ELECTRICAL & COMPUTER
ENGINEERING

Portland State
UNIVERSITY

Capstone Project Proposal:

Universal Plastic Shredder V2.0

***ECE 412 -** Senior Project Development I*
Winter 2026

***Prof.** Andrew Greenberg*
***Industry Sponsor:** MME / Ichor Systems*
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***Team Name:** I'm so Shredded inc.*
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Executive Summary

This project is sponsored by MME / Ichor Systems, a company that develops equipment for the semiconductor industry. The main users of this project are workers who handle plastic waste at the company.

The problem is that the company produces a large amount of plastic waste and does not have a cost-effective way to shred and reuse it. Buying large industrial shredders is very costly, and smaller shredders are not strong or safe enough for the types of plastic being handled. The plastic waste includes materials such as PVC, polypropylene (PP), and LDPE, often in the form of thick or rigid parts rather than thin packaging.

This capstone project focuses only on the electrical control and power system for a plastic shredder designed to handle these materials. The mechanical structure, cutting blades, and physical frame are designed by a separate Mechanical Engineering team and are not part of this proposal.

The Electrical Engineering team will design and build the systems that power and control the shredder. This includes motor control, VFD selection, electrical protection, safety interlocks, emergency stop circuits, and operator controls. These systems must be sized and rated based on the expected plastic types and thicknesses (approximately 0.25–0.5 inches thick) so the motor, VFD, and electrical components can be properly selected and tested.

This project will have an impact on the company because it helps reduce waste and allows plastic to be reused instead of being thrown away, which saves money and benefits the environment.

The capstone will be completed over two academic terms at Portland State University, beginning in Winter 2026 and concluding in Spring 2026. During this time, the Electrical Engineering team will design, build, and test the electrical control and safety systems while coordinating with the Mechanical Engineering team for system integration.

By the end of Spring 2026, we will deliver a functional electrical control system integrated with the shredder, along with design documentation and testing results, to the industry sponsor.

1. Background and Research

1.1 Sponsor Overview

- Ichor Systems is a company that designs and manufactures equipment used in semiconductor production. They focus on systems that safely deliver gas and chemicals needed to make computer chips. These systems control how much gas or liquid is used during the process like etching, cleaning, and coating.
- Ichor also makes metal and plastic ports for the machine. There machines weld, machine, and treat surfaces. And so that is why they produce so much plastic waste when developing these products.
- Ichor Systems headquarters are located in Fremont, California and have facilities across the United States and in other countries. They support over 2,000 employees and major semiconductor manufacturers around the world.

1.2 Technology Domain and Context

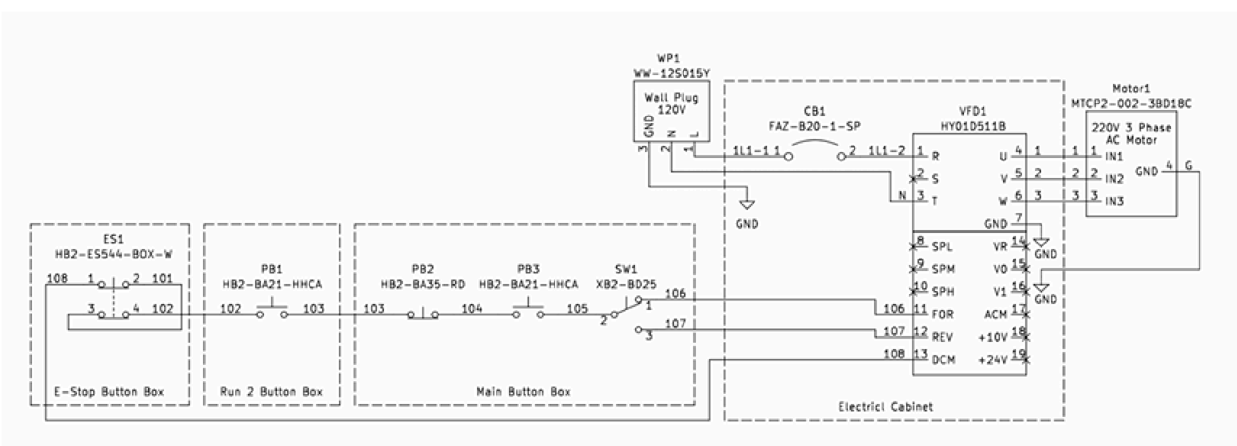
- Technical Domain:
  - This project focuses on electrical control and safety systems used to operate industrial recycling equipment. The scope includes motor control, electrical protection, safety circuits, and operator interfaces. Mechanical structure and cutting mechanisms are handled by a separate Mechanical Engineering team.
- Why These Systems Exist:
  - Plastic shredders are used to reduce plastic waste into smaller pieces so it can be recycled or reused. Electrical control systems are required to safely power and control the motors used in shredding equipment and to protect both the operator and the machine.
- How similar Systems Work:
  - Most industrial shredders use electric motors controlled by a Variable Frequency Drive (VFD). Safety systems such as emergency stops, interlocks, and overload protection are used to shut the system down if unsafe conditions occur.
- Project Context:
  - This shredder will be used as part of Ichor Systems' waste-handling process to support recycling and reduce plastic waste. This proposal covers only the electrical system required to safely operate the shredder.

