

GNG 1103
Design Project User and Product Manual

Nuclear Pipe Sampling Tool

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List of Acronyms and Glossary

Table 1. Acronyms:

Acronym	Definition
PVC	Polyvinyl Chloride
UPM	User and Product Manual
CAD	Computer-Aided Design

Table 2. Glossary:

Term	Acronym	Definition
Prototype	-	A preliminary model of the final product used for testing and refining the design.
Polylactic Acid	PLA	A biodegradable filament widely used for 3D printing components in prototype development.

Introduction

This User and Product Manual (UPM) provides the information necessary for nuclear technicians to effectively use the Nuclear Pipe Sampling Tool and for prototype documentation. The main goal of our tool is to gather a metal sample from the inside of a nuclear pipe for testing purposes. We are assuming that our user has a high school diploma and basic college degree or apprenticeship.

This document will cover an overview of our project, how to set up and understand our product, how to use our product, trouble shooting and support, our product documentation, conclusions and future considerations, and a list of references. The purpose of this document is to provide users with the necessary information required to operate our tool in a safe and efficient manner and recreate our tool if needed.

In this document we will provide CAD drawings of our complex parts and the bill of materials which goes over everything needed to recreate our product. It will go over exactly what steps we took to create our prototype, the assembly process of our tool, and all the considerations we took while creating the tool. This document is intended for students and workers who want to understand and incorporate aspects of our design into their own designs.

We have described safety measures in this document for all the manufacturing and assembling parts of our project. For the privacy of our client, we have not included a company name, or any names associated with the product.

Overview

The problem our product solves is a way to safely extract metal samples from the inside of a nuclear reactor pipe for testing while keeping the operator safe and completely securing the sample in a way that there is no contact to the operator or any other user. The nuclear pipes are sampled for testing around their 80-year mark to make sure that they are still suitable for use and that they do not pose any potential risks.

The user needs to be able to operate the tool safely and in a timely manner while keeping themselves and others safe from any high radiation contamination. Failure to do this can result in series injury or death to the operator or any user that encounters the highly radioactive material.

Our product offers a safe solution to this problem. Our tool does not include any electronic equipment that can malfunction or be disrupted by the intense radioactive waves. Our design is very simple and easy to use, only requiring one person to operate and can be controlled all by one control system.



Figure 1

The tool has four main functions to complete the required task. The main body is made from 5' sections of PVC tubing and reaches the full distance into the tube. The scraping device is

comprised of a sawed-off chisel attached to an axel system through the main body and can be rotated in a milling motion to collect sample. The collection device is a 3D printed container held by a mount that is attached to the main body. The container has a sliding lid that can be shut using a wire and held shut with magnets. The last main function are the wheel mounts. They are made of 120° sections that go around the circumference of the main tube and help it slide through the tube smoothly while keeping all our other features centered.

The PVC tubing was assembled with connectors that were secured with PVC glue. The chisel was cut with a grinder and attached to a CAD designed swivel system that can raise/lower it. The container and mount were drawn with CAD, 3D printed, then attached to the main body with PVC glue. The wheel mount was made from three parts that were drawn with CAD, 3D printed and then attached to the main body with PVC glue. It was made of the mount, the axel, and the wheel which was help together using hot glue.



2.1 Conventions

Please pay attention to action words used in the “Getting Started” section of this document. Words such as, “assemble, slide, attach, roll, pull” require action from the user in order to construct the tool.

2.2 Cautions & Warnings

The scraping system uses a chisel with a sharp end. It is protected with a rubber guard when not in use but please use caution when system is in use and guard is removed.

Do not attempt to wrap the wire used for the scraping system and collection system around any part of your body to pull it. Only pull from the very end of the wire at the control system end of the tool.

3 Getting started

3.1 Configuration Considerations

To assemble this prototype the user will require a screwdriver to attach the handle and aid in treading the wire through the inside pipe to push the wire through difficult sections. In addition, if the user wishes to use the device in vertical configuration, they will have to 3D print a different collection container that can slide into the existing black connection piece on the end of the exterior pipe.

3.2 User Access Considerations

This prototype can be used by scientists to collect samples from low access environments.

