- This strategic analysis is a MUST
  - There's a tendency to skip this stage, and to head straight into design and implementation
- You must know what you want to do before you can figure out how to do it
- Be realistic when evaluating strategies
  - Rules of thumb
    - Elite teams can do ~10 full field cycles per match (cpm) in perfect conditions (pc)
      - The best teams will do this only a handful of times in a season
      - These numbers have gone up
    - Middle tier teams can do 5 cpm in pc
      - Middle tier teams usually average 2-3 cpm in matches over a season
    - BE REALISTIC

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Cycling Rule of Thumb

- 10-5-2-1 (used to be 8-4-2-1)
- Elite team (99th percentile) is usually around 10 cpm in perfect conditions
  - Probably will average 8 cpm
- Good team (86th percentile. i.e. 1 sd above mean)
  - Usually averages around 4-5 cpm
- Average team (50th percentile)
  - Usually averages around 2-3 cpm
- Below average team (25th percentile)
  - Usually averages around 1 cpm
- What the heck happened this year?

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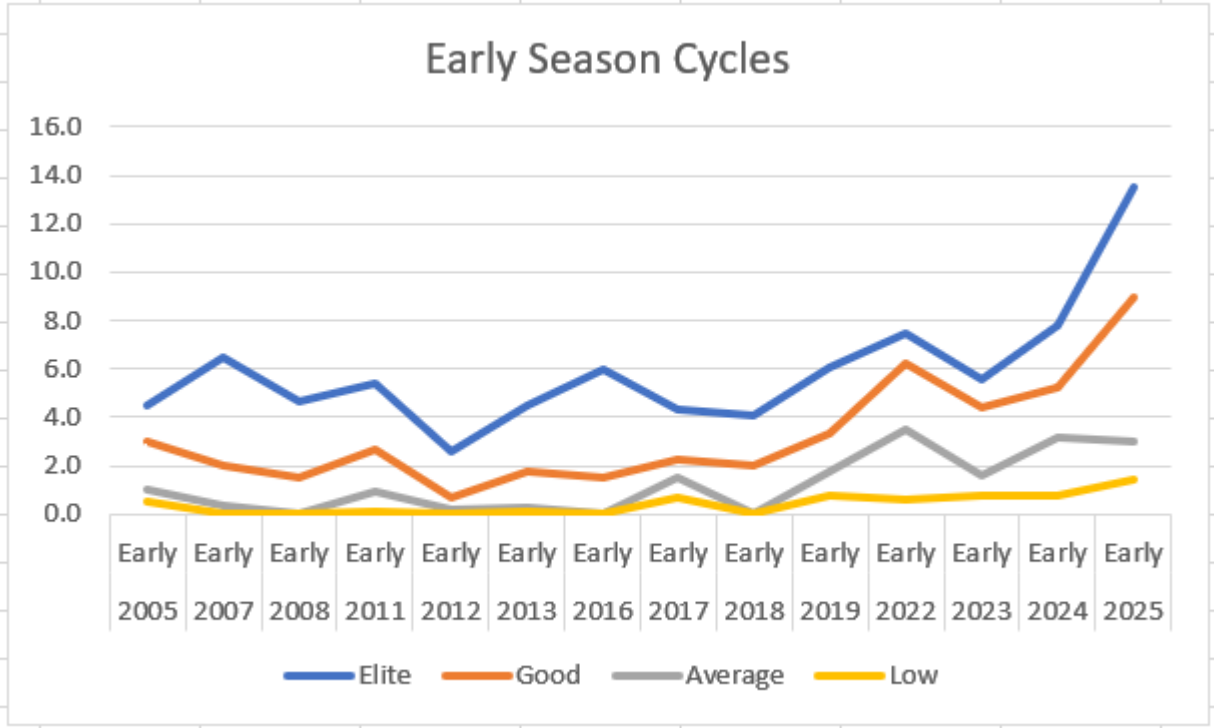
Cycling Rule of Thumb

