

GNG 1103
Design Project User and Product Manual

Hydroponic Farm Growing Raft Cleaning Device

Submitted by:

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List of Acronyms and Glossary

Table 1. Acronyms

Acronym	Definition
CAD	Computer aided design
BOM	Bill of materials
MakerSpace	Richard L'Abbe MakerSpace
UO	University of Ottawa

1 Introduction

Hydroponic farming consists of growing plants in nutrient filled water rather than soil. The client, Growcer, manufactures hydroponic farm systems where leafy greens are grown in plastic rafts that float on water and required a device to clean algae off those rafts. The “Hydroponic Farm Growing Raft Cleaning Device” was developed to meet the client’s needs.

This user and product manual gives an overview of the problem, the solution concept developed, and the final prototype created; explains how to operate the final prototype; lists support resources; details the manufacturing of and testing already performed with the final prototype; and provides recommendations for future work on the problem. Appendices provide links to all relevant design files and documents.

This user and product manual is intended to inform design teams of the work already completed on the problem, the lessons learned, and suggest avenues for future development, as well as provide practical information regarding the final prototype.

2 Overview

The problem this product seeks to solve is the labour time taken to manually clean algae off of rafts by hand, and as such, there was a need for a more automated, less labour-inducing product that could remove the algae. This product is unique in that to combat the standard high PSI required it uses heated water and jets that, through a certain threshold of water pressure and mechanical bearings, will rotate themselves without the use of a motor or electrical components. Water used is also recycled in the system to keep water costs low, and water is filtered to not compromise cleaning.

As previously described, the client, Growcer, required a device to clean algae off plastic rafts used for growing plants in hydroponic farm systems, shown in figure 1. The farm systems are operated by a diverse range of customers and users, often with little to no technical background. Growcer provides ongoing operation training, support, and monitoring. Many remote communities use Growcer's systems to provide readily available fresh vegetables year-round.



Figure 1: Hydroponic farm growing rafts

Currently the farm users clean algae off the rafts manually, requiring 6-8 hours a week of manual labour. Growcer required a highly usable device to reduce labour costs while still effectively cleaning the rafts. Additionally, Growcer wanted the device to be automated and require very little maintenance. Further detailed analysis of Growcer's needs can be found through appendix I.

The “Hydroponic Farm Growing Raft Cleaning Device” solution concept, shown in figure 2, was developed to meet Growcer’s needs. Details of how the concept was generated can be found through appendix I. The design uses a heated high-pressure water cleaning system to remove algae from the rafts, avoiding the risks of damage to the rafts and mechanical failure associated with contact-based brush or scrubbing systems. A combination of fixed and self-rotating water jets is used to achieve full coverage of the rafts without complex brush indexing systems, resulting in an average 94% cleaning effectiveness. Operating the system only requires 2 simple start-up steps, 5 steps per raft cleaned, and 2 shut-down steps, making it highly useable.

