Our game has some features that are similar to an FRC game:
1.The game is divided into 3 periods: autonomous, teleoperated, and end-game.
2.Each team has two drivers, one human player, and one coach.
3.A match lasts 2 and a half minutes.
4.The field is exactly the size of a regular FRC field for purposes of convenience for teams who have a training field, and areas that already have arenas for competitions.
5. The perimeter of the robot shouldn't exceed 120in.
6. The maximum height that a robot can be at the start of the match is 4 ft.

Design Process:

At the beginning of the season, we sat down and wrote all of the criteria for a game to be a good game and divided the list into three levels of criticism:

Critical:
-Have "low floor- high ceiling" (explanation above)
-Have a new and creative concept
-Have an interesting engineering challenges

Important:
-Be easy and entertaining to watch and understand
-Have a lot of room for strategy
-Have an option for defense between alliances

Not Critical:
-Have cooperation between the teams in the alliance

We know that some of these criteria can come at the expense of others. Because of that, when we came down to choosing between different ideas we came back to the list to make the best choice.

In addition, we wrote things that are important in a game but doesn't come at the expense of other criteria like the ones written above:
*Proper planning (balanced scoring system)
*A match can't be decided due to a human player's skills.

We wanted to provide an interesting, creative engineering challenge, that was never seen before on a FIRST game. Therefore, we chose to make cubes without sides.

We created three LEAVES, to make sure they can be built easily in a team's workshop, and they are. It took us half an hour to manufacture and assemble one LEAF, and it was very simple. It didn't necessitate complicated mechanical tools or knowledge. The connectors for the tubes are available at every Walmart, Home Depot, Amazon, etc. We iterated on the LEAF's design by trying our hooks of different diameters (see picture 7). Estimated cost for one LEAF is ~10$ for in house manufacturing.
We built a simple prototype, that enables collecting and hanging LEAVES. We designed it the simplest way possible, to ensure that both experienced and rookie teams will be able to hang LEAVES, whether it's on the BRANCH or on the TREE.

The CLIFF was designed to provide teams with a new, never before seen challenge. Over the years there were many different types of climb challenges. We wanted robots in our game to face a climbing challenge that isn't a bar, a stair, or a rope. we decided that the robots will climb up while supported by the walls of the CLIFF. This climbing task will face teams with a whole new challenge that is new, interesting, and considers engineering thinking from a different perspective than what past challenges provided them with.

The Scoring System:

We did some math in order to set the scoring for the game in an objective way. The following system ensured us that our game is balanced, and teams will get the scores they deserve based on their accomplishments, while also requiring complex strategic analysis from them.

In each competition there are teams at different levels, and different strategic decisions and robots, so we made a list of imaginary alliances that we thought would be common for this game. We put together 3 scenarios of matches with the imaginary alliances "playing" against each other. We decided which alliance should win the match, based on their performances, and determined the score difference (expressed by the scoring value of LEAVES) between the scores.

We gave variables to different missions and made equations based on the scenarios we wrote down. Those equations gave us the proportions between the different tasks in the game and helped us decide the points that each task is worth.

Variables:

LEAF value - x

Climbing the CLIFF value - y

Parking/ getting off the HILL value - z

Prior to calculating, we decided on a few assumptions to simplify the process.

We decided we wanted points in the autonomous period to be doubled. In addition, we assumed that the SPROUT factor of point multiplying is $\times 2$, that LEAF scoring values on all heights and field elements are identical and that parking on the HILL in end-game is identical in value to going off the HILL in autonomous.

First Matchup - early season matchup (weeks 1-2) Winner: Alliance #1

Alliance #1: Autonomous period - 3 robots got off the HILL, 2 LEAVES on the TREE. Teleoperated period - 6 LEAVES on the TREE. Endgame - 1 climb the CLIFF, 2 park on the HILL.

Alliance #2: Autonomous period - 3 robots got off the HILL, 1 LEAF on the BRANCH, 1 LEAF on the TREE. Teleoperated period - 4 LEAVES on the BRANCH and the SPROUT. Endgame - 2 park on the HILL

$$6x + 2 \cdot 2x + y + 2z + 3z = 2(yx) + x + 2z + 3z + \underset{\substack{\uparrow \\ \text{Desired score difference}}}{4x}$$

$$\Downarrow$$

$$10x + y + 5z = 15x + 5z$$

$$\Downarrow$$

$$y = 5x$$

Second Matchup (DCMP) Winner: Alliance #1

Alliance #1: Autonomous period - 3 robots got off the HILL, 2 LEAVES on the TREE, 1 LEAF on the BRANCH. Teleoperated period - 2 LEAVES on the TREE, 5 LEAVES on the BRANCH, and the SPROUT. Endgame - 2 climb the CLIFF, 1 park on the HILL.