Year	Portion	Elite	Good	Average	Low
2005	Early	4.5	3.0	1.0	0.5
2007	Early	6.5	2.0	0.4	0.0
2008	Early	4.7	1.5	0.0	0.0
2011	Early	5.4	2.7	0.9	0.1
2012	Early	2.6	0.7	0.2	0.0
2013	Early	4.5	1.8	0.3	0.1
2016	Early	6.0	1.5	0.0	0.0
2017	Early	4.3	2.3	1.5	0.7
2018	Early	4.1	2.0	0.0	0.0
2019	Early	6.1	3.3	1.8	0.8
2022	Early	7.5	6.2	3.5	0.6
2023	Early	5.6	4.4	1.6	0.8
2024	Early	7.8	5.2	3.2	0.8
2025	Early	13.5	9.0	3.0	1.4
Average	Early	5.9	3.3	1.2	0.4



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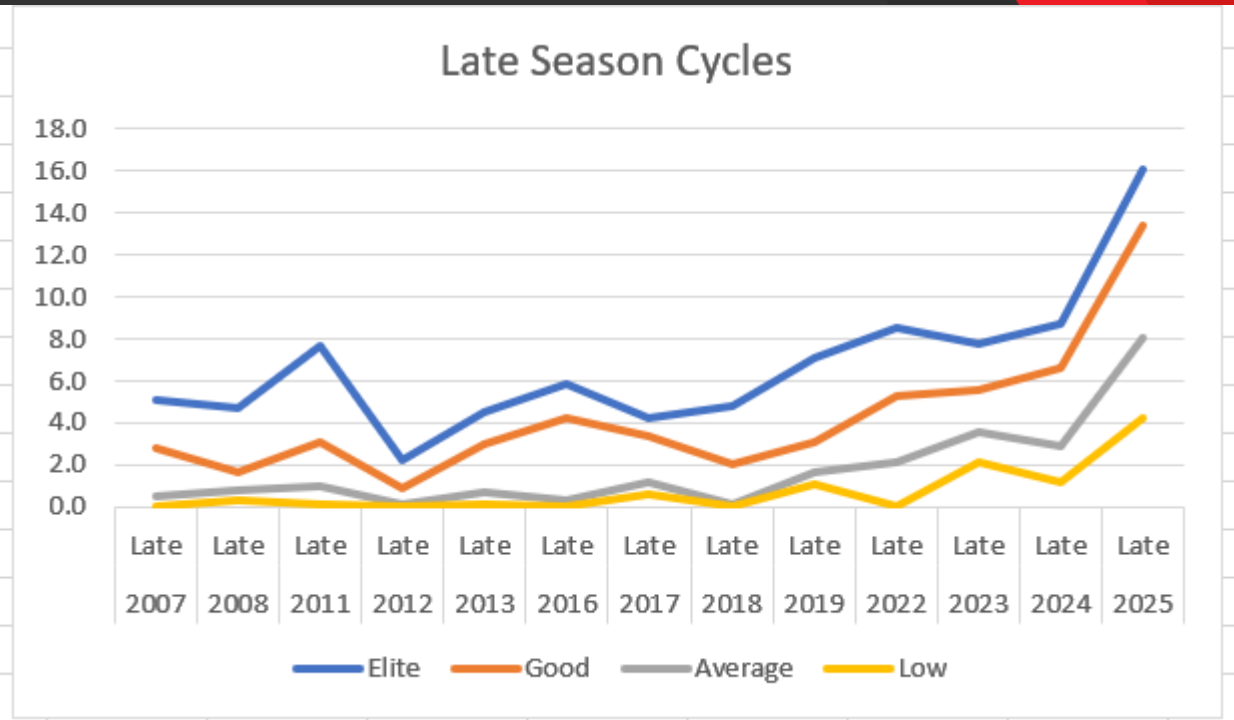
Cycling Rule of Thumb