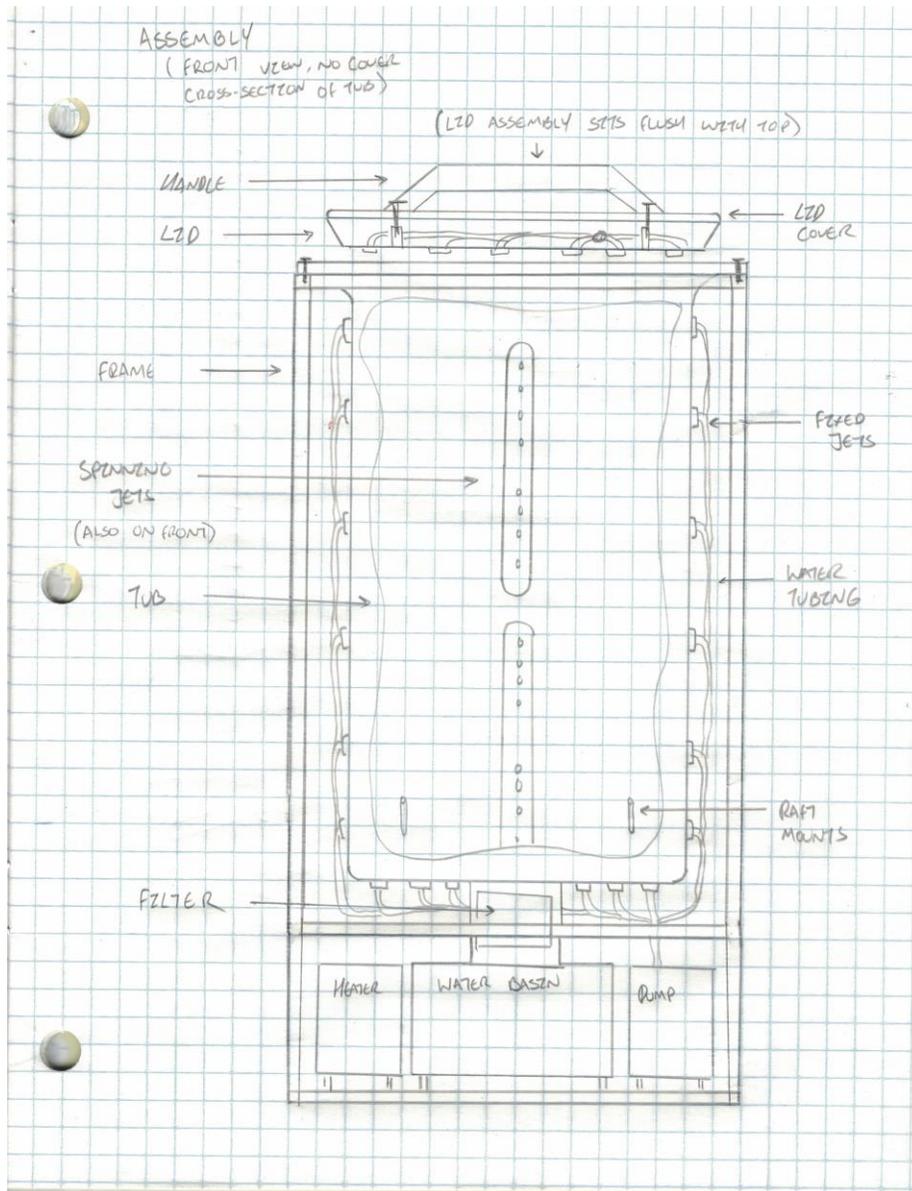


Figure 2: Solution concept

The final prototype, shown in figure 3, was developed to measure the performance of the cleaning system through practical small-scale testing. The prototype consists of a laser cut acrylic housing, a 3D printed spinning jet assembly, and a PEX pipe fixed jet array. A small-scale 3D printed raft was used for testing. Further details of the manufacturing and testing of the prototype can be found in section 6, Product Documentation.



Figure 3: Final prototype

3 Using the System

The main purpose of the final prototype was to measure the cleaning performance of the conceptual design. The prototype consists of three main subsystems: the water circulation system, the raft support system, and the housing system. The following subsections provide instructions for operating each subsystem individually, then for operating the system as a whole.

3.1 Water Circulation System

The main functional system of the final prototype is the water circulation system, which itself consists of two subsystems: the fixed jets, and the spinning jet. Further detail on each subsystem will be provided in the following subsections; however, both subsystems are connected and follow the same operation procedure.

To operate the water circulation system, the flexible tubing leading out from the system must be connected to a water source, as shown in figure 4. The final prototype includes a garden hose adapter, but future work could connect to a different source to provide higher pressure. Once the system is connected, the water source controls must be used to operate the prototype as, due to time constraints, it does not include a flow control mechanism. Figure 5 shows the water circulation system in operation. A video of the water circulation system in operation can be found through appendix I.



Figure 4: Connecting prototype to water source



Figure 5: Water circulation system in operation

3.1.1 Fixed Jets

The fixed jet subsystem consists of four lengths of PEX pipe connected by brass fittings surrounding the perimeter of the raft cleaning area. Each pipe has three to four evenly spaced drilled holes that act as nozzles when water is circulated through the pipes, spraying the sides of the raft. The previous figure 5 shows the fixed jets in operation.

3.1.2 Spinning Jet

The spinning jet subsystem consists of a 3D printed rotating nozzle assembly attached to the front face of the prototype housing. The assembly splits one water flow into six angled nozzles, which spray the face of the raft and rotate the assembly. Figure 6 shows the spinning jet subsystem in operation, removed from the rest of the prototype. A video of the spinning jet subsystem can be found through appendix I.



Figure 6: Spinning jet subsystem in operation

3.2 Raft Support System

The raft support subsystem holds the test raft in place surrounded by the water circulation system. The operation of this subsystem is straightforward: the test raft must be placed upright within the “U” shaped indents, as shown in figure 7. As detailed in section 4.4, Overall System, placing the raft is easiest if one or more of the prototype housing panels is removed.