1.3 Existing System or Prior Work

- What already exists
  - In 2024 a previous Portland State University (PSU) capstone team built a working plastic shredder for the Electronic Prototyping Lab (EPL). This shredder shreds common plastics like detergent bottles and left over 3d prints to smaller pieces. It's powered by a 2HP electric motor, a gear box torque multiplier, and a Variable Frequency Drive (VFD) to control motor speed. This machine also includes basic

safety features such as emergency stop and two-hand operation so the machines cannot run unless both buttons are pressed.

- What we are changing and improving
    - Electrical safety and control upgrades
    - Motor current monitoring for overload detection
    - Automatic forward/reverse to clear jams
        - via current overload detection
    - Thermal shutdown for overheating protection
    - Lid safety interlock
    - Status indicator lights
        - Power on status
        - Running
        - Fault
        - Separated from the VFD
    - Improve motor start up and shutdown behavior using VFD settings
    - Introduce a speed control knob
    - Collect data and tune the operating speed
        - Upgrade for fix speed operation
    - Add a motor contactor between VFD and motor for extra protection
    - Modify the VFD soft start and stop for safe reverse operation
        - Less stress on the motor
    - Optional exploration of additional safety sensing (capacitive touch or thermal sensing) to detect human presence near the feed area and trigger a safe shutdown
- Block diagram or figures of the current system



Electrical Schematic Drawn by: Jasmine Koski (2024)

- The current system takes wall power and sends it to a motor through a VFD. The motor turns a gearbox, which drives the shredder blades. Plastic is fed into the top, shredded inside the cutting chamber, and exits as small pieces. The operator controls the machine using buttons and safety switches.

1.5 Research Summary

Commercial Off-the-Shelf Products

1. **SSI Shredding Systems**
    a. **Model:** SSI Dual-Shear® M50
    b. **What it does:** Industrial plastic shredder designed for high-capacity shredding of rigid plastics, containers, and packaging. Uses dual-shaft shear cutters.
    c. **Suitability:**Very effective but expensive and large. It is designed for full-scale recycling facilities, which may be more capacity than needed for an in-house prototype. So expensive that they won't inquire about you unless you are working for the big companies.
2. **Vecoplab Vaz Series**
    a. **Model:** Vecoplan VAZ 1300
    b. **What it does:** Industrial shredder for plastic waste and other materials. Heavy-duty construction with selectable rotor designs.
    c. **Suitability:** Suitable for heavy industrial use, but also $145,700 and over-powered for our use. Offers good examples of safety features and structural design.
3. **UNTHA Plastic Shredders**
    a. **Model:** UNTHA RS40-4
    b. **What it does:** Medium to heavy industrial plastic shredder with four-shaft cutting. Designed for tough plastics and mixed waste streams.
    c. **Suitability:** Professional machine with strong construction. A good industrial standard shredder, but buying one is likely outside the sponsor's budget considering they don't even list the price.