3.3 Accessing/setting up the System

1. The tool can either be in the 5ft, 10ft or 15ft configuration. For these steps we will focus on the 5ft configuration. The 10ft and 15ft configurations follow the same steps.
2. First, take the white pipe with the chisel end and insert it from the non-chisel end into the larger grey pipe labelled 1-5 (the pipe section with the wheels):



3. Next thread the longer wire through the end of the small white pipe from the opposite end of the chisel until it comes out on the other end. Then attach it to the chisel using a carabiner.





4. Next have another person push on the white pipe chisel end while you slide the 1ft white handle on the opposite end using the gold connector. (first thread the handle through the wire)



5. Next thread the black handle through the wire onto the white pare of the handle so the holes line up. Then use the nut and bolt to attach the black and white handle components to form an L:



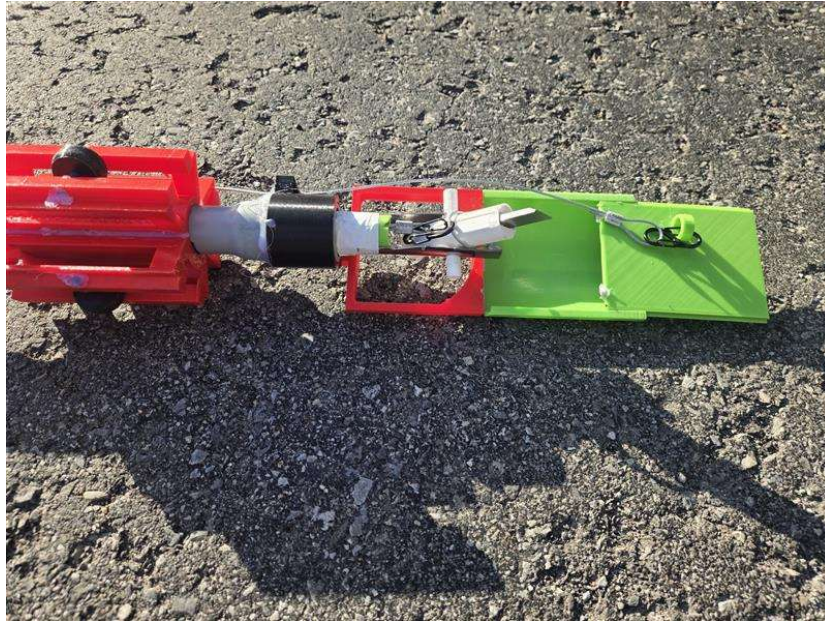
6. Now take the green-red collection box and slide it into the chisel end of the device.



7. Now attach the shorter wire with the large loop to the loop on the lid of the box. (DO NOT threaten this wire through. It rests on the outside of the tool).



8. Now the 5ft configuration is prepared to perform a scraping operation.
9. First, the tool must be oriented like the photo below with the lid open and the chisel all the way forward. Align the chisel and the handle. Then roll the tool into the pipe on the wheels.



10. Once the device has been rolled so that only the white pipe of the handle attachment is sticking out of the end of the pipe, pull the wire coming out of the white pipe, and then

rotate the black handle 45 degrees in each direction while maintaining tension in the wire. Do this rotation motion 5 times back and forward.





11. After performing the scraping motion, pull on the exterior wire with the big loop to close the collection container and roll the device out of the pipe:



12. After the tool is removed from the pipe, detach the carabiner and slide the sample box off the end.
13. Roll the tool out of the pipe
14. Remove collection container by sliding it off the rails and send the box to the lab for testing.
15. This process can be repeated for the 5ft and 10ft configuration of the tool.

3.4 System Organization & Navigation

As described above, once the user has built the 5ft, 10ft or 15ft configuration, they can roll the system into a nuclear pipe with the collection container lid open and the chisel manually set all the way forward. Once they read the desired sample collection length from the labels on the exterior of the system then they pull the interior wire to actuate the scraper, perform 5 forward and backwards scrapes with the handle, release the tension of the interior wire and then pull the exterior wire to close the collection container lid.

3.5 Exiting the System

To put away the system:

1. Take off the collection container
2. Unthread the outer pipes.
3. Unscrew and remove the black handle
4. Slide out the inner pipes from chisel end
5. Pull the wire from the inner pipes after detaching it from the carabineer
6. Disconnect the inner pipes

4.0 Using the System

4.1 Scraper

The Scraper is a chisel blade on the end of the inner PVC pipes. It can be pulled back to hit the pipe surface using a wire and released back to its initial position by releasing the wire. It scrapes by moving circumferentially along the inner surface of the nuclear pipe.