Figure 7: Raft support system

3.3 Housing System

The housing subsystem consists of the acrylic box which contains the other subsystems, as shown in figure 8. Two panels of the box, the front and left, can be removed to allow easy access to the internal subsystems. This subsystem practically does not have an independent operating procedure, but as described in the following subsection, 4.4 Overall System, the removable panels must be used when operating the system as a whole.



Figure 8: Subsystems within housing system

3.4 Overall System

As previously mentioned, the main purpose of the final prototype was to measure the performance of the cleaning system design. To perform a cleaning cycle using the system, the following procedure must be used:

- 1) The test raft must be coated with a suitable test material to be cleaned. As will be described in section 6.5, Testing and Validation, mud was used when testing the prototype. Figure 9 shows an example of coating the raft.

Note: The surface of the raft opposite to the spinning jet will only be cleaned by water reflected off the housing and should not be fully coated.

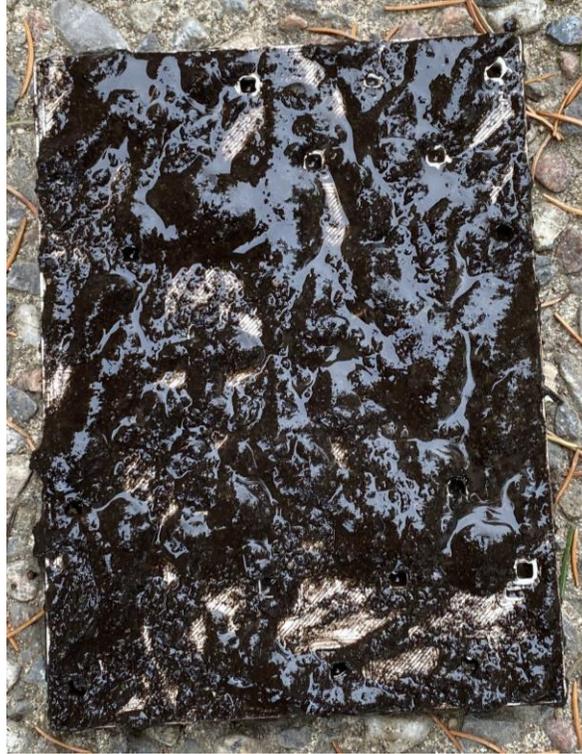


Figure 9: Test raft coated with test material

- 2) At least one removable housing panel must be taken off to load the test raft into the system, as shown in figure 10.



Figure 10: Left housing panel removed

- 3) The test raft must be loaded as described in section 4.2 Raft Support System.
- 4) All removable housing panels must be placed back on the system.

Note: Use of an external system, such as a simple strap, is recommended to secure the removable panels and reduce water leakage, as shown in figure 11.



Figure 11: Strap to secure removable panels (left panel still removed)

- 5) The water circulation system must be operated as described in section 4.1 Water Circulation System for the amount of time desired.

Note: When operating the water circulation system, water drains from the hole in the bottom housing panel. Placing the prototype above a container or drain is recommended.

- 6) Steps 3 and 4 must be reversed to unload the test raft.

A video of the prototype in operation can be found through appendix I.

4 Troubleshooting & Support

The following subsections detail errors and problems likely to occur when operating the final prototype, corrective actions to be taken, preventative maintenance, and support resources.

4.1 Error Messages or Behaviors

Table 2 details several common potential errors when operating the final prototype, likely causes, the appropriate corrective action to be taken, and any special notes:

Table 2: Potential errors and corrective actions

Potential Error	Likely Causes	Corrective Action	Notes
Raft is not completely cleaned.	Fixed jets are incorrectly aligned or spinning jet subsystem is not functioning.	Observe the system in operation, rotate the fixed jet pipes so that the water spray hits the side of the raft. See spinning jet subsystem not spinning.	Rotating the fixed jet pipes may require minor disassembly of the system. See section 6, Product Documentation for re-assembly instructions.
Prototype housing will not fully close.	Debris from cleaning is interfering.	Clean the connecting fingers of the prototype housing panels.	
Spinning jet subsystem does not rotate.	Insufficient water pressure or excessive friction.	Increase the water pressure. Manually rotate the spinning jet to “work it in”, reducing friction or breaking any obstruction generating friction.	Currently the spinning jet subsystem does not rotate due to the listed likely causes. Due to time constraints this error was not corrected.
Fixed jet pipes begin to loosen or fully detach.	Excessive water pressure	Manually push the pipes and fittings tighter. Disassemble the subsystem and reassemble using glue, ensuring the jets are properly aligned.	See section 6, Product Documentation for re-assembly instructions if required.