Open Source Projects

- Project name and license
    - Plastic Shredder 2.0
- What it provides
    - Open-source designs and documentation for plastic shredders, mainly the electrical control side of things
- What parts are useful
    - Example VFD control wiring
    - PLC ladder logic structure
    - Safety interlock and emergency stop ideas
    - Sensor input handling
    - General control panel layout ideas

- Limitations or risks
  - Most open-source control projects are not designed for industrial environments and do not meet important safety and electrical standards such as NFPA 70 (National Electrical Code), OSHA safety requirements, UL certification, and NEMA enclosure standards. They often do not include proper grounding, fault protection, emergency stop design, or industrial-grade wiring practices. Because of this, these designs cannot be used directly. They are only useful for learning concepts, while the final system must be redesigned to meet real industrial safety and electrical standards.

Patents, Papers, and Articles

- Citation
  - Plastic Recycling Shredder Capstone Report, Portland State University (2023–2024)
- Key ideas or results
  - The past team successfully designed and built a functional plastic shredder prototype that could shred household plastic into reusable pieces.
  - They tested different cutting tooth geometries and showed how tooth shape affects shredding torque and efficiency.
  - The machine included a working VFD, forward/reverse control, two-hand safety start, and emergency stop.
- Relevance to our design
  - Their work gives us a proven baseline instead of starting from zero.
  - The previous report specifically states the system still needs more safety systems and electrical upgrades before it is fully operational, including better protection hardware, braking, interlocks, and improved control design.
  - Our project focuses on scaling to a larger industrial system, so we will redesign the electrical system to meet standards such as NFPA 70, NEMA enclosure requirements, UL-style safety thinking, PLC control, industrial-grade wiring, and improved safety interlocks.

2. Product Design Specification(Contract)

2.1 Product Overview

- What the product or service does
    - The Universal Plastic Shredder V2.0 will be a larger, safer, and more powerful plastic shredding system designed to process tougher industrial plastics such as high-density PVC. It will shred plastic sheets into roughly 1-inch pieces using a geared motor system controlled by a VFD and industrial electrical controls.
    - The system will include proper fuses, relays, breakers, safety interlocks, and an emergency stop.
- Who uses it
    - The shredder will be used by Ichor Systems technicians and operators who handle plastic waste from manufacturing. It may also be used by PSU faculty and students for demonstration and educational purposes.
- How it is used
    - Operators will hand-feed plastic sheets into the shredder. Motor speed (target 70–90 RPM) will be controlled using a VFD-based interface. The electrical system will follow industrial wiring practices and provide clear operator controls and safety protections.
- Why the sponsor wants it
    - Ichor produces thick plastic waste that the previous student shredder could not safely handle. They want an industrial-style system that is reliable, safe, and compliant with electrical standards, while staying within the $3000 total project budget. Approximately $1000 is allocated to the Electrical Engineering team, subject to change depending on project needs, funding availability, and component sourcing, and not all allocated funds may be used.

2.2 Concept of Operations (ConOps)

- Typical user workflow
    - Operator powers on the system
    - Performs a safety check
    - Starts the motor using the control panel
    - Feeds plastic into the shredder
    - Stops the system normally or uses the emergency stop if needed
    - Collects shredded plastic after shutdown
- Inputs, outputs, and interactions
    - Inputs: Plastic material, operator control button presses, VFD control signals, safety sensor signals, and power input.
    - Outputs: Shredded plastic pieces (target ~1 inch), system status lights, fault indicators, motor speed control, and safety shutdown responses.