Year	Portion	Elite	Good	Average	Low
2007	Late	5.1	2.8	0.5	0.0
2008	Late	4.7	1.7	0.8	0.3
2011	Late	7.7	3.1	1.0	0.1
2012	Late	2.2	0.9	0.1	0.0
2013	Late	4.5	3.0	0.7	0.1
2016	Late	5.9	4.2	0.3	0.0
2017	Late	4.2	3.4	1.2	0.6
2018	Late	4.8	2.0	0.1	0.0
2019	Late	7.1	3.1	1.7	1.1
2022	Late	8.5	5.3	2.1	0.0
2023	Late	7.8	5.6	3.6	2.1
2024	Late	8.7	6.6	2.9	1.2
2025	Late	16.1	13.4	8.1	4.2
Average	Late	6.7	4.2	1.8	0.7



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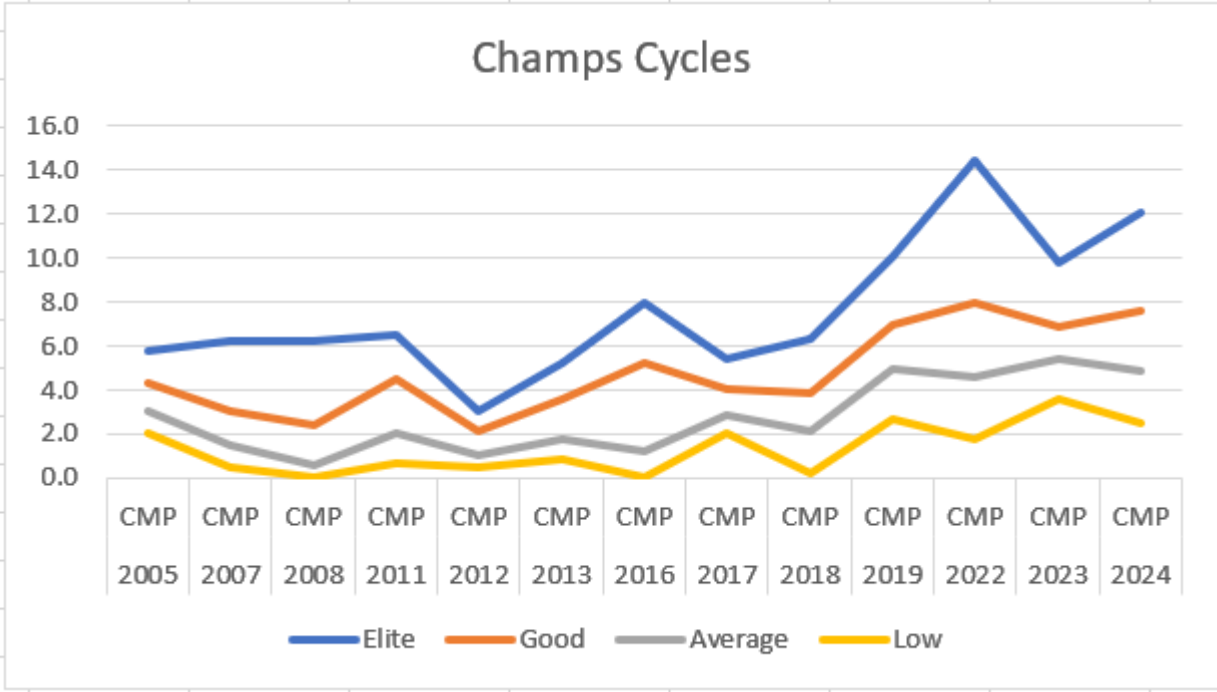
Cycling Rule of Thumb

