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**Team B8**

# APPLICATION AREA AND SOLUTION APPROACH

- Application Area: Microgreens Cultivation
  - High in nutrition and expensive
  - Fast time-to-harvest
  - Difficult and time-consuming to grow
- MiGroBox seeds, waters, and raises crops until they are ready for harvest



# IMPLEMENTATION PLAN

- **Software:**

- FreeRTOS running on ESP32
- GRBL CNC firmware ported to run on ESP32 with FreeRTOS using interrupts
- Custom grow routine running on ESP32
- Custom website interface built from Django framework

- **Electrical Hardware:**

- ESP32 Microcontroller
- TMC2209 stepper motor drivers
- Off-the-shelf motors, sensors, light strips, relay board, power supply
- Custom main board to plug everything in, handle voltage distribution

- **Mechanical Hardware:**

- Vacu-formed seed hoppers from 3D printed molds
- 3D printed seed distributor pawl and miscellaneous parts
- Linear rails for CNC
- Mylar insulation sheeting walls
- 80/20 aluminum extrusion frame
- PVC and plastic piping plumbing

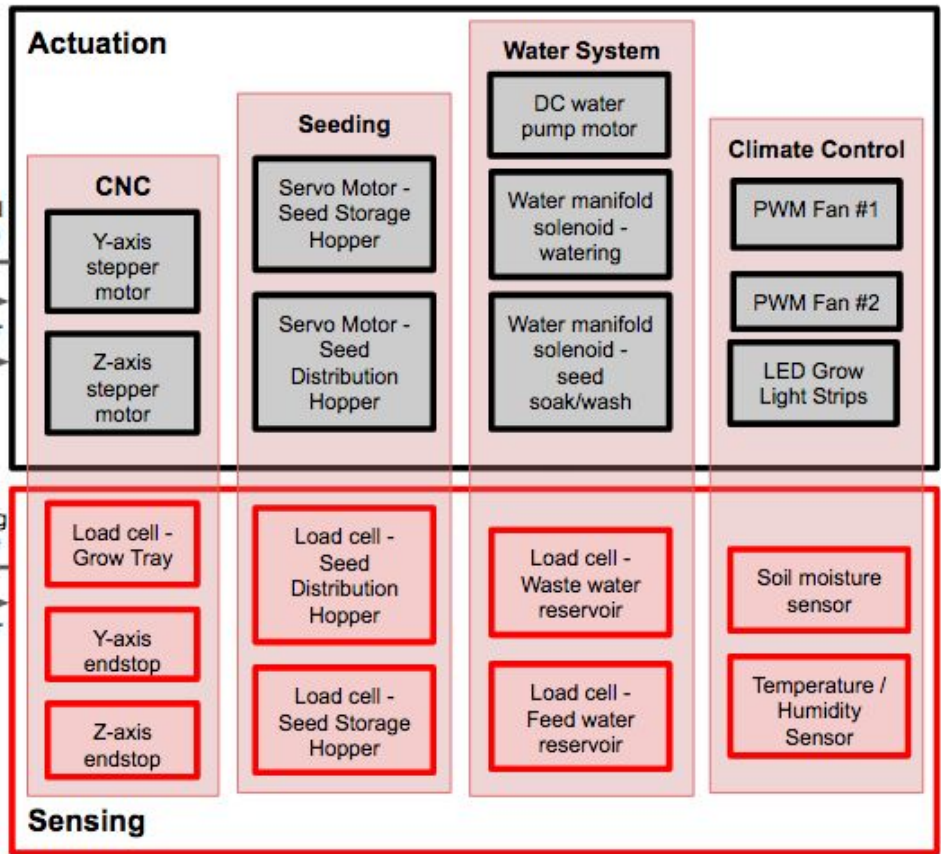
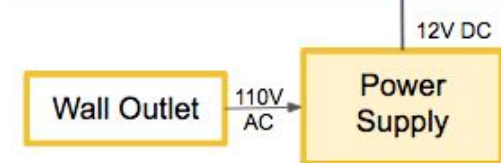
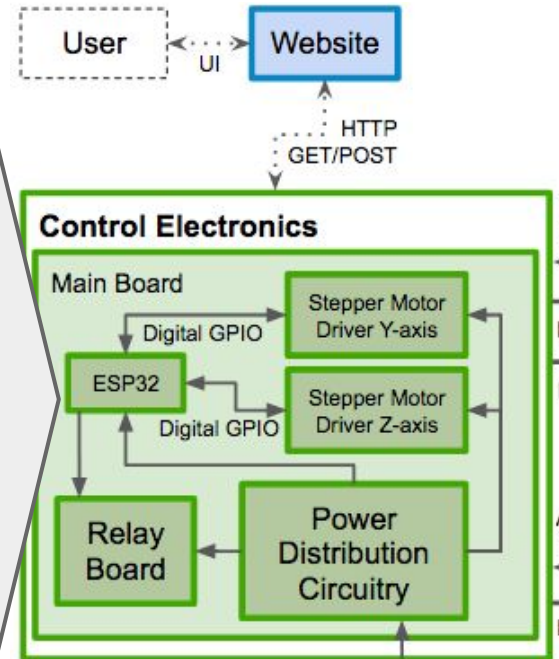
# SYSTEM SPECIFICATION