Alliance #2: Autonomous period - 3 robots got off the HILL, 2 LEAVES on the BRANCH, 1 LEAF on the TREE. Teleoperated period - 6 LEAVES on the BRANCH and the SPROUT. Endgame - 1 climb the CLIFF, 2 park on the HILL.

$$2y + z + 2\cdot 2x + 2x + 2\cdot 6x + x + 3z = y + 2z + 2x + 2\cdot 7x + 2x + x + 3z + 3x$$

$$\Downarrow \qquad \uparrow$$

$$2y + 4z + 19x = y + 5z + 22x$$

Desired score difference

$$\Downarrow$$

$$y = z + 3x$$

$$z = 4x - 3x = x$$

Third Matchup (Einstein) Winner: Alliance #2

Alliance #1: Autonomous period - 3 robots got off the HILL, 2 LEAVES on the TREE, 3 LEAF on the BRANCH. Teleoperated period - 4 LEAVES on the TREE, 6 LEAVES on the BRANCH, and the SPROUT. Endgame - 2 climb the CLIFF, 1 park on the HILL.

Alliance #2: Autonomous period - 3 robots got off the HILL, 2 LEAVES on the BRANCH, 2 LEAF on the TREE. Teleoperated period - 3 LEAVES on the TREE, 8 LEAVES on the BRANCH and the SPROUT. Endgame - 2 climb the CLIFF, 1 park on the HILL.

$$x + 2y + z + 2\cdot 8x + 2x + x + x + 2\cdot 2x + 3z = 2y + z + 2\cdot 9x + 2x + x + 2\cdot 2x + 3z$$

$$\uparrow \qquad \Downarrow$$

Desired score difference

$$25x = 25x$$

proves that the autonomous points should be doubled (because the comparison is between autonomous and teleop performances)

CLIFF Mechanism Proof of Concept:

In order to determine if the CLIFF mission is an accomplishable task, we roughly calculated the force needed to push the CLIFF walls in order to achieve a great enough friction to sustain the weight of the robot when it is supported only by the wall.

We set some base parameters:

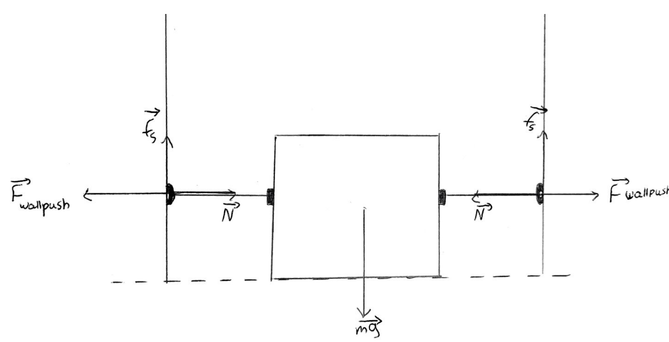
Robot weight - $mg = 65\ [kg]$, Coefficient of friction (for rubber) - $\mu^s = 1.15$,

Earth's acceleration - $g = 9.81\ \left[m/sec^2\right]$

Robot weight - $mg = 65\cdot 9.81 = 637.65\ [N]$

$F_s = \mu^s\cdot N = \mu^s\cdot F_{wall\ push} = 1.15\cdot F_{wall\ push} = mg/2$

$F_{wall\ push} = mg/2.3 = 637.65/2.3 = 277.24\ [N]$



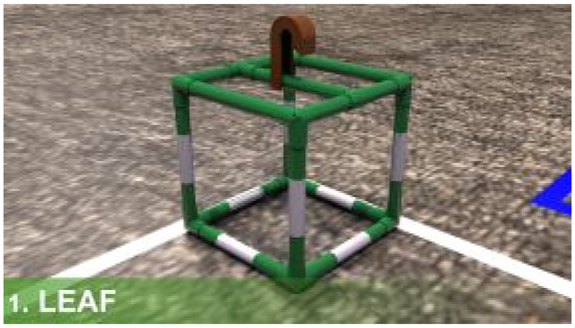
Conclusion: in order to sustain the weight of the robot teams will need to push each wall with $277.24\,[N]$, To prove this can be achieved, let's calculate the opening force of a standard pancake piston.