4.2 Collection Container

The sample collection system is a box with a lid that can be shut by pulling a wire that runs along the exterior of the tube. The lid remains shut using magnets and this works because the nuclear pipe metal is non-magnetic. This collection container can slide into the corresponding attachment point at the end of the tool. It has an open area of the scraping chisel to rotate within.



4.3 Exterior structure

The exterior structure is made of 3 5ft sections of 1in diameter PVC pipes. These pipes are connected in series with male and female threaded PVC couplings. The exterior structure is a flexible material that can handle slight bends in a nuclear pipe. The last section of 5ft PVC (the one that is the furthest into the nuclear pipe) has wheels mounted on it to match the 4in diameter of the nuclear pipe for stability while collecting a sample with the circumferential scraping motion. On

the exterior sections of PVC there are also labels for measuring distancing into the pipe: there is a 1-5ft section, at 6-10ft section and an 11-15ft section. These can be used to give the user feedback on how far they have wheeled the system into the nuclear pipe and therefore at what depth they would be collecting the radioactive sample from.



4.4 Control System and interior structure

The interior control system is made of 5 ft 3/4in diameter per PVC pipes that are connecting in series with shark bite couplings that are cramped onto the ends. Each 5ft section also has 2 metal spacers crimping onto its exterior to match the inner diameter of the external structure. The inner pipes can be connected in series. At the end of the 15ft pex pipe connected in series, a 10in handle attached can be connected at the opposite end to the chisel. The chisel itself is actuated against the wall of the nuclear pipe when the user pulls on the 17ft wire that runs through the interior pex pipes. The wires are also meant to keep tension so that the pex pipes stay aligned and don't rotate individually those this did not end up working; to mitigate the induvial rotation for the components

of the inner 15ft 10in of pex pipe the user should install small bolts and nuts at the couplings joints that can be screwed in to still allow for a modular system.



5.0 Troubleshooting & Support

This section is mainly dedicated to potential problems, special care, maintenance tips, and avenues of assistance that may be faced when employing the prototype tool for this project. As this tool is a fully mechanical drive system, the troubleshooting process is mainly centered on the mechanical parts' wear and tear, the accuracy of the assembly, and the structure's stability. All of this can be performed by hand by the user.

5.1 Error Messages or Behaviors

System	Problem	Solve
Scraper system	Chisel becomes dull or dislodged due to high friction or improper alignment.	Replace or sharpen chisel; ensure 3D-printed holder is properly secured and the pivot mechanism rotates freely.
Collection system	Sliding lid does not close properly or magnets lose hold during movement.	Check magnets for strength and replace them if needed; realign sliding track and test lid motion.

Main body	PVC frame detaches at couplers or becomes unstable due to impact or wear.	Reapply PVC glue; tighten couplings; add support brackets or test alternative coupling designs.
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5.2 Special Considerations

1. All components are mechanical components. Please ensure environmental safety and avoid using them under high temperature, humidity, or strong magnetic fields to prevent material deformation or decreased magnetic performance.
2. Operators are advised to wear gloves to prevent accidental injury or hand pinching by scrapers during the cleaning process.
3. If disassembling components is required, please use tools of appropriate size to avoid damaging the 3D printing material with excessive force.
4. Sliding structures and magnetic systems are susceptible to external forces during transportation. It is recommended to install external physical limit devices (such as tape or buckles) to ensure stability.