**Embedded Software Stack**

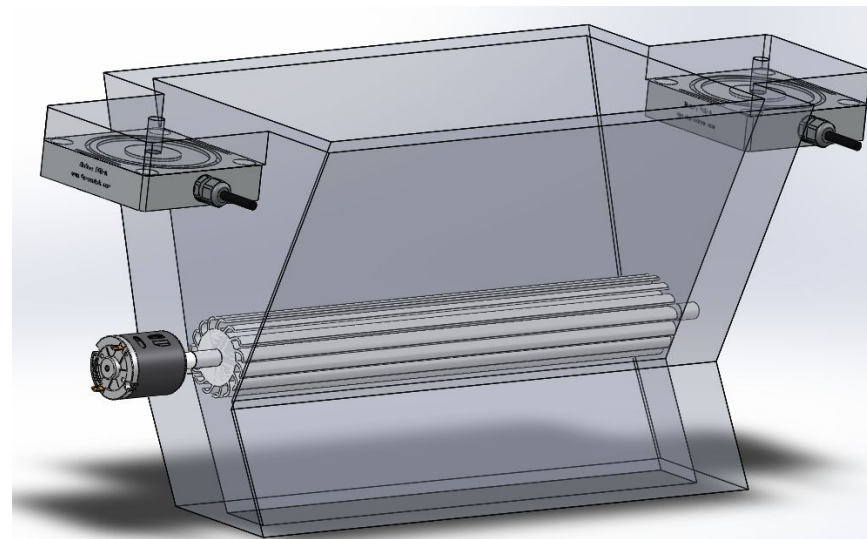
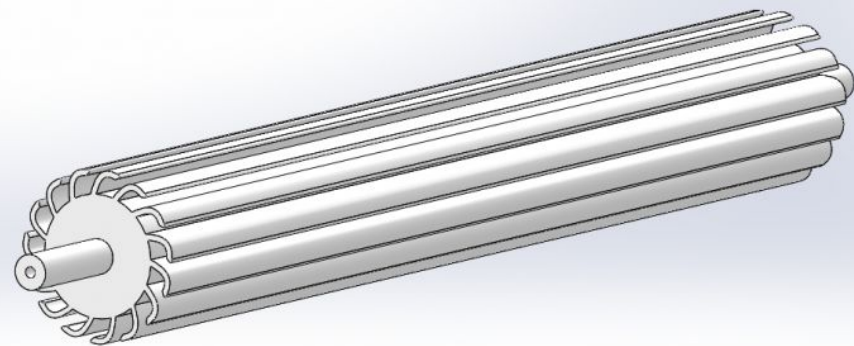
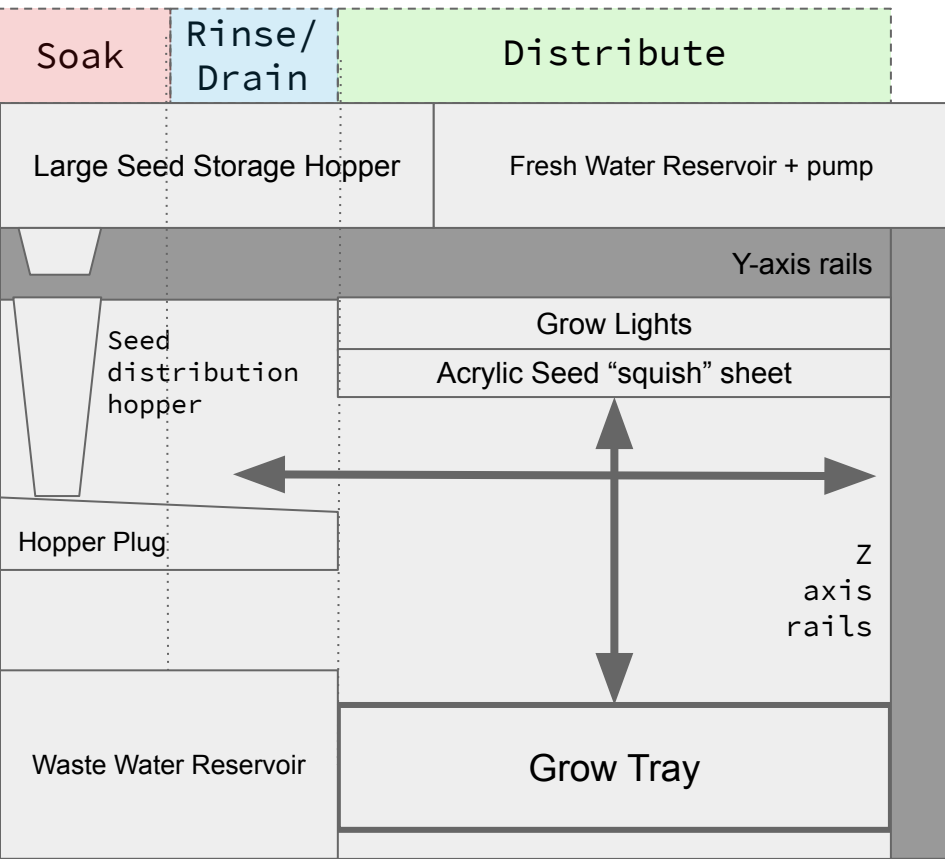
**Top Level Routines:**  
Poll sensors, track time, send web updates, etc.

