Prototype 3 Deliverable
Design Team 6
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Objectives: The objective of our third prototype was to create a final comprehensive prototype, by combining the focused prototype of the break beam lasers, with the comprehensive prototype of the sand filtering system, which were previously tested in prototype 2. In addition, the objective of this prototype was to implement design tweaks, that were based off the feedback and concerns that Erin raised after our 3 minute presentation.

Prototype Test plan
There are three aspects of our prototype that we wish to test.

1. The break-beam sensors
2. The effectiveness of the filter
3. The effectiveness of the ramps at disposing of dirt/sand

Filter:
Our goal was to test the filter as well as our assembly's structural weaknesses.
Because our prototype was comprehensive, we used it to gain knowledge on the performance of the filter when it was assembled with the other components.
Our test involved observations on the overall performance of the system as well as the ability of the filter to evacuate sand.

Stopping criteria of testing: Determine the necessary dimensions of the filter where 75% of the sand filters through the filter, while keeping the trash in the filter.

Laser sensors:
In order for the sensors to be successful, their break points and range had to be tested.
For the lasers to be implemented, we had to gain an understanding of their capabilities and how they work. This test involved developing code for the sensors and then testing the effects of different code in the output. We tested this by setting the lasers to be in alignment, then obstructing the beam and analyzing what data was returned on the control monitor.

Stopping criteria: The lasers print “empty space”, “blocked” after 10 seconds and “blocked empty space” after 10 seconds when the hopper is empty, when the hopper is full, and when an object passes through the hoppe, respectively.

Ramps:

The ramps are a simple yet critical aspect to our design. Ramps that are too tall will cause a great imbalance in the center of gravity of Bowie, and ramps with a shallow angle will not be able to dispose of the dirt/sand. To test the ramps, we tested a piece of cardboard and angled it at different angles to see what configuration worked best. We found that an angle between 25 and 30 degrees worked the best. We took a minimalist approach and went with 25 degrees since this would result in the hopper being elevated less than if we were to chose 30 as the significant angle. We also tested the surface of the ramps and found that the smooth 3D printing surface worked well in conjunction with our chosen angle, alongside the obvious benefit of the material being biodegradable.

Stopping criteria: When the critical angle of the ramps is determined, that is steep enough to allow sand to exit Bowie without getting stuck on its way out.

Analysis of critical subsystems

Lasers: The critical function of the lasers are to notify the user that the hopper is full and that there is a blockage between the lid and the space underneath. In the previous prototype, we simply only designed, wired and implemented the code for the lasers. In order to cover the most amount of area inside the hopper, we decided to place the 2 laser systems on diagonals from opposite corners since this allowed for the most amount of area within the hopper to be in the lasers pathway (see pictures below for location of lasers). We had to orient them this way because the lasers are effective up until approximately 25 cm, whereas the hopper length is 30 cm. After the implementation, there were 3 specific ways that were important to test and analyze in order to make sure the lasers are working as we intended. The first of these methods was when the hopper is empty, or not filled up until the height of the lasers. Through our testing, both lasers in fact worked as intended, since they both printed “empty space” to the serial monitor in the situation described. The next situation was when the hopper is full. This occurs when either laser is blocked for more than 10 seconds. After 10 seconds of blocked lasers, “blocked” is printed to the serial monitor of one of the lasers. In the situation that one laser is “blocked” and one has “empty space”, that is up for the interpretation of Robot Missions on how to handle it as this signifies that the hopper is almost full, yet it still has room. The last situation is when an object passes through the lasers but does not block the lasers. In order to differentiate from step 2, 10 seconds after the object clears the lasers “Blocked” is printed to signify an object passing through followed immediately by “empty space” to signify that the object cleared and there is still room.

Filter: The critical function of the filter is to ensure that sand, specifically wet sand, falls through the filter holes, without letting any of the small trash pass through. In order to ensure that this is the case, we tested many different filter designs, by tweaking the dimensions of the holes, along with the type of filter. Ultimately, we determined that a filter with holes of 1cm by 1cm would be the best type of filter, since it allows the most sand, specifically wet sand, to filter through, while maintaining the trash in the filter. This benefit of the filter that we chose, unlike other designs, is that it is able to filter wet sand. We felt like this was a significant issue for Robot Missions, as it is generally hard to dispose of the wet sand because it gets stuck onto trash inside the hopper. However, when we accounted for the vibrations of the hopper as Bowie moves around, the wet sand detaches from the trash and is able to fall through the filter with no issue.Obviously, it was also found that there was no issue with dry sand, and it would fall right through the filter as intended. One concern regarding our filter is that small objects such as cigarette butts would theoretically be able to fall through the holes and back onto the sand. However, through testing we determined that this occurred on extremely rare occasions because it would have to fall perfectly vertical without anything impeding it. Given that there is trash in the filter and sand on the object, it is extremely rare that it would fall directly through on a 90 angle. In many situations, there is lots of trash in the filter which would not allow the cigarette butt from even reaching the bottom of the hopper. With this said, this does not account for the effect of sand on the cigarette butt, which would further deter it from falling straight through. As a result, we were able to determine that the filter is able to successfully filter the necessary trash from the hopper, while maintaining the trash in the hopper.