5.3 Maintenance

Maintenance Task	Frequency	Description
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Chisel inspection and sharpening	Every 5 tests or weekly	Check for dull edges or cracks; sharpen or replace as needed
Magnet and lid inspection	After each use	Clean sliding track, test magnet strength, and ensure the lid closes securely
PVC joint and coupler check	Weekly	Look for loosening or detachment; reapply glue or reinforce as necessary
Wheel rotation and balance	Two weeks	Ensure wheels spin freely; remove debris; test for alignment in the pipe
Storage condition check	Monthly	Store in a dry, cool location to prevent warping of 3D-printed components

5.4 Support

If there are problems beyond the basic troubleshooting scope during actual use, team members can help. Encourage users to clearly record their questions and contact them through the following contact information:

Team Member	Responsibility Area	Contact Info
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Sam Stano	Wheel mounting and mobility components	sstan049@uottawa.ca
Owen Kaine	Collection system assembly and testing	okain055@uottawa.ca
Ziyi Wang	CAD design, scraper system support	zwang063@uottawa.ca
Aidin Moradi	Prototype assembly and general mechanical support	amora106@uottawa.ca

Reporting Issues

1. Standard Issues: Send a detailed email including the subsystem affected, the problem description, and photos if available.
2. Urgent Issues: Reach out through team communication channels (e.g. Teams) or speak to a team member in person.
3. Safety Hazards: If any part of the system appears structurally unstable or poses a risk of injury, immediately cease operation and report the issue to a support contact.

6.0 Product Documentation

Our final prototype is operated using only mechanical component. The first component is the scraping tool, which is used for our testing to ensure it efficiently removes debris from the pipe's interior surfaces. The second component was the collection system, designed to securely gather and store the debris scraped off during the testing process. The third component is the wheel mount and wheel design, which will be used to stabilize and facilitate the smooth movement of the prototype in various environments. The last component is the core Support Frame (Main Body), which is made of two durable 10-foot PVC pipes that are used to ensure mechanical support throughout the operation.

Mechanical Components:

6.1 Core Support Frame:

The Core Support Frame (main body) serves as the structural backbone of the prototype. It is made of two durable 10-foot PVC pipes connected using male and female couplings (glued on with PVC glue). These materials were selected for their durability, and lightweight nature. The frame acts as the mounting base for the scraping tool, collection system, and wheel assemblies, providing essential mechanical support during operation. The pipes were also joined using detachable couplers.

Assembly Instructions:

1. Cut two 10-foot PVC pipes to desired lengths.
2. Connect with male and female PVC couplings; secure joints using PVC glue.
3. Allow adhesive curing time (as recommended by the glue manufacturer).

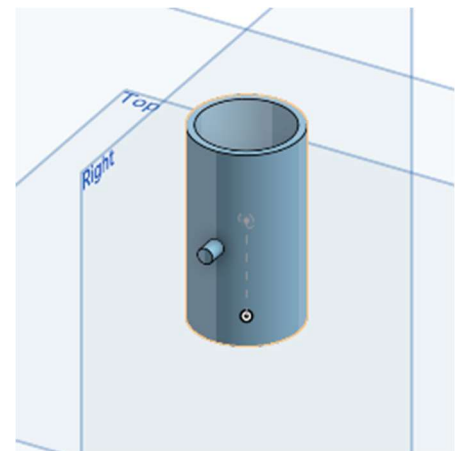
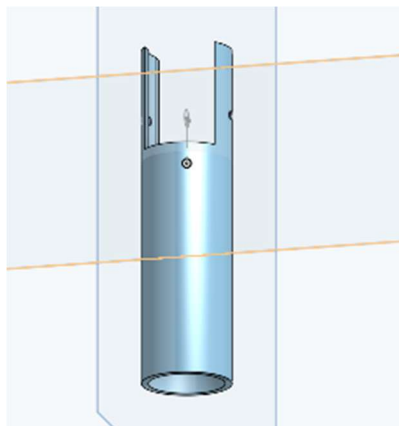


Scraping Tool (Chisel):

The scraping tool is built to effectively remove debris or gather samples from the inner walls of the pipe. For the final prototype, a chisel was selected for its sharp edge and durability. The chisel holder was 3D-printed with PLA filament, offering a fast and budget-friendly approach to prototyping. It's designed to rotate along the shaft, allowing it to scrape from multiple angles.

Assembly:

1. Insert the chisel firmly into the 3D-printed holder.
2. Secure the holder onto the rotating shaft with fasteners or adhesive.
3. Test rotation and adjust alignment accordingly.