4.2 Maintenance

The following maintenance should be performed after every operation of the prototype to avoid errors.

- Clean and dry the interior of the prototype, ensuring any debris on the housing panel connecting fingers and around the spinning jet is removed.
- Empty the fixed jet pipes, spinning jet, and flexible tubing of water.
- Check that all pipe and tubing connections remain tight and tighten any that have come loose.

4.3 Support

This user manual serves as the primary support resource for the final prototype. Additionally, the following members of the initial design team can be contacted by email to report errors or problems. Please mention “GNG 1103 Raft Cleaner Support” in the email subject and include a description of the issue, when it occurred, and what corrective actions have been attempted. If possible, including photos and / or videos of the issue will help to clearly explain the issue.

- Owen Duncan: odunc079@uottawa.ca
- Zachary Chaloux: zchal076@uottawa.ca
- Ankit Singh Kapoor: akapo096@uottawa.ca
- Ryan Gorodezky: rgoro009@uottawa.ca
- Nic Maquis: nmarq040@uottawa.ca

5 Product Documentation

The final prototype consists of three subsystems: the spinning jet, the fixed jets, and the housing and raft support. The following sub-sections will detail the materials and equipment used to build each subsystem, as well as include detailed manufacturing and assembly instructions for each subsystem and the complete system. The miniature raft used for testing has been included in the housing and raft support sub-section.

5.1 Spinning Jet

The spinning jet subsystem cleans the large faces of the rafts. In the conceptual design, two spinning jets per side clean both faces of the raft, whereas the final prototype used only one spinning jet to test the design and measure the cleaning performance on one face. This subsystem was mainly manufactured through 3D printing because this was the simplest, quickest, and most accessible method to create the complex internal geometry required for the parts. Future prototypes of this subsystem would likely also use 3D printing until an effective design was finalized, at which point injection molding would likely be more suitable.

5.1.1 BOM (Bill of Materials)

The following materials were used to create this subsystem:

Note: Whenever possible, the exact product is linked. If the exact product is not available, a generic version will be listed.

- CAD software, [Onshape](#), available to UO students.
- Slicing software, [Ultimaker Cura](#), available to public.
- PLA 3D printer filament, [Materio3D PLA Filament](#), available to UO students through the MakerSpace.
- Bicycle headset bearings, [Ball Bearing Retainer](#), sourced from team member.

Note: Bicycle headset bearings, which support an axial load, were used for availability. Bearings designed to support radial load, [Radial Bearing](#), would be more suitable.

- Adhesive, [Gorilla Glue](#), sourced from team member.

5.1.2 Equipment list

The following equipment was used to manufacture and assemble this subsystem:

Note: Whenever possible, the exact tool used is linked. If the exact tool is not available, a generic version will be listed. Common tools will not be linked.

- 3D printer, [Ultimaker 2+](#), available to UO students through the MakerSpace.
- Vise, available to UO students through the MakerSpace.
- C clamps, sourced from team member.
- Sandpaper, sourced from team member.

5.1.3 Instructions

The following steps were used to build and assemble this subsystem:

- 1) Rough sketches of the design were created. The design consists of the jet nozzle, split into two halves; the rotating shaft; a bearing placement key; and the shaft housing, split into two halves.
- 2) Based on the rough sketches, the dimensions of the pipes used in other subsystems, and the dimensions of the bearings available, CAD models of the parts were created, as shown in figure 12. The CAD files are available through appendix I.

