## Targets and Metrics

After completing the functional decomposition of the customer needs, a set of metrics and targets must be found to accomplish the desired functions and complete the design criteria. Metrics are the means by which the most important functions or features can be quantified. Targets are specific values of those metrics that must be met. The critical functions, targets, and metrics can be found in the table below. Refer to Appendix A for a full table of targets and metrics.

| Function | Target | Metric |
|---|---|---|
| **Clean** | The device will clean panels to a degree which customers are **satisfied** | Client Satisfaction<br>**Satisfied/Not Satisfied** |
| **Provision of Solution**<br>**(UTILIZE SOLN)** | The solution provided will not exceed **0.5 gallons per panel** | Amount of water utilized (**gallons/panel**) |
| **Induce Friction** | Must contain a **friction coefficient > 1** for the duration of its operation | **Coefficient of friction**<br>Ensures cleaning force is greater than normal force |
| **Navigate Environment** | Device will have **at least 1** sensor per side to take in data from its environment<br>ensure it does not drive off the edge of array | **# sensors/side**<br>Device will move along the panel autonomously |

| | | |
|---|---|---|
| **Move** | Device will clean **at least 1 panel/hour** | **# panels/hour** |
| **Interface with User** | Autonomous Functionality supported by **< 10 input** parameters from user | **# inputs from user** |
| **Generate Power** | **Utilizing a power source**<br><br>DC INPUT- Lithium polymer (type 18650) acting as cells or similar light weight battery to maintain a constant voltage source<br><br>AC INPUT- 120V onsite power source | **Volts** maintained by power source |
| **Distribute Power** | Device will be **able to power all components** using a battery bank or an AC voltage source | Available **volts** |
| **Physical connection to array** | Device maintains at least **one point of contact** at all times | **Points of contact** to array |
| **Structural integrity** | Sum of forces in all directions **equal zero** | **Equilibrium** must be achieved for this to be a free standing structure |
| **Store solution** | Device will store at least **3.75 gallons** of vinegar | **# gallons** of vinegar needed to mix with water to create solution |
| **Propel solution** | Apply solution to brushes at a rate **< 0.5 gallons/minute** | Flow rate **gallons/minute** |

**Other targets:**

20 panels cleaned per hour

Have to be kept under 16-17 pounds per square foot

½ gallon of solution (water) per panel - Duke energy standard

Product will have at least one point of contact

Robot is able to work on slopes up to 45 degrees - IGN metric for common solar panels in florida

Robot is able to move at a maximum variable speed of 30 meters/minute

Robot accomplishes a cleaning rate of 5,000 square meters of solar panel per day

**Critical Targets/Metrics**

| **Critical Targets** | | | | |
|---|---|---|---|---|
| **Utilizing a power source of predetermined voltage** | The device will clean panels to a degree which customers are **satisfied** | Autonomous Functionality supported by **< 10 input** parameters from user | Device will have **at least 1** sensor per side to take in data from its environment | Sum of forces in all directions **equal zero** |

**Method of Derivation (Discussion):**

**Power:**

We plan to use a lithium polymer battery set and cells to power our device. Our critical target for power is to maintain a constant predetermined voltage number power supply. Lithium batteries are lightweight. They were our first choice, based on the fact that weight management is extremely important for this project, excessive weight will likely cause gradual damage to the solar panels. We referenced one of our sources from IGT who recommended a constant 6v power supply.

**Cleaning:**

The cleaning critical target is dependent on customer satisfaction. The overall goal of solar panel cleaning is to optimize performance. That being said, performance measurement would be extremely labor intensive on our end, and would involve too many variables based on solar panel age, previous damage, client use metrics, etc. Through this, we determined that the most optimal critical target would be for the client, who is more knowledgeable on their solar panel performance metrics, to examine the solar panel performance before and after the cleaning, and provide "satisfactory" or "unsatisfactory" feedback on the cleaning.

