## Concept Generation

For our concept generation, we first began by creating a morphological chart that was used to come up with individual concepts for each of our critical targets. We then used concept generation tools to come up with more concepts that were more for out of the box thinking.

After we generated the 100-200 concepts, we took the time to individually vote on each concept. The votes can be seen in the morphological chart and were then counted up to create the high and medium fidelity concepts. Going through this process has helped our team see how each component of our critical targets will work together with one another to be able to complete the robot needed.

### Concept Table/ Morphological Chart

This morphological chart takes different systems that our final product will implement and comes up with different methods on how to accomplish these implementations. Each column represents a different system and their different concepts. Assuming every system concept can function together this chart provides (# of rows ^#columns) ideas, in this case approximately 250,000 concepts. In reality not all of these concepts for the system will work in conjunction with each other, for instance, an air jet as our mode of cleaning does not require any provision of solution. Therefore this morphological chart provides an estimated 100 - 200 viable concepts.

| **Power** | **Clean** | **Control** | **Support** | **Provision of solution** |
|---|---|---|---|---|
| Lithium Polymer Battery -**I, KP EC, DS, CA** | Sprinkler next to or over panel **EC, DS** | Autonomous drone flying over panel | Clamps - **KP, I** | Brushes holstered on solution dispenser- **DS, EC, CA** |
| AC power OR Generator **EC I, DS** | Drone flying over panel | Magnetic movement | Multiple attachment point spools - **I, EC, CA** | Solution stored in tank connected to design - **I, DS, EC, CA** |

| | | | | |
|---|---|---|---|---|
| DC Power - **KP**<br>**I**<br>**EC,I, DS, CA** | dry/wet brushes - **I, KP**<br>**EC, CA** | Tank wheels with suction cups - **KP,I, EC, CA** | Tank track along top panel<br>**I, EC** | Solution stored in external tank and pumped - **KP, I,DS,I, EC** |
| Solar Power - **I, KP**<br>**EC, CA** | rectangular brush (linear Motion)<br>**I, CA** | Arduino autonomous control - **KP,I,I, EC, DS, CA** | Caster Wheels within spring loaded clamps to fit all panel thicknesses<br>**I, CA** | Rail at top of panel that sprays down solution at an effective incident angle<br>**EC** |
| Wind power | Circle Brushes (Angular Motion) - **KP,I,I**<br>**EC, DS** | Robotic Operating System via linux machine with python programming | Rails on top and side of panel (movement grid) - **KP, EC** | Only Water hose<br>**I, I** |
| Hydro power | Brushes holstered on solution dispenser- **DS, CA** | Proximity Sensors - **KP,I, EC, CA** | Magnetic attachment | Recirculate solution - **KP** |
| Magnetic power - **KP** | Water Jet | Measurement / Dynamic Range sensors - **I** | Robotic legs attached to device | No solution |
| Geothermal power from induced friction | Air-**I, KP** | suction/negative pressure | I-Beam with AC motor (x-axis motion) | Soaker sponges - **KP, CA** |
| PhotoCells **CA** | Squeegee<br>**CA** | Physical rail that prevents device from leaving array - **KP** | suction/negative pressure hubs/skirt Essentially a hovercraft - **I, CA** | Pressurized tanks to hold solution<br>**DS, CA** |
| Interchangeable battery packs -**II, CA** | Rail at top of panel that sprays down at an effective incident angle<br>**EC, DS** | Negative pressure hubs walk device along array<br>**CA** | Silicone wheels (high coefficient of friction between panel and machine) - **I, CA** | Long thin rectangular jet **CA** |

| | | | | |
|---|---|---|---|---|
| Wireless | Ultrasonic brushes - **KP,I, CA** | Sensors on robot **I, CA** | Bungee cords **EC, CA** | Compressed Tanks |

In the morphological chart above, it can be seen how all group members voted to narrow down concepts. The initials in bold next to each concept shows who voted for what concept. The concepts with the most initials are the ones that got chosen for medium and high fidelity.

The methods below represent out of the box thinking for concept generations. Crap shoot forces the group to think outside of the box to think about concepts that might not be practical but could get the job done. Biomimicry is used to look at the natural world and see how our technological robot can mimic them.

## Crap Shooting

Crap shooting is the process of throwing out random far fetched ideas that you may not even consider feasible, and then attempting to relate them to a possible practical usage on the project. This spurs creativity and encourages abstract thinking. Below is a list of our craziest ideas. None of which made the final cut but the last concept, two point attachment, is tied into a chosen design.

- Drone that sprays solution over panels
- Vibrations shake the array clean
- Corkscrew brush to increase torque and reduce power usage
- Robot that spans the whole length of array and moves along horizontally
- Bars with brushes that shift down the line of the panel
- Laser dirt removal
- Two point attachment via rope pulleys to control position of robot

## Biomimicry

Biomimicry is the process of conceptualizing your design solution while keeping nature in mind. Nature has been evolving for millions of years, and takes advantage of universal laws of physics. There are many examples of this around us in modern society, such as supersonic jets shaped like birds of prey.

As one of our biggest design concerns is security of the device to the roof, many of our biologically inspired concepts come from animals with ‘sticky fingers’. Below is a list of our biologically inspired concepts, some of which made appearances in our  chosen concepts, such as suction cups. It is also highly likely we will use materials with high coefficients of friction on glass, such as silicon.

- Robot secures itself with pods similar to gecko feet
- Suction cupped to panel like octopus arms
- Robot traverses on tracks similar to tank tracks made of sluglike non-slip material
- Basitarsal Brushes similar to what bees use to wipe pollen off of their face
- Suction cups as an octopus on tank tracks connected to robot

## Medium Fidelity Concepts

We have chosen these for our medium fidelity concepts because they offer alternatives to the most likely to be chosen concepts in the high fidelity concepts section (in case of unexpected complications). This is especially prevalent in the power concept. This is especially prevalent in the power, movement and solution provision concepts given that these are the areas in which we are most likely to run into unexpected obstacles.

1. AC Power OR Generator - dry/wet brushes - arduino - sensors - tank wheels with suction cups - solution stored in external tank
2. Solar powered - Circular brushes - Arduino controlled with sensors - Suction/ negative pressure - external solution

3. Magnetic power - circular brushes - arduino - sensors - solution in external tank
4. Interchangeable battery packs-circle brushes-Arduino controlled with sensors- Tank track with adjustable clamps-Solution in external tank with pump
5. Lithium Polymer Battery  - Air - Arduino controlled with sensors - suction/negative pressure - no solution

## High Fidelity Concepts

These concepts were chosen because they were the most viable concepts from generation and seem to have the most possibility of working as well as meeting the customer needs in the best possible way. These high fidelity concepts will be compared with medium  fidelity concepts as well as some select concepts not listed in either medium or high fidelity, in order to select a final concept for design.

1. Lithium Polymer Battery - Circle Brushes - Arduino controlled with sensors - Clamps - External solution storage
2. DC Power - dry/wet brushes -  Arduino controlled with sensors - Tank wheels with suction cups - External solution storage
3. Lithium Polymer Battery - dry/wet brushes - Arduino controlled with sensors - rails on sides of panel - external solution storage