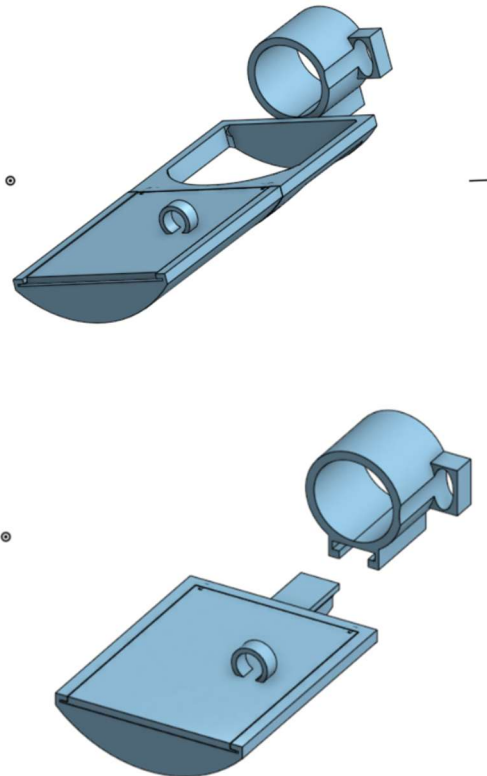


Collection System:

The collection system is designed to securely gather and store samples removed from the pipe walls. It features a box with a functional lid that opens and closes using a sliding mechanism. Magnets provide a light seal to prevent sample loss without obstructing debris flow. The container operates effectively in both vertical and horizontal orientations.

Assembly:

1. Print collection box and sliding lid from finalized CAD files.
2. Attach magnets securely to the lid and box edges.
3. Slide the box onto the PVC frame via the custom loop connector.

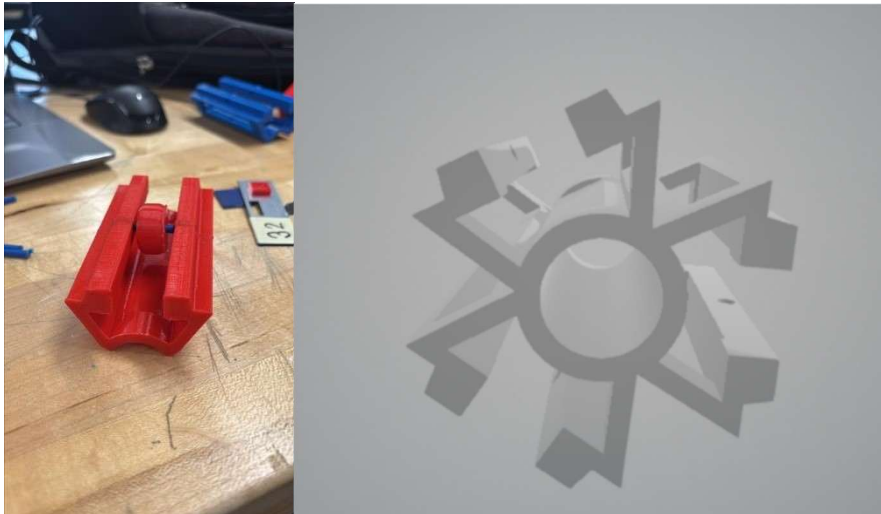


Wheel Mount and Wheels:

The final wheel mount was printed based on updated CAD with corrected measurements. It improved tool balance and allowed smoother movement through the testing pipe section. The Wheel Moun and Wheel is printed using the 3D printer in the lab. The new design proved to be more stable than earlier versions, reducing wobble and maintaining consistent contact with the pipe walls during operation.

Assembly:

1. Print wheel mounts and wheels from finalized CAD.
2. Attach wheels securely onto the mount.
3. The mount wheel assemblies onto the main PVC frame at predetermined positions.



6.1.1 BOM (Bill of Materials)

Material	Amount	Cost (CAD with tax included)	Source
Chisel	3	19.20	Canadian Tire

3d printing filament	Undetermined	Free	N/A
3/4in diameter, 5ft PEX pipes	3	13.5	Home Depot
Metal Spacers	6	Already in Possession	N/A
10ft PVC pipes (1in diameter)	2	24.3	Home Depot
Female PVC couplings	2	4.23	Home Depot
Male PVC couplings	2	3.44	Home Depot
PEX pipe connectors	2	4.25	Home Depot
Hot glue gun	NA	Already in possession	NA
PVC glue	NA	10.4	Home Depot
Magnets	60 pack	7.91	Amazon
50ft Metal Wire	1	18.1	Home Depot
Metal Wire Ferrules	10	7.1	Home Depot

Final Total		112.43	

6.1.2 Equipment list:

Mechanical Equipment:

- **3D Printer** – Used to print the chisel holder, wheel mounts, and collection box
- **Drill Press** – For precise drilling of holes in mounting brackets and frames (as needed).
- **Hot Glue Gun** – Used for quick, temporary assembly of prototype parts during testing.
- **Screwdriver** – Used for assembling and securing various components.