- User Interaction: The operator mainly interacts with the control panel, emergency stop, and feed system. The system provides feedback using indicator lights and controls.
- Possible Future Enhancements (Not Guaranteed):
  - If time and budget allow, the team may explore additional features such as a wireless control interface, touchscreen display, data logging, alternative or non-traditional safety sensors, or improved automation. These features are not required for the core system and will only be considered after a safe, fully working shredder system is complete.

- Lifecycle and deployment context
  - The system will be designed and tested at PSU and intended for use in a lab or industrial environment. The goal is a durable and serviceable electrical system that can be safely used beyond the capstone project.

2.3 Stakeholders

	Stakeholder	Role	Impact on design
Sponsor:	MME / Ichor Systems	Provides project goals, budget, expectations, and final approval. Supplies requirements and feedback.	Drives performance expectations, safety standards, and budget limits. Requires an industrial-style, safe, and reliable shredder design.
End Users:	Technicians/Operators at Ichor or PSU EPL	Will use the shredder to process plastic waste. Responsible for daily operation, handling materials, and basic maintenance.	Design must prioritize safety, ease of use, clear controls, proper emergency stops, and durable construction suitable for real operation.
Project Team:	Mechanical + Electrical Students	Designs, builds, and tests the system. The mechanical team handles structure and shredding mechanics. The electrical team handles controls, safety, and power systems.	Decisions on components, control systems, safety features, and wiring standards affect cost, complexity, timeline, and overall functionality.

2.4 Requirements

Must Requirements

- **M1:** The electrical system must safely support shredding plastic into ~1-inch pieces when integrated with the mechanical system
- **M2:** A controllable VFD must be used
- **M3:** Electrical design must follow NFPA-70 (NEC) guidance
- **M4:** An emergency stop must safely shut down the system
- **M5:** Overcurrent and overload protection must be included
- **M6:** At least one safety interlock must be used
- **M7:** Motor speed must operate around 70–90 RPM
- **M8:** The VFD must support a 3–5 HP motor
- **M9:** The system must include an HMI for operator control and status display
- **M10:** The total project cost (Electrical + Mechanical) must remain under $3000

Should Requirements

- **S1:** The system should include clear status and fault indicators
- **S2:** The electrical enclosure should follow NEMA-guided practices
- **S3:** Controls should be clearly labeled and easy to understand

May Requirements

- **O1:** The electrical system cost may target approximately $1000, subject to change based on project needs and funding
- **O2:** Wireless monitoring may be explored
- **O3:** Data logging may be implemented
- **O4:** Additional safety sensing may be explored

2.5 Specifications (Optional)

- Quantitative performance targets
  - Target shred size: ~1 inch pieces
  - Target motor speed: 70–90 RPM (adjustable via VFD)
  - Plastic material: High-density PVC, polypropylene (PP), and LDPE, 0.25–0.5 inch thick, 4–12 inch width
  - Expected duty cycle: abuse it within reason
  - Power requirement: Standard facility AC power (120 VAC or higher industrial supply, such as 208–240 VAC, depending on availability)
  - Budget limit: $3000 total project budget (EE + ME), electrical portion subject to change
- Sponsor-imposed technical constraints
  - Must safely handle tougher plastics than the previous capstone design

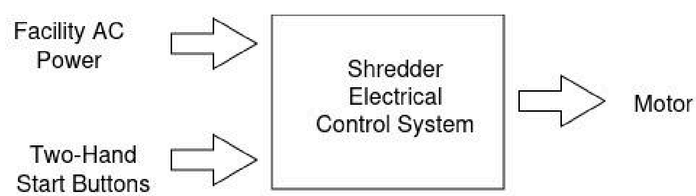
- Must follow industrial-style electrical safety (NFPA-70, NEMA enclosure guidance)
- Must include emergency stop and overload protection
- Must be hand-fed in this version (automation optional for future)
- Must be scalable and designed with potential future improvements in mind