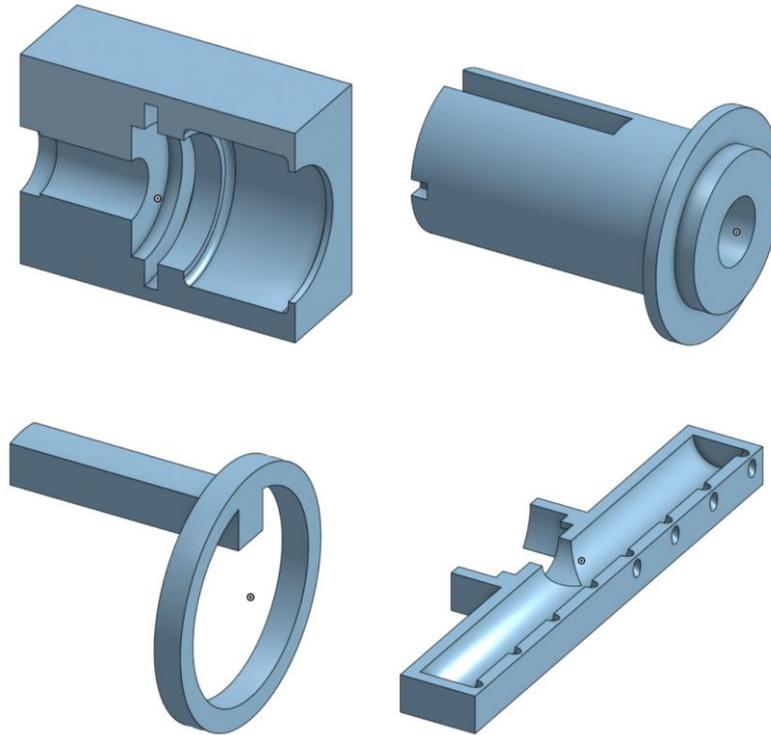


Figure 12: CAD models of spinning jet parts

Note: Many part dimensions were determined arbitrarily or based off the dimensions of available materials due to time constraints and should not necessarily be used in future work.

- 3) The CAD models were prepared for 3D printing using the slicing software, then manufactured using the 3D printer.
- 4) The 3D printed parts were assembled using the detailed steps below.
 - a. One bearing was slid onto the shaft.
 - b. The bearing placement key was slid onto the shaft, using the square key to index its position.
 - c. The second bearing was slid onto the shaft.
 - d. The shaft assembly was placed into one half of the shaft housing, as shown in figure 13.



Figure 13: Spinning jet shaft and bearings in shaft housing

- e. The second half of the shaft housing was glued to the first. Clamps or a vise should be used to ensure a tight fit.

Note: It is important to periodically rotate the shaft while the glue sets, or else the shaft may be glued in place. If this occurs, it should be possible to forcibly rotate the shaft free, but performance of the system will be reduced.

- f. The two halves of the nozzle were glued together. Clamps or a vise should be used to ensure a tight fit.

Note: It is important to avoid filling the nozzle openings with glue, or else water will be blocked. If this occurs, the excess glue can be removed with a sharp tool.

Note: Before continuing the assembly, the shaft and housing assembly must be attached to the prototype housing.

- g. The nozzle assembly was glued onto the shaft, using the square keys to index its position.

The final assembled subsystem is shown in figures 14 and 15.

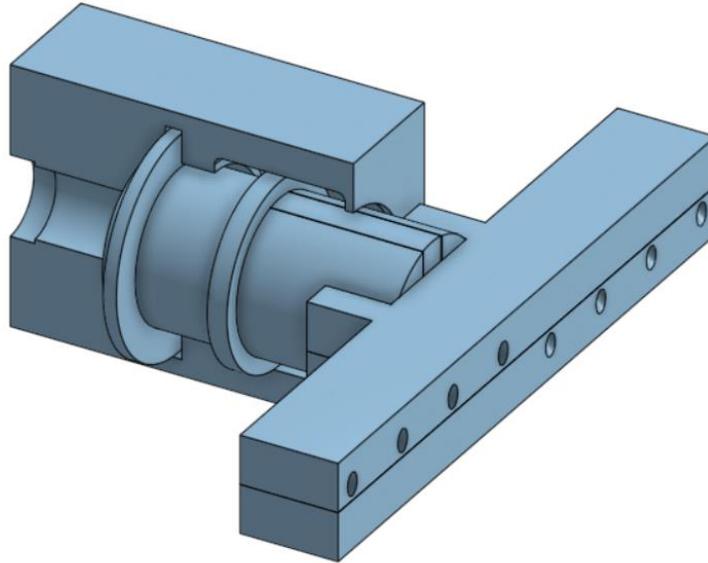


Figure 14: CAD model of assembled spinning jet (half of shaft housing removed)



Figure 15: Photo of assembled spinning jet

5.2 Fixed Jets

The fixed jet subsystem cleans the sides of the rafts. The prototype is a relatively high-fidelity representation of the conceptual design, except that in the conceptual design, a break in the pipes would be required to allow the device's lid to open and the system would be integrated with the housing to reduce water leakage. This subsystem was manufactured using plastic pipes and brass fittings as these materials were affordable and accessible. Future prototypes would likely use the same materials.