Year	Portion	Elite	Good	Average	Low
2005	CMP	5.8	4.3	3.0	2.0
2007	CMP	6.2	3.0	1.5	0.5
2008	CMP	6.2	2.4	0.6	0.0
2011	CMP	6.5	4.5	2.0	0.7
2012	CMP	3.0	2.1	1.0	0.5
2013	CMP	5.2	3.6	1.8	0.9
2016	CMP	8.0	5.2	1.2	0.0
2017	CMP	5.4	4.0	2.9	2.0
2018	CMP	6.3	3.9	2.1	0.2
2019	CMP	10.1	7.0	5.0	2.7
2022	CMP	14.4	8.0	4.6	1.8
2023	CMP	9.8	6.9	5.4	3.6
2024	CMP	12.1	7.6	4.9	2.5
Average	CMP	7.6	4.8	2.8	1.3



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Scouting

How to get a leg up

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Scouting

- An area that is often neglected by many teams
  - Offers a great opportunity to get a leg up on the competition
  - Excellent way to involve more students in the competition
- Crucial for two main reasons
  - Predict your opponent's strategy for future matches
  - Essential for alliance picking
    - Especially crucial in getting a good second-round pick

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Case Study on Data

- Carter Racing has a massive race in an hour in front of many sponsors on live TV
  - If they race and do well they'll pick up sponsorships to cover the team for years
- Problem: in seven of the last twenty-four races, they've had an engine blowout
  - A failure on live TV will jeopardize any future sponsorships and the future of the team
  - Plus general safety risks
- The team has a hunch about the failures; They might be related to colder weather
- The analytics group has put together a graph to test this hunch

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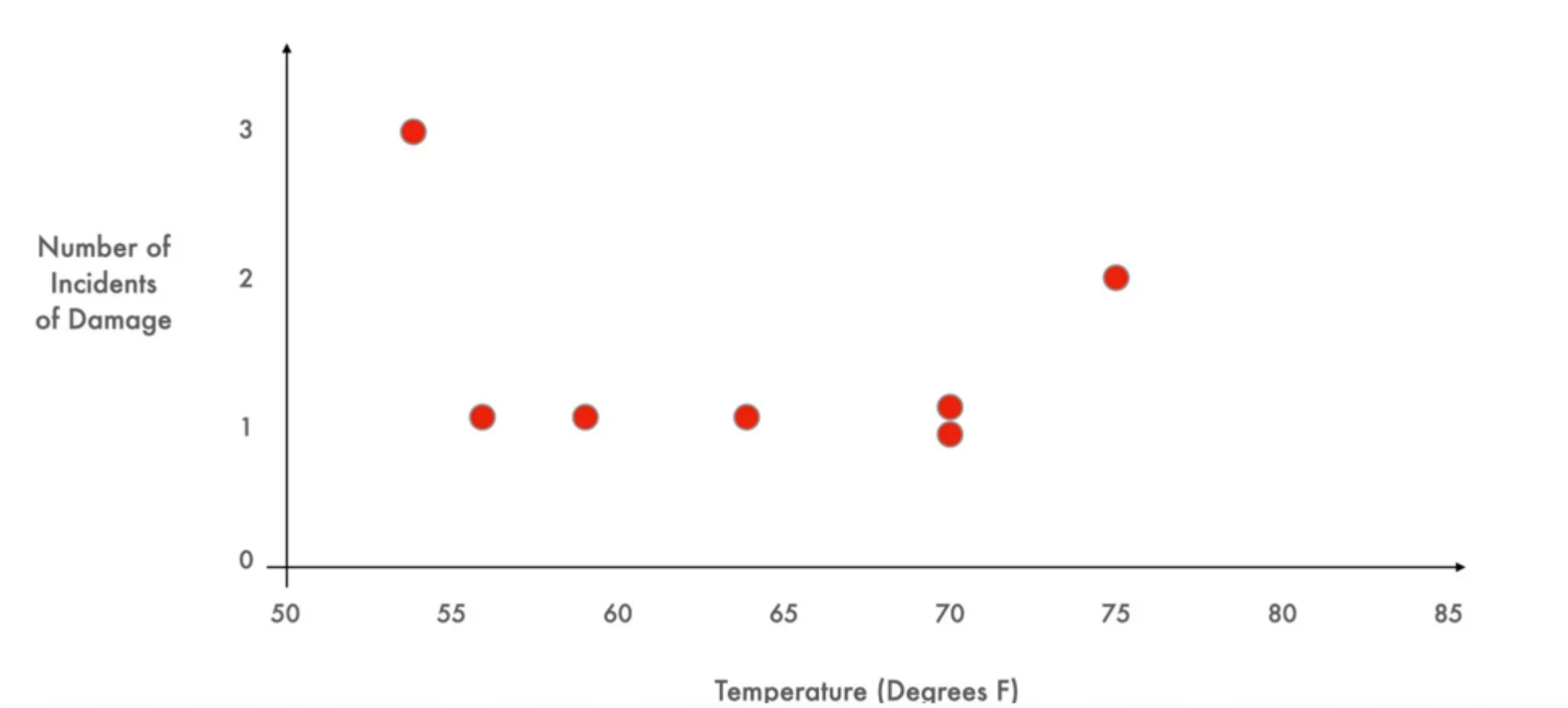
Case Study on Data