2.6 Initial Product Design

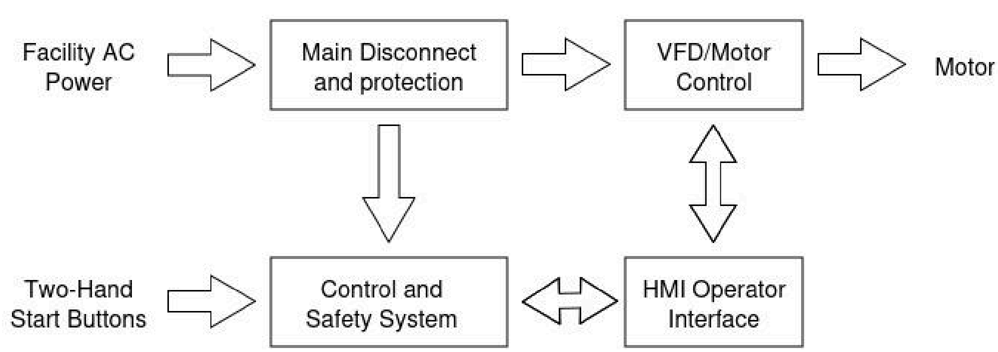
Hardware Architecture

- Major subsystems
  - Power input, disconnect, and electrical protection
  - Control and safety systems
    - 2-hand start, E-stop, interlock, other sensors
    - VFD motor controller
    - HMI operator display interface
    - Motor and mechanical drive interface

- L0 Block diagrams



- L1 Block diagram



Software Architecture

- **Languages and Environments**
  - Programming Language: C/C++ (Arduino-style)
  - Development Environment: Arduino IDE

- Target Hardware: ESP32 with integrated display (HMI), RS485 to connect to VFD MODBUS safely.
- The Arduino IDE uses a simplified form of C/C++. The code is written in Arduino "sketches," which are compiled as C/C++ programs.

- **Major Modules and Responsibilities**
  HMI / User Interface
    - Displays system status, faults, and speed
    - Reads operator inputs (Start, Stop, Reset, Speed control)

  Safety Input Handling
    - Reads safety signals (emergency stop, two-hand start buttons, interlocks)
    - Prevents operation if any safety condition is not met

  Control Logic
    - Manages system states (Idle, Ready, Running, Fault)
    - Controls when the motor is allowed to run

  VFD Interface
    - Sends run/stop and speed commands to the VFD
    - Reads fault or status signals from the VFD if available

  Fault Handling
    - Detects and displays faults
    - Forces safe shutdown behavior

  Optional Features
    - Basic data logging
    - USB serial output for debugging

Data Flow

- Key data paths
    - Operator Inputs to ESP32 Control Logic
        - Start, stop, reset, speed settings, and two-hand start buttons are read by the ESP32 through digital inputs or the HMI interface.
    - Safety Inputs to Control and Safety Logic
        - Emergency stop, lid/door interlocks, and optional safety sensors are continuously monitored. If any safety condition is violated, the control logic blocks operation or triggers a shutdown.
    - ESP32 to VFD
        - The ESP32 sends run/stop commands, direction commands, and speed setpoints to the VFD. The protocol between VFD and ESP32 is unknown, but most commonly used is MODBUS protocol.
    - VFD to ESP32
        - The VFD provides status and fault signals back to the ESP32 so the system can display faults and respond safely. Most VFDs from Automation Direct have this capability.

    - ESP32 to HMI Display
        - System state, speed, and fault messages are sent to the HMI for operator feedback.
- Storage and communication
    - The ESP32 may save simple information such as fault messages or total run time in its built-in memory if needed.
    - Communication Interfaces:
        - Digital inputs and outputs for buttons, safety interlocks, and control signals
        - USB connection for programming and debugging
        - Optional Wi-Fi or Bluetooth for monitoring, if used
    - No Network Required:
        - The system can operate safely without being connected to the internet or any external network.

User Interface and Experience

- How users interact with the system

  The user interacts with the shredder through a simple HMI screen and physical controls. The HMI displays system status such as Ready, Running, or Fault, along with motor speed and basic fault messages.