5.2.1 BOM

The following materials were used to create this subsystem:

- Rigid pipe, [1/2" PEX Pipe](#), sourced from Home Depot.
- Pipe elbow, [1/2" Brass PEX Elbow](#), sourced from Home Depot.
- Pipe tee, [1/2" Brass PEX Tee](#), sourced from Home Depot.
- Garden hose adapter, [Garden Hose Repair Kit](#), sourced from Home Depot.
- Hose clamp, [Garden Hose Repair Kit](#), sourced from Home Depot.
- Adhesive, [Gorilla Glue](#), sourced from team member.

5.2.2 Equipment list

The following equipment was used to manufacture and assemble this subsystem:

- Bandsaw, available to UO students through the Brunfield Centre.

Note: A dedicated pipe cutter would have been more suitable but was not available.

- Drill press, available to UO students through the Brunfield Centre.
- Power drill, sourced from team member.

5.2.3 Instructions

The following steps were used to build and assemble this subsystem:

- 1) The dimensions of the subsystem were determined based off the dimensions of the test raft and the pipe fittings.
- 2) The required lengths of PEX pipe were marked, then cut using the bandsaw. Two short lengths and two long lengths were required.

Note: It is important that the short and long pipes are of pairwise equal lengths so that the system will can be connected tightly.

The final assembled subsystem is shown in figure 17.

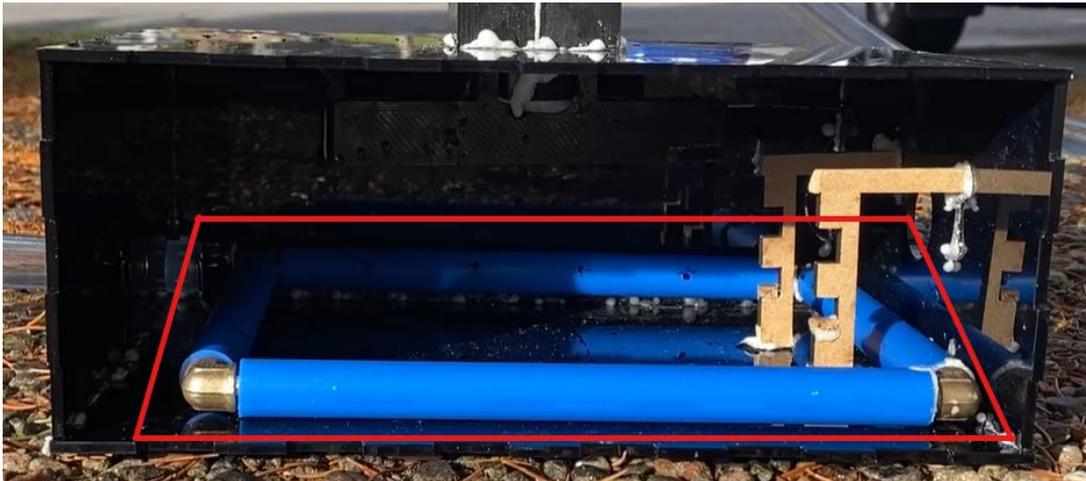


Figure 17: Assembled fixed jet system

5.3 Housing, Raft Support, & Test Raft

The housing subsystem both contains the other subsystems, reducing undesired water leakage, and supports parts of the water circulation system. The raft support system holds the raft in the correct position for the water circulation system to function. The prototype housing and raft support subsystems are closely related and are thus detailed in the same subsection. The test raft was used in measuring the cleaning performance of the design and is most closely related to the other two subsystems described in this subsection.

These subsystems of the prototype are relatively low fidelity representations of the conceptual design, as several key features, such as the opening top lid, were not relevant to the purpose of the prototype. Except for the raft support subsystem, as noted in the following subsections, the materials used for these subsystems would be appropriate for future prototypes.

5.3.1 BOM

The following materials were used to create this subsystem:

- Laser cut box plans, [MakerCase](#), available to public.
- Vector art software, [Inkscape](#), available to public.
- Acrylic sheet, [12" x 24" 1/8" Acrylic](#), sourced from the MakerStore.
- MDF, [12" x 24" 1/4" MDF](#), scrap sourced from the MakerLab.

Note: Scrap MDF was used for availability; acrylic or a similarly water-resistant material would be more suitable.

- CAD software, [Onshape](#), available to UO students.
- Slicing software, [Ultimaker Cura](#), available to public.
- PLA 3D printer filament, [Materio3D PLA Filament](#), available to UO students through the MakerSpace.
- Adhesive, [Gorilla Glue](#), sourced from team member.

5.3.2 Equipment list

The following equipment was used to manufacture and assemble this subsystem:

- 3D printer, [Ultimaker 2+](#), available to UO students through the MakerSpace.
- Laser cutter, [Epilogue Mini](#), available to UO students through the MakerSpace.
- Hacksaw, available to UO students through the MakerSpace.
- C clamps, sourced from team member.