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Case Study on Data

- Today's race is in 40-degree Fahrenheit weather
- Question: Race or Withdraw

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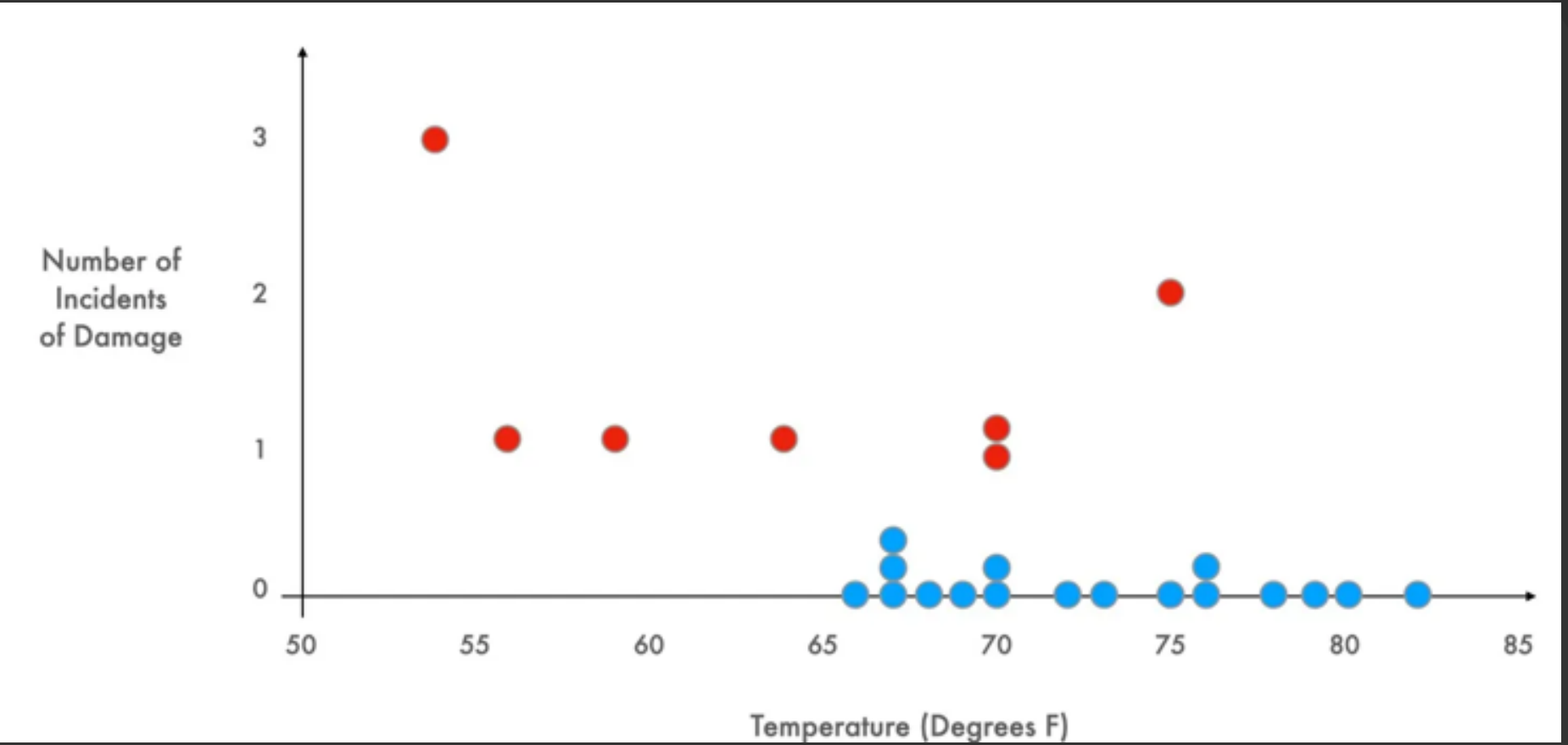
Case Study on Data