  To start the machine, the operator must press two physical start buttons at the same time. This two-hand control helps keep the operator's hands away from the feed area during startup. A separate Stop button and Emergency Stop are available to safely shut down the system at any time.

  The HMI allows the operator to:
    - Start and stop the system
    - Adjust motor speed
    - View system status and fault messages
    - Reset the system after a fault, when safe

- User stories
    - **As an operator**, I want to clearly see whether the system is ready, running, or in a fault state so I know when it is safe to use.
    - **As an operator**, I want the machine to require a two-hand start so my hands are not near moving parts when the shredder begins running.
    - **As an operator**, I want to stop the machine quickly using a stop button or emergency stop if something goes wrong.
    - **As an operator**, I want to see clear fault messages so I know why the system stopped and when it is safe to reset.
    - **As a technician**, I want basic status and fault information on the HMI so troubleshooting is easier.

- **As an engineer**,I want a maintenance or test page on the HMI that shows the status of safety inputs (such as emergency stop, interlocks, or optional capacitive or thermal sensors) so I can verify that safety systems are working correctly during testing.

Other Considerations

- Security
  - The system is designed to operate locally and does not require an internet connection. This reduces security risks related to remote access. Any optional wireless features, if used, will be limited to monitoring and will not allow direct control of the machine. Access to maintenance or test features on the HMI can be restricted to prevent unintended use.
- Safety
  - Safety is a primary focus of this project. The electrical system includes an emergency stop, safety interlocks, two-hand start operation, and overload protection to reduce the risk of injury or equipment damage. The control logic is designed so that the system enters a safe state if a fault or unsafe condition is detected. Optional safety sensors, such as capacitive or thermal sensing, may be explored as additional layers of protection but will not replace required safety systems.
- Regulatory compliance
  - The electrical system will be designed using industrial-style practices guided by NFPA 70 (National Electrical Code) and general NEMA enclosure guidelines. While full certification (such as UL listing) is outside the scope of this capstone project, safety concepts and wiring practices will follow recognized standards to support safe operation in a lab or industrial environment.

2.7 Verification Plan

- How requirements will be tested
  - We will test the shredder by running it under real operating conditions. This includes powering the system, controlling it through the VFD and control panel, and shredding real plastic samples that match the sponsor’s material (high-density PVC, 0.25–0.5 in thick). Safety systems such as the emergency stop, interlocks, and overload protection will be tested individually to confirm they work correctly. Torque testing and motor behavior will be verified during initial mechanical testing to ensure the selected motor and gearbox are appropriate.
- Pass/fail criteria
  - The shredder must successfully shred plastic into approximately 1-inch pieces.
  - The VFD must control motor speed and allow safe start/stop operation.
  - The emergency stop must immediately and safely shut down the system.
  - Safety interlocks must prevent the system from running when access points are open.

- Overcurrent / overload protection must trigger when unsafe electrical conditions occur.
- System must operate at the target speed (~80–90 RPM)
- The system must operate safely without electrical faults, dangerous exposed wiring, or unsafe behavior.

  If any of these fail, the system will be revised and retested.

- Tools and test setups
  - Torque testing tools (torque wrench or torque reader as discussed)- could be changed anytime
  - VFD configuration and monitoring tools
  - Multimeter and electrical testing tools
  - Indicator lights / fault monitoring
  - Test plastic material supplied by sponsor
  - Lab safety supervision during testing

2.8 Risks

- Technical risks
  - The selected motor or gearbox may not provide enough torque to shred thick PVC material.
  - The electrical system may require more protection or safety components than expected.
  - Integration between mechanical and electrical systems may be more complex than planned.
  - Safety systems (interlocks, E-stop, overload protection) may need redesign to fully meet standards.
- Schedule risks
  - Torque testing and motor selection may take longer than expected.
  - Mechanical CAD work may delay electrical enclosure planning.
  - delivery for motors, VFDs, or electrical components may slow progress.
  - Coordination between Mechanical and Electrical teams may impact timing.
  - Access to the power lab is unknown
- Resource risks
  - Budget limits may restrict component choices.
    - Can also affect the amount of back up equipment
  - Availability of used parts or lab equipment may change.
  - Limited access to lab space, tools, or testing resources may slow work.
- Mitigation strategies and backup plans
  - Perform torque testing early to guide motor and gearbox selection.
  - Keep close communication between EE and ME teams to coordinate interfaces.
  - Prioritize MUST functionality and safety before optional features.
  - Source components early, look for surplus or used equipment to stay inside budget.