**CNC Firmware:**  
GRBL

**OS:**  
FreeRTOS



# HARDWARE OVERVIEW

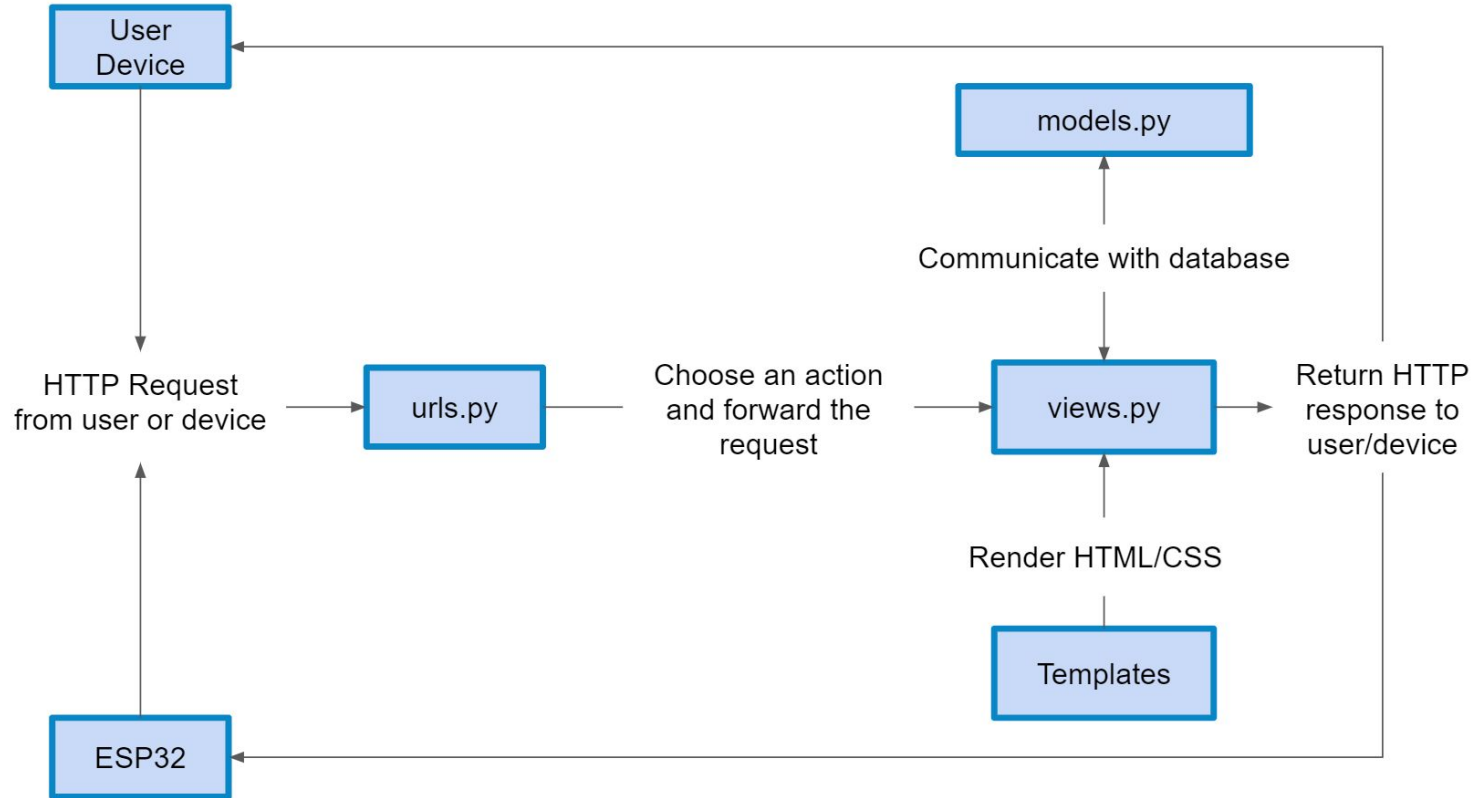


# EMBEDDED SOFTWARE OVERVIEW

- ESP32 running FreeRTOS
  - PWM and ADC drivers
- GRBL CNC firmware
  - Already ported to ESP32 by 3rd party
- Custom software to run grow routine, interface with website
  - Interrupt-based



# WEB APPLICATION OVERVIEW



# REVISED REQUIREMENTS - FEATURES

## 1. **Climate control/monitoring**

- a. Water irrigation system
- b. Full spectrum lighting
- c. Air circulation
- d. Temperature sensing
- e. Humidity sensing

## 2. **Seed storage, distribution, and care**

- a. Long term seed storage
- b. Seed dispensing
- c. Seed rinsing and soaking
- d. Seed distribution
- e. Seed pressing

## 3. **Seed grow regime pre-sets**

- a. Saved optimal values for at least the plant varieties grown over the course of the semester project (two so far)

## 4. **WiFi user interface**

- a. Custom website
- b. Device connected website interface via WiFi 24/7



# REVISED REQUIREMENTS - TECHNICAL METRICS

- 1. Seed density/distribution:** Seed density at any given square inch of the grow tray can be maximum 33% higher than target density
- 2. Water spread/coverage:** 100% coverage/saturation and drainage within 20 minutes
- 3. Seed weight dispensing accuracy:** Weight of seeds dispensed by storage hopper into distributor within 1 gram of target
- 4. Watering Frequency:** At least once every 12 hours
- 5. Website latency:** Time-to-first-byte latency of <2 seconds

# REVISED REQUIREMENTS - PROJECT VALIDATION

- 1. Yield Ratio:** Seed-to-greens weight ratio produced by MiGroBox must be >85% of manually-grown control group
- 2. Labor-Hours:** Time taken to cultivate microgreens via MiGroBox must be <70% that of manually-grown control group
- 3. Wage Comparison:** Metric combining yield ratio and labor-hours with seed costs and miscellaneous overhead must surpass minimum wage (\$7.25/hr) and increase over manually grown wage by at least 20%