Testing Equipment

- **Measuring Tape** – For precise measurement of components, ensuring accurate dimensions and fit.

Safety Equipment:

- **Safety Goggles/Glasses** – To protect eyes during cutting, drilling, and assembly.
- **Gloves** – To handle sharp tools, and avoid skin contact with chemicals or sharp edges.
- **Protective Clothing** – To protect from dust or other workshop materials

6.1.3 Instructions

Please refer to the previous section for detailed explanations and design justifications for each component of this subsystem.

6.2 Testing & Validation

Our team performed several tests to validate the performance accuracy of Prototype III. The tests were designed to confirm that each subsystem functioned effectively both individually and as part of the integrated whole.

Prototype III Analysis and Test results

Number	Test Description	Results
1	Attach a chisel to the end of the small diameter PVC to collect sample. Ensure that the chisel holder can accurately secure the chisel while scraping.	The chisel will scrape well against the inside of the tube, but we still need to test sample sizes a little more to ensure we get accurate numbers.

2	Measure our diameter with all the wheels attached and then send the product through the tubing to make sure it stays straight and stable.	The diameter is a little smaller which we made it to be so there is still room for it to work around a little bit. The wheels move smoothly within the tube.
3	Do some strength tests with the magnets and fit tests with the tubing. Attach the wire to the container and test that the lid can close smoothly.	We determined the magnets hold the lid together very well, as well as the lock-in mechanism for the container.
4	Test the optimal angle for chisel to scrape against pipe and how efficient it can be put into place.	We found the aircraft wire works very well by putting it into place and provides strong tension throughout the tubing.
5	Test the overall system integration by running the full product through a mock operation cycle, including scraping, collecting, and sealing the container.	The system performed smoothly, with the chisel scraping properly, wheels staying aligned, and the magnetic lid locking securely. Minor alignment adjustments may improve efficiency further.

For more information regarding Testing & Validation, please refer to the excel sheet provided: [Prototype and Test Plan Template](#)

7.0 Conclusions and Recommendations for Future Work

Throughout the course, our team maintained clear communication, effective task allocation, and collaboration. These values play a crucial role in ensuring that every component of our prototype - from scraper tools to collection systems and structural frameworks - is iteratively and thoughtfully developed.

Experience and lesson:

From the early stages of conception to the final prototype, we understand the importance of the following content. Firstly, there is iterative testing and redesign, especially when dealing with mechanical parts. We have found that millimeter level tolerances may affect the functionality of the product. The second feedback integration helps us rethink the initial design elements (such as the funnel in the collection box) and improve the performance of the product. We should directly design more suitable and reliable 3D printing components based on the accuracy of the third CAD modeling.

Future improvements:

If we have a few more months to complete this project, we will prioritize the following items. Firstly, the integrated modular connectivity system. Because according to our current design, components such as the scraper and collection box need to be manually adjusted. The modular locking system makes replacement and reconfiguration easier. The second development is adjustable scraping angle. Future versions may include a mechanism for dynamically changing the

angle of the chisel, thereby increasing the versatility of pipelines with different internal contours. Thirdly, compact storage and transportation design. Although the 10-foot PVC body structure is effective, there are challenges in terms of portability. Foldable or segmented versions can significantly improve on-site usability.

8 Bibliography

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9 APPENDICES

APPENDIX I: Design Files

Table 3. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
MakerRepo	https://makerepo.com/AidinM1/2404.gngl103five-alivesampling-tool-	April 4 th , 2025
Wheel Mount	 Wheel Mount Proto 3.SLDPRT	April 4 th , 2025
Wheel	 Wheel Proto 3.SLDPRT	April 4 th , 2025
Axel	 Wheel Axel Proto 3.SLDPRT	April 4 th , 2025