- Build in schedule buffer time to handle delays.
- If torque capacity is too low, adjust gearbox ratio or scale mechanical design.

2.9 Deliverables

- Project proposal
  - Formal written proposal defining scope, objectives, and requirements.(What we are doing here)
- Weekly progress reports
  - Short updates documenting progress, challenges, and next steps, scrum.
- Final report
  - A full engineering document covering design decisions, analysis, testing, and results.
- Capstone poster
  - Would be nice, not necessary
  - Brief overview of the main design log documents covering design decisions.
- Working prototype
  - Functional electrical control and safety system integrated with the mechanical shredder. Ideally designed in schedule in reference of the ME team.
- Design files and documentation
  - Electrical schematics, wiring diagrams, PLC logic (if used), VFD configuration, parts list, safety analysis, and any required NFPA/NEMA compliance documentation to support future use.
  - Operators manual
  - Debug manual

Delivery Method:

- **Github**
- **Google Drive**

3. Project Management Plan

3.1 Timeline and Milestones

- Research complete by week 3-5
- Initial design finished by week 6-8
- First prototype finished by week 10+
- Integrated prototype 10+
- Final validation 10+

3.2 Budget and Resources

The budget is $3,000 for both the ME and EE group.

Item	Cost	Source	When Needed
Motor 3-5 HP?	~$100-$400?	Second hand? Ask around? Ebay	3-4th week of the term
VFD?	~$100-$300?	Reputable online vendor. Automation Direct. Ebay	3-4th week of the term
Wire/Contacts/Other?	~$100-$200?	EPL, Ebay, Amazon	3-4th week of the term

3.3 Intellectual Property

- IP ownership
    - All work produced during this capstone project will be released as open-source. The project team and Portland State University retain authorship of the work, and the sponsor is permitted to use the results.
- Licensing terms
    - Project materials such as source code, schematics, and documentation will be shared under an open-source license to allow reuse, modification, and educational use.
- Sponsor agreements
    - The project will follow Portland State University policies and agreements with MME / Ichor Systems. No confidential or proprietary information will be included in the open-source materials.

3.4 Team

Team members: Bao Nguyen, Fearghus Tyler, Yaqoub Rabiah, Fox Kang

- **Bao Nguyen** will focus on documentation and assist with programming and setting up the HMI, including the GUI layout, icons, and status indicators, and assist with connecting the HMI/ESP32 to the VFD.
- **Fearghus Tyler** will serve as the team lead and primary point of contact with the sponsor, and will focus on research, the bill of materials (BOM), and overall electrical safety planning.
- **Yaqoub Rabiah** will focus on start/stop controls, emergency stop integration, and VFD selection, wiring, and programming, and may also assist with ESP32 HMI programming as needed.
- **Fox Kang** will focus on system integration, safety circuit layout, and evaluation of advanced safety sensing such as capacitive touch or thermal sensors.

  Roles and responsibilities are subject to change over the course of the project based on project needs and team availability.

3.5 Development Tools and Process

- We have a good deal of tested devices to draw from, the shredding industry is fairly old and established.
- For collaboration, a google drive is sufficient.
- Microsoft Planner or Trello used for scheduling.
- Github

Sponsor Approval

By signing below, the undersigned acknowledges review of this proposal and agrees with the project scope and objectives as described.

Industry Sponsor Representative:

Name:_Bridget Lannigan___________

Organization:__Ichor Systems_______

Signature:____Bridget Lannigan__________

Date:___January 16th, 2026_____