**Sensors:**

For the algorithm to function, the software needs to be able to reference the physical environment. Furthermore, we felt necessary to place a minimum of one sensor per side of the robot. In regard to power consumption and resource cost, it would be ideal to place a singular large sensor on the bottom that could track the bot's location and preemptively avoid moving too far off of the solar panel edges. However, in the event of unexpected obstacles and software error, we realized that it would be much safer to place multiple sensors that would give us a more clear image of the robot's location. Furthermore, this would allow the robot to adapt more effectively to its environment, learning where the edges are and avoiding them, as opposed to a methodology based on preemptively mapping its environment, which would open the project up to numerous potential errors and damages. The robot will be able to accurately outline the surrounding environment and traverse it effectively.

**Autonomous Functionality**

For the robot to truly function autonomously, the implication is that the user will provide minimum input for the drone to initiate its algorithm. From there, the drone should be able to detect the height and width of the frame using its sensors, move across the entire solar panel area (without falling off), and apply cleaning (the degree to which the user specified at the beginning) to every square inch of the panel frame. Furthermore, this implies that the user will not need to input the solar panel dimensions, provide any input regarding the movement and positioning, or aid the cleaning process (other than provide a solution if they so wish). The user would ideally select the cleaning mode (deep clean or maintenance), provide cleaning solution if they wish, and proceed to watch the robot perform its task.

**Sum of Forces**

The critical target of making forces in all directions equal to zero coincides with the major function of support. The reason we chose this as a target is because with zero forces in all directions the product will remain stable on the solar panel allowing for the product to accomplish the customer needs.

**Method of Derivation (Table):**

| Critical Target | Derivation | Metric |
|---|---|---|
| **Utilizing a power source of predetermined voltage** | Speaking with sponsor and associates on power required for product | **Volts** maintained by power source (although the batteries will act more as capacitors in this case) |

| | | |
|---|---|---|
| The device will clean panels to a degree which customers are **satisfied** | Least labor intense way to quantify level of cleanliness | Client Satisfaction<br>Satisfactory or Unsatisfactory |
| Device will have **at least 1** sensor per side to take in data from its environment | Sensors will be necessary for product to accurately represent environment, and one sensor will be necessary for each side | **# sensors/side**<br>Device will move along the panel autonomously |
| Autonomous Functionality supported by **< predetermined number of input** parameters from user | To maintain autonomy user input needs to be mitigated to least amount possible | **# inputs from user** |
| Sum of forces in all directions **equal zero** | Forces must be equal to zero in order to ensure that the product will remain on solar panel to accomplish customer needs | **Equilibrium** must be achieved for this to be a free standing structure |

Other targets and metrics were found through research of similar products as well as speaking with customers about products that are currently in use. For example when deriving the target for the amount of water used our team spoke with Duke energy, a large consumer of solar power, and we were told that all products that they use only require approximately a half gallon of water per panel.

**Method of Validation**

To validate our critical targets, separate electrical and mechanical tests must be performed to make sure our system is on the right track. Starting with the *power* critical target, these tests will be performed by the electrical engineers. Methods that will be used to test the power of the system are the use of a multimeter to measure voltage, current and power.

To test the *clean* critical target that cleans the panels to the clients satisfaction, the test that will be performed is to ask the client to fill out a survey explaining if the panels are cleaned to their satisfaction.

Another critical target is the ability for the robot to *move* where there will be sensors to help it move across the solar panel. To test the movement of the robot, the first tests will be done on a flat surface to ensure the motors are working properly and the robot can sense the sensors. Then after that test is passed, the robot will be put on a tilting solar array to test the amount of friction it has to be able to cling to the solar panel and move along it.

*Control* of the robot is another critical target where there is a small amount of inputs so the robot is as autonomous as possible. To test how the robot is controlled, first the code that controls the robot will be tested and approved. Once that test is passed, we can test the robot for full autonomy.