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Case Study on Data

- This isn't actually a hypothetical case from business school
- The data is from the Space Shuttle Challenger about o-ring failures
  - The first set of data was presented in a meeting prior to the launch, and while some argued against the launch, the expert consensus was to go ahead
  - The shuttle broke apart after takeoff, killing all seven crew members
- What's the lesson learned here in regards to *FIRST*?
  - Need to be smart about data
  - Having data isn't enough, having the right data matters
  - Must ask questions about the data!
  - Don't rely on numbers without exploring the context
    - Do you know what a given stat means!

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Advanced Scouting

- Regional results from current and past seasons
  - Match scores, awards, seedings, draft positions, eliminations results
  - Can further analyze data to find patterns
    - Least-squares scoring estimation, other custom metrics
    - Commonly known as “OPR”
  - High correlation between past success and future success

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OPR

- Calculated Contribution / OPR
  - How can I know how well a team has performed without watching their matches?
  - Could look at average score, but that only tells part of the story
  - Let each team's contribution be represented by a variable
  - For each alliance, let $t_i + t_j + t_k = s$, where s is the amount of points scored by the alliance
  - Solve the matrix
  - Now you have calculated the average contribution of each team throughout the regional
  - How valuable is this data?
    - Depends on the game!!!
- Component OPR
  - Based on a game component, not total score
    - e.g. Total Game Pieces, Auto Coral, etc.

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OPR in 2025

- It was fantastic
  - Linear scoring so OPR just makes sense
  - Component OPRs provide discrete data
  - Total game piece cOPR is my favourite this year. High correlation to scouted data
    - More value than game piece point OPR since teams aren't always trying maximize total score when playing for RPs

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OPR vs EPA

- Both are very useful!
- OPR – A better indication of what a team has done in a given event
  - Needs about 8-9 matches to stabilize
- EPA – A better predictor of future events, as it factors in more than just the given event
  - Stabilizes very early
  - EPA has a long memory. Not great for teams who are trending upward or downward
    - Teams who've done big rebuilds
  - Cumulative stat – Favours teams who have played more
- I prefer to use EPA for the first half of the event, but then pivot to OPR when things stabilize
  - Therefore, more likely to use OPR for a picklist
- Both are valuable tools with different uses!

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OPR vs EPA

- Don’t expect a single statistic to tell you the full story
- Use multiple pieces of data, empirical and subjective!
- The “eye test” has value when comparing between similar items
- At the same time, the eye test can be inherently flawed; that’s why we use data

> ...I've *always* said that the best evaluation of players is subjective judgment; this is just the first time I have acted in a way that is consistent with what I have written. I've always railed against "great statistics," arguing that it is inappropriate to try to summarize everything a player can do in one number unless or until you can actually measure everything that he does. The problem with formal rating structures is that there are simply too many things that we don't know. To rate players by strictly objective methods, we have to construct a model of the baseball world. The real baseball world is inevitably going to be hundreds of times more complicated than the model that we construct, and therefore we are going to have to a) leave out many factors, factors which are very real and very important even though we can't measure them, and b) make assumptions about things that we don't really know.