Ramps: The critical function of the ramps are to ensure that the sand and dirt that is filtered through the hopper is disposed of through the sides and away from the circuits and other important components of Bowie. In order to verify that the design is working, we tested the ramp with dry and wet sand, as this is the type of sand that Bowie will encounter. When using dry sand, the filtered sand slid off the ramps as intended. When using wet sand, the filtered sand also slid off the ramp as intended. Through our analysis, we determined that this occurs so smoothly for the following reasons. When the sand falls through the filter, the force of gravity allows it to generate enough speed so the shift in angle from falling straight down to the ramps does not affect it enough to block it from flowing. Also, the 3D printed PLA plastic of the ramps is a smooth surface with coefficient of static and kinetic friction of approximately .16 and .10, respectively. The smoothness of this surface ensures that the sand does not get stuck to it.
In our first prototype testing, we determined that there was often a buildup of sand in the middle of the filter, since the holes were blocked by the ramps. In order to overcome that issue in our design, we made sure to align the ramps with the center of the filter, so that there would be no build up. Through testing, we verified that this works, and we were able to overcome an issue with the ramps that we dealt with in the first prototype.

Steps needed to install filter

1) Design half the filter on Autodesk 360 and implement the tweaks in the dimensions from the previous prototype and Erin’s feedback
2) Print two half filters and glue them together using gorilla glue
3) Design the hopper walls as a vector PDF to laser cut from an acrylic sheet
4) Purchase an acrylic sheet from the Maker Lab and laser cut the dimensions
5) Design and 3D print 8 brackets
6) Using the 8 brackets and gorilla glue, attach the printed filter to the hopper walls

Steps needed to install the ramps

1) Using the critical angle of the ramps from prototype 1, determine the necessary length of the ramps
2) Design the ramps on this length on autodesk 360
3) 3D print the ramps twice (one for each side)
4) Using the same critical angle, determine the necessary height of the support columns
5) Design the support columns on autodesk 360
6) 3D print 4 support columns
7) Using gorilla glue, attach the ramps to the hopper and filter
8) Using gorilla glue, attach the 4 columns to the ramps, filter and hopper

Steps needed to install the lasers

1) Ensure the lasers are working as intended, and the soldering of the wires is done properly. Solder the wires as necessary if they come loose
2) Place the first set of lasers on diagonals in the hopper. Ensure that the lasers are on the right angle by testing to make sure the signal is being printed to the serial monitor
3) Hot glue the lasers to the hopper. Hot glue the support devices to the lasers
4) Repeat steps 2 and 3 for the second set of lasers and retest
5) Attach both PCB boards and arduino boards to the hopper

Through our feedback with Erin, we learned and implemented three things. The first thing is to ensure a time delay mechanism in the laser program to ensure the hopper is truly full when it receives the blocked message. In the focused prototype of the lasers, we foreshadowed this and made the time delay 5 seconds. However, in order to satisfy Erin's concerns we increased the time delay to 10 seconds so that the blocked message is guaranteed and a passing can si not misinterpreted. The second piece of feedback that we received from Erin was to rigorously test the filter, in order to guarantee that small objects do not pass through the filter. We took this feedback seriously, because it is paramount that the filter works as intended or else it ruins the whole point of a new hopper system for Bowie. Through testing and benchmarking, we decided to reduce the size of the squares in the filter by .2mm to make the filter 1cm by 1cm, while reducing the height of the filter to .5cm. We determined that this size was an ideal balance between filtering dry sand and wet sand, while also ensuring that small objects are not able to fall through the holes of the filter. The last piece of feedback we received from Erin was related to the elevation of the ramps. One of her concerns was the height in which the hopper would be raised, because this would affect the center of mass of Bowie, and it would be necessary to increase the length of the scooper to account for this increased height. Previously, we determined that the critical angle of the ramps was between 25 and 30 degrees. This critical angle was based upon ensuring that wet sand would not get stuck on the ramp, rather than slide down. Factoring in her concerns, we made the angle of the ramps 25 degrees, on the low end scale where we determined it needed to be. This led to an increased height of the hopper by 10 cm. Since the ramp filter system is the backbone of our design, we felt the effects of the new height would be negligible and worth the small inconvenience of extending the scooper, since it frees up more space inside the hopper and it will allow Bowie to collect more garbage and better perform his task.

After we received our feedback from Erin, there were certain things that we received from feedback and reviews. Firstly, she enjoyed the ideas of lasers, provided that they work properly. This is because the lasers vastly improve the user experience, by detecting when the hopper is full as opposed to the user guessing. Another positive aspect of the feedback that we received from Erin was about the filtration system, provided that it works properly and doesn't let any trash through the filters. The reason for this, is that we showed that the filter is able to filter wet sand out of the hopper. Many filtering systems struggle with wet sand, which our system is easily able to filter out. This received positive reviews, since it tackles a significant issue that has hindered Robot Missions goals.

In order to improve the results of the lasers, we utilized 2 different laser sensors, rather than the previously planned single laser system. The reason for this is that we believe the beams of the lasers would be able to cover more area inside the hopper if we placed them on diagonal angles, instead of just simply one across. This improves our previous results because a full hopper will more likely be noticed by the dual beam setup as there is more chance that an object interferes with a laser’s path (compared to a single laser system) and it will notify the user.

Results:

Filter

The metric for our design is the percentage of sand that is filtered from the hopper. As we were creating our original design criteria, we had created our ideal and acceptable target specification as 75 and 50 percent, respectively, of sand being filtered from the hopper. Through our testing and benchmarking, we determined that we had hit our ideal target specification, as 75% of the sand is being filtered. Although this is what we had hoped for, the reason that we did not surpass the ideal specification is based on 2 factors that are out of our control. The first is that often times when there are many objects in the hopper, wet sand would sometimes stick to the trash, as the hopper got more and more full. Also, as the hopper filled up, sometimes there was no where for the sand to go, as it was being blocked from reaching the filter. This sometimes led to sand not exiting the hopper as planned.

Lasers

The lasers performed as intended as they always printed the necessary messages to the serial monitor, for each situation that arises, letting the user know if the hopper is empty, or full.

Ramps

The ramps worked as intended, as they always disposed the sand. Through our extensive testing, we did not arrive at a situation where the sand would filter through the hopper, yet got stuck on the ramps.