The final critical function for the robot is *support* where the sum of all the forces on the robot must equal zero. To test this we will confirm calculations and take the physical robot when not moving and set it on a solid surface to make sure it holds together. Then after that test is passed, the robot will be put in motion to make sure it still stays together while moving.

**Summary**

When viewing the power section in the targets and metrics table, the team has decided not to declare an exact voltage the system will receive as an input or generate as an output. The reason the group is doing so is that each motor, motor driver and microcontroller requires different voltages and consumes various amounts of energy. At this time the team is performing calculations and conducting research to find the best options for the system.

Our critical targets will be the first thing our team focuses on to complete because without those, our robot will not be able to perform any of the minor functions that are also necessary. While we move onto concept generation, we will keep the critical functions at the forefront of our minds to make sure that every component is contributing to at least one of the functions.

In conclusion, our targets and metrics began to give us a good understanding on what our robot will need to function and how it will function. The targets gave each function a value and goal while the metrics were able to quantify the functions. Moving forward to concept generation, this gives the team a solid base for what our final design will need.

# Bibliography

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Appendix A

**Target Catalog**

| Metric # | Need | Metric | Importance | Units | Marginal Value | Ideal Value |
|---|---|---|---|---|---|---|
| 1 | 1, 6, 5 | Satisfied cleaning on solar panels | Extremely Important | Satisfied/ Unsatisfied | Satisfied | Satisfied |
| 2 | 1, 3, 5 | Amount of water utilized | Important | (gallons/panel) | 0.25 - 1 gallons per panel | 0.25 gallons per panel |
| 3 | 1, 3, 5, 6 | Ensures cleaning force is greater than normal force | Extremely Important | Coefficient of friction | 0-1 | 0.4 |
| 4 | 2, 4, 3 | Navigation of environment with sensors for autonomy | Important | # sensors/side | 4-6 sensors | 4 sensors |
| 5 | 2, 3, 4 | Movement along solar panels | Extremely Important | # panels/hour | 1-30 panels per hour | 10 panels per hour |
| 6 | 2, 4 | Interface for user with inputs | Moderate | # inputs from user | 1-10 | 2 |
| 7 | 3, 4 | Generate power for maintained power source | Extremely Important | Voltage | 120 V AC or 5-12 V DC | 120 V AC |
| 8 | 3, 4 | Distribute power for maintained power source | Important | Voltage | 5-12 V DC | 9V DC |
| 9 | 3, 5, 7 | Points of contact to array | Moderate | # of points of contact | 2-10 points | 4 points |
| 10 | 3 | **Equilibrium** must be achieved for this to be a free standing structure | Extremely Important | Forces equal to zero | 0 | 0 |
| 11 | 1, 3, 5 | vinegar needed to mix with water to create solution | Moderate | # of gallons | 0.1 - 1 gallon | 0.25 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 12 | 1, 3, 5 | Flow rate | Moderate | gallons/minute | 0.1 - 1 gallon | 0.25 |

**NOTES:**

- An average residential array consists of 20-30 panels (IGT). At 0.5 gallons of solution required for each panel (Duke) that's 10-15 gallons of water. One gallon is 8.3 pounds. (That's 80+ lbs). So basically, we have to cut water usage (which I think can be done by implementing dry light cycles and using soaker brushes for heavy cycles).
    - Let's assume we can cut it in half (0.25 gallons/panel) and that we are designing for about 20 panels right now. That's 5 gallons of water which is still 40 lbs.
        - We either clean without water or we need a hose (we can use a hose that is attached to a solution tank outfitted with a mixture value, so the amount of water on the roof at one given point is ideal). Light cycle will not require water and thus no hose, so the hose spool must be detachable.

Storing solution: requires about a 1:4 ratio of vinegar to water. If we use 10-15 gallons of water (20-30 panels max water usage) then we need 2.5-3.75 gallons of vinegar