- Bill James, the godfather of Sabermetrics

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Pit Scouting

- Make sure you check out every team at the event
- Start on Day 0
- Take pictures of every robot
  - Three views (get the team number in the shot)
- Things to look for
  - Functionalities
  - Type of Drivetrain
    - Is it swerve
    - Number of wheels, Traction/Wheel Type, Gearing, Motors
  - Quality of Construction
- Ask questions

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Match Scouting

- Watch every match
- Things to keep track of:
  - Match score
  - Points scored by each team
  - Scoring attempts and failures
  - Penalties
  - Autonomous modes, starting position
  - General strategy and tendencies
  - Drivers and human players
    - How fast do they react after autonomous…
- Make sure you capture this data for all teams in the match

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Match Scouting

- 1 team of at least 3-6 people
  - Value in using 12 for redundancy checks
- Very tiring, some people have a hard time focusing for the entire day
  - Rotate team members, allow time for ample breaks
- Forcing people to scout will result in unreliable data
  - Validate data against the *FIRST*/TBA API
- Make it fun!
  - A team with a culture that respects scouting will result in better scouts
    - People are very good at recognizing busy work
    - Don't make scouting a spot for "leftovers"
  - SimBucks!
- Do we still need to do this?

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Averages vs Maximums

- Averages and maximums are confused greatly by FRC teams
  - Averages include matches where you don't move because your radio lost power
  - Averages include matches when you got defended for 1:30
- Teams usually say "average" when they mean "maximum over perfect conditions"
- Beware of strategists who use these terms interchangeably
  - It's crucial to have your own data
- Not a bad idea to work with 4 items
  - Min, Min > 0, Avg, Max
  - Orrrrr… with so few data points, look at everything
- What's the difference between 5.7 and 5.2 cpm?
  - Beware of ordinal ranks – use tiers!
  - How to rank teams within tiers?
  - Very important at Champs

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Alliance Selection

- The entire process is dependent on scouting
- Make a preliminary pick list on Thursday night, full list on Friday night
  - Review scouting data
  - Discuss criteria of ideal partner based on elimination strategy
  - Rank teams from 1 through ~28/36 based on established criteria
    - Slightly more than 24/32 necessary for full eliminations tournament, to allow for surprises
- The “Do Not Pick List”
  - Should you have one or is it excessive?

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Alliance Selection

- Tweak the list through Saturday's matches
- Make sure your alliance captain is level-headed enough not to get flustered on the field
- Remember that the second pick can be crucial to the success of your alliance
  - Excellent teams often (usually) get missed in the first round
- To break up alliance or not to break up alliances? (Galileo 2011)
  - “Scorched Earth” strategy
- When should you decline?
- Strategies should be different based on selection point
  - High or low variance picks

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Getting Picked This Week

- What are your goals?
  - Do you think you're going to be a top (1-3) picker? 4-8, first round, second round, third round pick?
  - Be realistic!
- Demonstrate what's in demand!
  - 2 Offense + 1 Defense vs 3 Offense
  - If you want to be picked as a defender, pivot early
    - The best way to be noticed as a defender is to defend a top team, because those are the teams people are trying to beat
    - Toss that net on your robot now
  - Backside auto + algae + D + deep climb
- Top teams should be picking for consistency, lower seeds need to go for the high ceiling

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Match Strategies

How are you going to win?