5.3.3 Instructions

The following steps were used to manufacture the test raft:

- 1) Using the detailed drawings of the rafts provided by the client, a CAD model of the rafts was created, as shown in figure 18. The CAD file is available through appendix I.

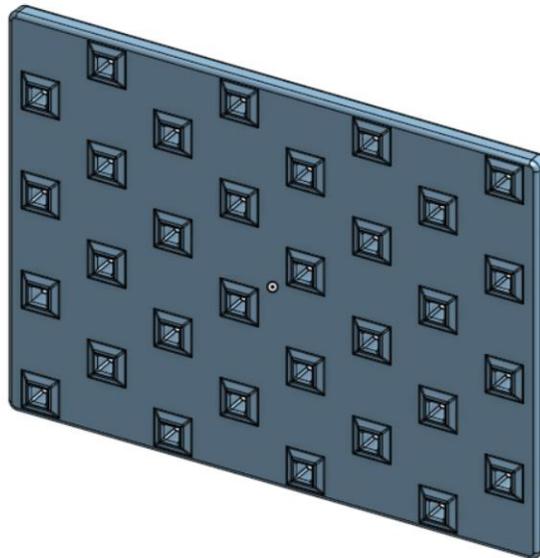


Figure 18: CAD model of raft

- 2) The raft CAD model was prepared using the slicer software and manufactured using the 3D printer.

The following steps were used to build and assemble the housing subsystem:

- 1) Using the dimensions of the available acrylic sheets, the dimensions of a box with maximum volume given a width to height ratio of three to four were determined as a reference point.
- 2) Based off of the calculated maximum volume dimensions and the dimensions of the other subsystems, dimensions for the housing were determined. The chosen dimensions were less than the maximum volume dimensions where possible to reduce the amount of material used.
- 3) Using the laser cut box plan generator, plans for the housing were created. The plans are available through appendix I. Holes for flexible tubing connecting to the fixed jet subsystem on the top panel, the spinning jet subsystem on the front panel, and for water drainage on the bottom panel were added using the vector art software. The housing panels were then laser cut.
- 4) Four out of six housing panels were glued together. The remaining two were left unattached to allow for easy access to the internal subsystems. At least one panel must be left removable to be able to load the test raft.

The following steps were followed to build and assemble the raft support subsystem.

Note: The initial plan for building the raft support subsystem failed. Due to time constraints, the following alternative plan was followed. Future prototypes could improve the raft support subsystem.

- 1) The basic shape of the raft supports was cut from the scrap MDF using the hacksaw. The “U” shaped indents were finger joints for a box.
- 2) The small additional support pieces were cut from the scrap MDF using the hacksaw and glued on.

The final assembled subsystems are shown in figure 19.



Figure 19: Assembled housing and raft support subsystems with test raft

5.4 Overall Assembly

The previously described subsystems are assembled as detailed in the following subsections.

5.4.1 BOM

The following materials were used to assemble the subsystems:

- Flexible pipe, [1/2" Tubing](#), sourced from team member.
- Hose clamp, [Garden Hose Repair Kit](#), sourced from Home Depot.
- Adhesive, [Gorilla Glue](#), sourced from team member.

5.4.2 Equipment list

The following equipment was used to assemble these subsystems:

- Hacksaw, available to UO students through the MakerSpace.
- Flat head screwdriver, sourced from team member.

5.4.3 Instructions

The following steps were used to build and assemble the overall prototype:

- 1) The flexible tubing was inserted through the top hole of the prototype housing and connected to the tee joint of the fixed jet subsystem, then secured using a hose clamp. The flexible tubing was cut off using the hacksaw at a length long enough to reach the position of the spinning jet.

Note: Due to time constraints and the relatively low water pressure used in the prototype, the fixed jet subsystem was not securely attached to the prototype housing. Future prototypes, especially if using higher water pressure, should attach the subsystem to ensure a consistent fixed jet angle.

- 2) The spinning jet subsystem was attached through the front hole of the prototype housing.

Note: The spinning jet subsystem must not be fully assembled before this step; the nozzle assembly must be attached to the shaft after the shaft has been inserted through the hole.

- 3) The pipe connector was glued into the spinning jet subsystem as shown in figure 20.