# RISK FACTORS AND MITIGATION

- Design/execution details:
  - Temperature homeostasis → Add mylar layers
  - Seed soaking/draining mechanism → Continue to refine machine tolerances
- Uncertain externalities of automation
  - Additional machine maintenance may lead to increased labor time → Refine actuator control accuracy
  - Failure rate of hardware is unknown → Test constantly, place parts as needed
- Testing/evaluation
  - Testing highly dependant on real grow data → Run staggered tests, 2x per week
  - Takes a week to conduct a single, full start-to-finish system test → test subcomponents separately as needed
  - Failed week of crops could rob us of valuable data → Weekly trials

# PROJECT MANAGEMENT AND REVISED SCHEDULE

Lucas, Greg, Team	Week of 9/20	Week of 9/27	Week of 10/4	Week of 10/11	Week of 10/18	Week of 10/25	Week of 11/1	Week of 11/8	Week of 11/15	Week of 11/22	Week of 11/29	Week of 12/6
<b>Research</b>												
Research/Decide Microgreen selection	Team	✓										
Write Up Microgreen Plant Profiles	Team	✓										
Research/Decide Grow Media	Team	✓										
Research/Decide Watering Techniques	Team	✓										
Research Humidity Control Methods	Greg	✓										
Research Water Level Sensing Methods	Team											
Research RTOSs / bare-metal	Lucas											
Trade Study for Stepper Motor Drivers	Lucas											
Research CNC firmware options	Lucas											
Research Lighting Methods	Team - ✓											
Research Embedded System Architecture	Lucas											
Trade Study for Embedded System Core	Lucas											
Trade Study for Climate Sensors Selections (all)	Lucas											
Trade Study for Climate Controllers (lights, temperature, humidity, air flow, ph)	Team											
<b>Software Design: Web Application</b>												
Design Website Backend (block diagram, documentation, etc.)		Greg - ✓										
Design Website Interface/frontend		Greg										
Write Basic Backend		Greg										
Write Frontend			Greg									
Iterate on Website Design				Greg								
<b>Software Design: Embedded</b>												
Design Embedded Firmware Subsystem: Lighting (Actuation + sensing)	Lucas											
Design Embedded Firmware Subsystem: Water (Actuation + sensing)	Lucas											
Design Embedded Firmware Subsystem: OS+CNC	Team											
Design Embedded Firmware Overall Routine	Team											
Design Core Device-side grow routine		Greg										
Implement Embedded Firmware Subsystem: OS/Baremetal			Lucas									
Implement Embedded Firmware Subsystem: Stepper Drivers			Lucas									
Implement Embedded Firmware Subsystem: Miscellaneous Sensors			Team									
Implement Core Website Functionality (Device-side)				Team								
Implement Device-side Core Grow Routine					Greg							
Iterate/fine tune grow parameter controls								Team				
<b>Hardware Design</b>												
Design Water/Plumbing Subsystem (Hardware)	Lucas											
Design Lighting Subsystem (Hardware)	Lucas											
Design Device Frame (MVP)	Lucas											
Design CNC Layout	Lucas											
Design Seeding System (Hardware)			Lucas									
Design Main Board Schematic			Lucas									
Design Power Management Subsystem			Lucas									
Build out MVP Frame				Lucas								
Build CNC System					Lucas							
Build Water System						Lucas						
Build Lighting System						Lucas						
Build Seeding System							Lucas					
Preliminary Main Board Layout					Lucas							
Build Preliminary Main Board					Lucas							
Final Main Board Layout								Lucas				
Build Final Main Board									Lucas			
<b>Integration</b>												
Establish connection between device controller and website							Team					
Integrate Lighting system into device frame									Lucas			
Integrate Watering system into device frame									Lucas			
Integrate Seeding system into device frame									Lucas			
Integrate sensor inputs and actuator outputs into software system						Greg						
<b>Testing</b>												
Microgreens Control Batches (Manual)			Team									
MIGroBox Light System Test Batch								Lucas				
MIGroBox Water System Test Batch									Lucas			
MIGroBox Seeding System Test Batch										Lucas		

- Exploring vacuforming design/manufacturing via TechSpark
- Starting manual grow cycle (waiting on seeds to arrive)
- Starting website design
- Starting main board layout