Pressure - $P = 60\ [psi] = 413,685\ [Pa]$, Area for opening - $A_{opening} = 2.82\cdot 10^{-4}\ \left[m^2\right]$

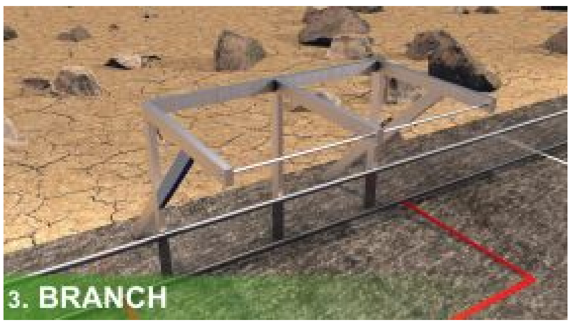
$F_{opening} = P\cdot A_{opening} = 413,685\cdot 2.82\cdot 10^{-4} = 116.66\,[N]$

Conclusion: each side needs roughly 3 pancake pistons in order to sustain the robot's weight on the walls.

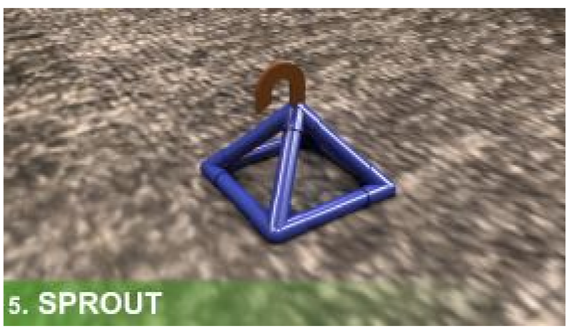
Supplementary Information


1. LEAF

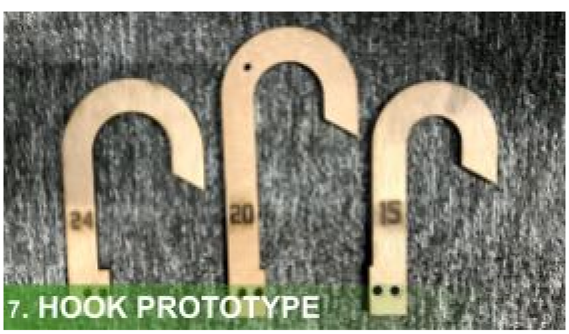

2. TREE


3. BRANCH

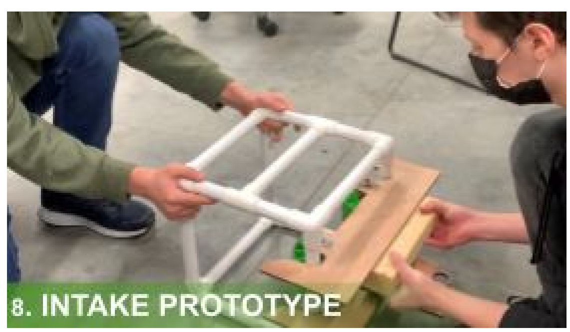

4. CLIFF

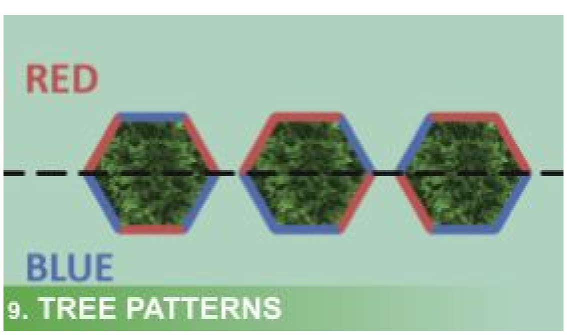

5. SPROUT


6. VINE OF THREE LEAVES

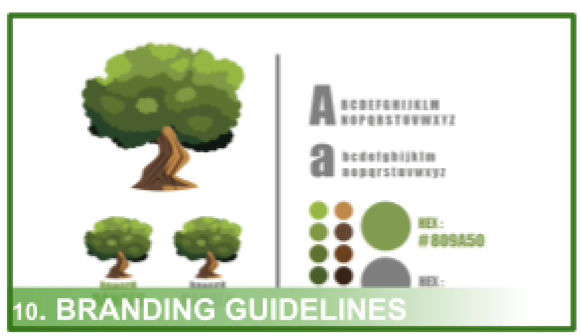


7. HOOK PROTOTYPE


8. INTAKE PROTOTYPE



9. TREE PATTERNS



10. BRANDING GUIDELINES