Figure 20: Pipe connector attached to spinning jet

- 4) A short length of flexible tubing was cut using the hacksaw and attached to the spinning jet pipe connector.
- 5) The flexible tubing from the fixed jets was connected to the tubing from the spinning jet using a tee connector, then secured with hose clamps, as shown in figure 21.



Figure 21: Flexible tubing connection

- 6) The remaining flexible tubing was connected to the tee connector and secured with a hose clamp.
- 7) The garden hose adapter was attached to the end of the flexible tubing.
- 8) The raft support subsystem was glued to the bottom and back panels of the prototype housing, sitting over the bottom fixed jet pipe.

The final assembled prototype is shown in figure 22.



Figure 22: Assembled prototype

5.5 Testing & Validation

The main purpose of the final prototype was to quantitatively measure the performance of the cleaning system. To accomplish this goal, several cleaning cycles were performed as described in section 4.4 Overall System.

To obtain cleaning performance data, the flat surface of the test raft was divided into 64 equal grid sections. A cleaning cycle was performed as describe in section 4.4 Overall System, and the number of completely visibly clean sections afterwards was recorded.

Initial testing was performed using wetted flour as the sample material; however, after several cleaning cycles of increasing duration where little flour was cleaned from the raft, it was determined that the water pressure used in the system was insufficient to effectively clean the material. Testing of previous prototypes had demonstrated that high pressure water effectively removed wetted flour after a sufficient time interval, thus further testing was performed using mud as the test material. The water pressure was sufficient to effectively remove mud. Several trials of various cleaning cycle durations were performed to gather data on the correlation between cleaning time and cleaning performance. The cleaning system removed the mud so quickly that cleaning time had no appreciable impact on cleaning effectiveness, thus all further testing used a cleaning cycle of 20 seconds. Six trials performed with mud generated the following results, shown in table 3.

Table 3: Cleaning performance testing results

Trial	Number of Grid Sections Clean
1	63 / 64
2	62 / 64
3	56 / 64
4	57 / 64
5	58 / 64
6	64 / 64

The recorded results show that the cleaning system was on average 94% effective.

6 Conclusions and Recommendations for Future Work

The final prototype successfully demonstrated the effectiveness of the cleaning system design. Future work would mainly consist of performing more rigorous testing and refinement of the cleaning system design. Several notes regarding material selection and assembly features for future prototypes can be found in section 5 Product Documentation. Additionally, with the final prototype having addressed the most critical system of the conceptual design, future work should focus on testing and developing secondary systems, such as the top lid mechanism and water filtration system.

APPENDICES

7 APPENDIX I: Design Files

Design files and documents referenced throughout this user and product manual can be found in table 4.

Table 4: Referenced Documents

Document Name	URL
MakerRepo project page	https://makerepo.com/ryangorodezky369/1430.hydroponic-farm-growing-raft-cleaner-gng-1103-a02-algaegees
Detailed analysis of client needs	https://uottawa-my.sharepoint.com/personal/odunc079_uottawa_ca/_layouts/15/guestaccess.aspx?docid=0b26562ef9f9042b78d6bb054c09bd9df&authkey=AUT6-x_2GJaPJc6XSTtZIJ8&e=NrBar4
Detailed analysis of design concept generation	https://uottawa-my.sharepoint.com/personal/odunc079_uottawa_ca/_layouts/15/guestaccess.aspx?docid=0382ac2da2b9e442c85c3cf0e8dbb92c3&authkey=AS3aZSDbWwFKQT2bPKcIb_s&e=ozVuRb
Onshape prototype CAD files	https://cad.onshape.com/documents/f445ff60cd5b4aef8a8a135e/w/2dd74fd5216eaeacaeb1f3b0/e/e740fa5a417ff9e34096c3d0
Onshape raft CAD file	https://cad.onshape.com/documents/69ef4f14fb589a821498d1a7/w/6f2e09b2e3758a7fc04f7bfa/e/0d0fa71566e84a197b8df40c
Housing box plans	https://uottawa-my.sharepoint.com/personal/odunc079_uottawa_ca/_layouts/15/guestaccess.aspx?docid=0e682e5ce228645e6acd9b63a14acd906&authkey=ARUM7xw2N2ls5lLbO3Uw7Kg&e=sxmpEJ https://uottawa-my.sharepoint.com/personal/odunc079_uottawa_ca/_layouts/15/guestaccess.aspx?docid=03f831899af2342fca9fb6c3e9dc3a018&authkey=AX9k31iRz06q4Px13tHKqjY&e=WzB14b
Additional photos and videos of final prototype	https://photos.app.goo.gl/GiQfa1JrxUhaRXAaA