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Match Strategies

- Planning and Execution
- The most important part of the competition
- Good strategy and scouting can allow a mediocre robot to win the majority of its matches
- Good strategy and a good robot are an almost unbeatable combination

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Pre-Competiton

- To develop a good set of strategies, you need to know what you can do
- Analyze and evaluate your robot's abilities
  - Be honest, don't under or over-estimate
  - Factor in the abilities of your drivers
- Create a playbook
  - Possible match strategies that can be run
  - Different strategies for different circumstances
    - Defensive, High Risk, Safe
    - Going for the win, going for the RP, with partner type X, etc.

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Match Plans

- Develop a plan for each match with your partners
  - Everyone must agree on the plan, or chaos will ensue on the field
  - How to decide who does what?
    - No freaking bullying; recognize your power and privilege
- The plan should outline what each robot will do for the entire match
- Create time limits on actions. If something is taking too long, you have to move onto the next
  - Many teams lose matches because they don't abandon failed objectives

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Match Plans

- Each plan should include contingencies
- Winning the match is the first priority, showcasing features is second
  - Not playing to win is no different than throwing a match
  - Throwing matches and/or RPs is UNACCEPTABLE
- Never mislead your partner about your abilities
  - Can't do something? Make sure they know that
- Make sure your strategies are complementary
  - Don't try to occupy the same space of the field, leave each other room

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Coaching a Match

- The role of the field coach cannot be overstated
- Drivers can only watch the robot and the immediate area
  - The coach must watch the entire field, keep track of the score and the robots
- The coach should make all decisions to deviate from the initial strategy
- Must keep the drivers aware of what's going on
- The field coach must also watch the referee for warnings
- Field coach also must communicate with the alliance partner's field coach
- Instructions must always be given
  - The driver will come to depend on the coach, don't leave them hanging

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During a Match

- You must be able to make on the fly decisions
  - Too many teams lose matches because they behave in a very static manner
- The drivers do not have time to look up at the clock
  - The field coach should be updating the clock every 10 seconds, with a 10 second countdown at the end
- Everyone on the field must focus on the match
- Never lose sight of the main goal – Winning the match and getting RPs
- If you fall behind, don't panic, calmly re-evaluate and come up with a new plan
- Leave it all on the field
  - Give it your all, don't be afraid of damage
  - That being said, don't take overly dangerous risks

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After a Match

- Sit down with the key team members, discuss what went right and what went wrong
- After a couple of matches, you'll quickly discard and add strategies
  - Don't bang your head into a wall doing the same thing over and over
- You must adapt to the competition
- You often learn more in defeat than you do in victory

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Other Strategy Tips

- Change things up
  - Teams with good scouting will notice if you do the same thing every match
- Don’t be too conservative or too risky
  - Know your abilities
  - Don’t try to do too much in a match
- Learn how long two minutes is
  - Run your practices with a timer
- Slow and steady wins the race
  - Spend 5 seconds setting up, as opposed to 30 seconds doing it over again

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Preparing for the Finals

- Meet with your new alliance and discuss strategy for eliminations
- Make sure key players from all three teams know each other
- Start planning match strategy for the first round
- Be prepared for more (and more targeted) defense
- Good strategy is the only way to beat a technically much superior alliance
- Be prepared to be unconventional if necessary
- Take advantage of extra planning time to come up with more effective strategies
    - It's too late to change your robot; it's not too late to change your strategies

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Final Comments

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- Read the rules!
- Come up with a clear, consistent strategy for how your robot will play the game
- Remember the Golden Rules
- Scouting is the easiest way to make your team more successful at competition
- The role of the coach cannot be understated
- Each *FIRST* match is like a high-speed game of chess: You need to have a well thought-out plan, but be prepared to counter your opponents' moves
- Remember why you're doing this
- Have fun!

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Resources

- Contact
  - karthik.kanagasabapathy@firstroboticscanada.org
    - Always copy another adult on any communication with an adult
  - Feel free to ask questions, I actually enjoy this stuff!
- Range by David Epstein
- Your local public library

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Thank You!

Questions? Comments?

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