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ABOUT THE DESIGN PROCESS

I. INTRODUCTION

Throughout the design of our robot, we have kept one universal theme in mind:

> ***USER FRIENDLINESS***
>
> *The measure of how robust, simple, easy to maintain, and easy to use the notebook is.*

We wanted our notebook to be easy to write and also easily understood by readers without sacrificing the quality of our notebook entries. Our goal with the notebook is to document all of our experiences, decisions, and reasonings behind those decisions. All in all, it may seem complicated and lengthy to write every experience and decision, but we made it easier to write *and* read by following one universal design process.

The design process not only helps us make smart mechanical decisions, but also serves as a guide for our notebook entries: our thought was that if we follow the design process throughout our decisions, we can easily write about each step that we follow and our reasonings behind our decisions.

This makes entries easier to write because all of our decisions can be supported by a universal design process. With an overall understanding of the design process, it is easier to understand why we made the decisions that we did. Also, each step of the design process has a description of the information that it should contain, so crucial steps do not get glanced over.

This also makes things easier to read because our design process is implemented with a color-coded system that everyone can follow: a rainbow. This rainbow shows our progress through the design process—the further down the rainbow we are, the closer we are to a finished project. Also, each step of the design process is labeled with each entry that we do.

THE DESIGN PROCESS	
DEFINE A PROBLEM	• Specify the problem • Document specifics (the number of points the problem is worth, the level of importance/priority) • Criteria and Restraints

GENERATE CONCEPTS	• Brainstorm solutions to the problem
	• Narrow down to a singular solution
	  ○ Use Design Matrix
	  ○ Analyze Pros and Cons

DEVELOP A SOLUTION	• Create rough sketch of solution • Create CAD of solution • Have other eyes review the design *If Design does not show promise, go back to a different concept*

CONSTRUCT AND TEST A PROTOTYPE	• Make a prototype based off of CAD
	  ○ Can be rough or specific
	• Analyze outcome of prototype
	  ○ “Prototype works with 80% accuracy”
	  ○ “Design may need tweaking – Prototype does not work very well”
	  ○ “The plastic prototype doesn’t work but the final mechanism will be made of aluminum and that should work”
	  ○ “A tiny design change helped the prototype – Add to CAD”
	
	If Prototype does not show promise, go back and improve the design

FABRICATE AND INTEGRATE	• Fabricate a finalized solution based off of the CAD • Put item on robot *If Fabrication does not show promise (difficulty/possibility), go back and improve the design*
EVALUATE AND TWEAK	• Evaluate the effectiveness of solution • Analyze flaws and where tweaks can be made • Improvements and changes to final design *The Design Process never ends! Keep improving, but keep your priorities in mind!*

II. THE DESIGN PROCESS

DEFINE A PROBLEM

The design process always starts with one thing: defining a problem. These problems are NOT just any situation that needs to be overcome, such as having a screw that is too big to fit in a hole. These are overlying problems that need to be solved with a mechanism/system. Specifically, in FTC, our problems are trying to complete the point-scoring objectives. This is also where we specify where the problem falls within our priorities and give any constraints/criteria. To define the difference between the two, constraints are parameters that limit that the design (eg. size constraints, weight constraints, motor limit) and criteria are the characterizations of the design (eg. speed, accuracy, robustness)

GENERATE CONCEPTS

Once a problem has been identified, a solution must be found. If someone just attempts to build a mechanism to solve the problems with any planning or preliminary procedures, it will most likely not be the best design or maybe not even work. That is why it is very important to plan!

The first step of planning is generating concepts, also known as brainstorming. During this stage, no ideas are ignored because something that may seem like a bad idea may actual be the best idea! After listing as many ideas that we can think of, it is important to extensively compare the pros and costs of each idea. This can be done using a design matrix that prioritizes/weighs the pros and cons and assign a rating for each design. After this whole process, a final decision of a solution is made (sometimes multiple solutions depending on how easy it is to test one).

DEVELOP A SOLUTION

The next step is to plan out the design of the solution. This step is crucial to see whether our concepts our actually designable. Design can be done by hand, but preferably in a computer software to get a better idea of the design as a whole.
In this step, we can also explore the feasibility of the concept. Creating CAD designs of our ideas give us a better idea of how the mechanism would work, or if it cannot work at all. We can decide to go back to a different concept or move forward to prototyping, depending on the outcome of the design.

CONSTRUCT AND TEST A PROTOTYPE

Prototyping is a very important stage in the design process. A robust solution may take a long time to fabricate, so it would be upsetting to see it not work at the end. With prototyping, we can make a less robust design to test the concept before actually creating the solution. Prototypes can be as easy as something made of cardboard, but it can also be made out of more reliable material such as polycarbonate. The more robust the prototype, the more accurately it would represent the real thing. We keep in mind that the prototype generally predicts the outcome of the real fabrication, but it will not always be accurate. It is also possible to iterate during the prototyping stage. We can run tests on prototypes with minor changes to see which performs the best.

FABRICATE AND INTEGRATE

If the prototype works, then we can finally start fabricating the solution. We follow the designs that were previously drawn as well as make (and document) any design changes that are needed, but we did not foresee. Then, the mechanism can be put on our robot for testing and evaluation. More tweaks can be made after we see the performance on the robot.

EVALUATE AND TWEAK

After doing tests with the real fabrication, or using the mechanism in a competition, there will always be ways to improve the design. Constantly evaluating the performance of a mechanism is key to creating the best product possible. We may decide to innovate the design or even go back a few steps in the design process.

This whole process is iterative: it is a procedure where we can get a desired result (a solution) through repeated cycles. Following this design process is not always a linear, start-to-finish procedure; we can take step back from a path if something does not end up working with the knowledge that we gained from going through that path. If a prototype does not work, then we can refine the design OR go back to a previously generated concept. Like all iterative processes, a desired result would converge with more iterations.

III. INTEGRATION INTO THE NOTEBOOK

This procedure can easily be implemented into our notebook. We sectioned out each step of the design process and used the same color-coding system as the diagram shown above. Using this, we can always follow what step of the design process we're on and what we should be doing.

Also, since this is an iterative design process, it should be able to flow between meetings throughout the whole season. The design processes should start at the beginning of the season and only end at the end of the season because a design is never truly done; there is always room for improvement!

The entries should able to flow between meetings by having a title for each process. If someone wanted to see the journey of our team marker mechanism throughout the whole season, they can flip through the notebook entries and read anything titled "Team Marker Mechanism" and it will pick up where it left off last time it was worked on.

THE MIRACLE WEB

As a large team with many complicated and long-term functions, we've found a way to pull together our team strengths and weaknesses to set goals, organize our team, and utilize the design process to best identify and face these challenges. Below is a visual depiction of the interactions between these systems, showing how and why our team works!

Each arrow represents one process facilitating another. In other words, every interconnection makes our team more organized, productive, and effective, while still keeping our foundation simple and intuitive.