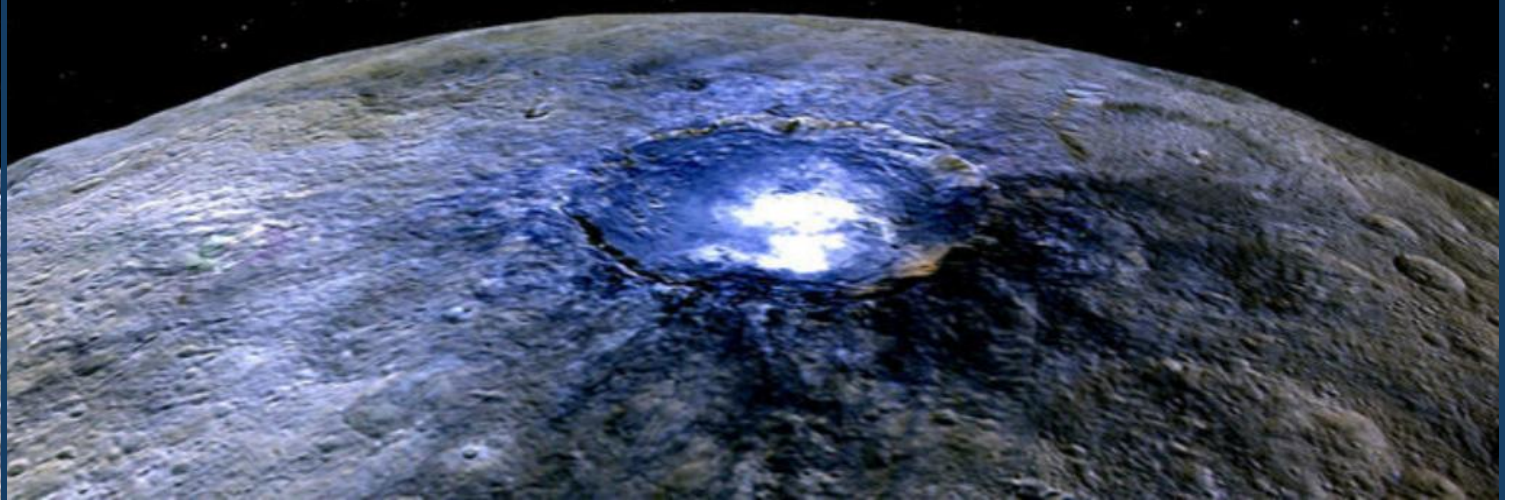


GURNOOR KAUR

# Agricultural Module

-  
Cereal Shoppers Stop v2



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## Executive Summary

The multi-tiered Agricultural Module of the Cereal Shoppers Stop (CSS) is the main food farming and production hub for our settlement. Built as one of the 5 sectors of the toroidal ring of the settlement, this section forms the core of CSS's self-sustaining food system and is designed to fully support a future population of 5,000 residents. The base area of the module is 980,180m<sup>2</sup>, however, with the 8 stacked levels, the total area is 7841440m<sup>2</sup>. At full capacity, the module can produce large amounts of fresh food per day, achieving complete self-sufficiency for the settlement.

The module is organized into 3 linked tiers – Smart Farm, Supplement Manufacturing Hub & Food Processing, Fermentation, and Algae-Based Oil Production. The Smart Farm layer is engineered to maximize production of crops such as microgreens, lettuce, berries, bananas, eggplants etc. Robotics handle seeding, monitoring, and harvesting, while AI-based vision systems detect plant stress early and automatically adjust environmental conditions. The Supplement Manufacturing Hub used 3D Printing technologies to produce PHB based capsules & supplements. The last tier, Food Processing, Fermentation & Algae-Based Oil Production transforms raw harvest into nutrition dense foods, conducts controlled environment fermentation and produces oil using algae grown in photobioreactors. This tier also links to the settlement's CRISPR Lab, where processes such as gene-editing and modification of plant traits take place. Additionally, a strong focus on nutrition has been emphasized, which reflects in our daily fermented drinks – the CSS Bio Boosters.

The CSS Agricultural Module expands gradually over 15 years, a 10-year initial establishment followed by a 5-year stage wise expansion and population increase from initial 100 to full capacity of 5000. This approach allows the system to stabilize, diversify and expand crops, and adapt. In a nutshell, this Agricultural Module works so seamlessly and efficiently that even the crops would have their own fan club if they could read reports!

**1. Cereal Shoppers Stop v2 Introduction:** The CSS settlement has 3 major sections – the toroidal structure, the tubes and the central prolate spheroid. There are 5 subsections called module within the toroidal area. The agricultural module is designated for food production in controlled environment leveraging farming techniques like aeroponics, bioreactors and Hydroponics.

**1.1 CSS-v2 Agricultural Section Overview:** The agricultural sector’s base floor area is 980,180 m<sup>2</sup>, and its interior height (200m) is organized into multiple tiers to maximize productivity.

Smart Farm (110 m) is divided into three levels - A 50m floor for Hydroponic Racks, a 50m floor for Aeroponic Towers and a 10m CRISPR Genetics Lab for editing crop traits. The Supplement Manufacturing Hub (60m) contains two equal levels - a 30m capsule 3D-printing floor and a 30m assembly floor for supplements and quality control. The Food Processing, Fermentation & Algae Oil Unit (30m) is divided into three 10 m floors, each for food processing, fermentation and oil extraction from microalgae. Stage wise Agricultural module explosion plan, Floor Area details and targeted food production yields with growing population needs are captured in Appendix1.

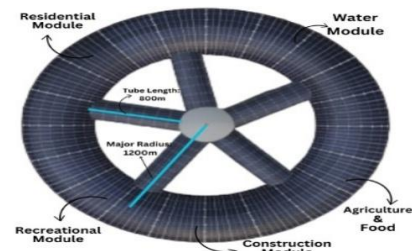


Fig1: Top view of CSS-v2 Layout

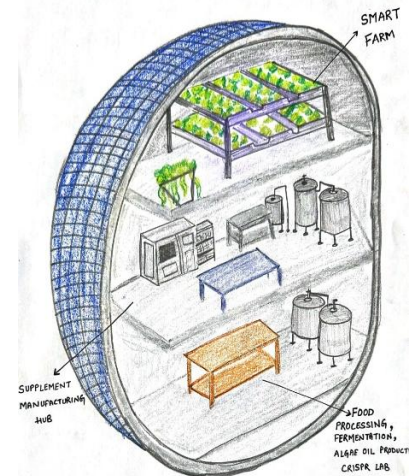


Fig2: Smart Farm

APPENDIX 1

Tier & Dimension	Primary Function	Key Systems
Smart Farm (110m)	Crop production using aeroponics and hydroponics techniques.	Vertical racks, Plant monitoring. Controlled CO2, temp. & lighting.
Food Processing, Fermentation & Oil Production (60m)	Harvested crops to preserved foods, fermented drinks, and algae-extracted oils.	Fermentation tanks, algae-processors, mechanical oil pressers, food quality checks.
Supplement Manufacturing Hub (30m)	Produce algae-based PHB capsules and supplements.	PHB polymer printers, algae dryers, dose dispensers, quality testing units.

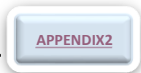
**2. Smart Farms:** CSS’s Smart Farm, the main production area for food for settlement, is designed requiring minimal human effort and providing maximum yield. It utilizes a combination of hydroponics, aeroponics and vertical farming towers with integrated automated systems that monitor and manage watering, lighting, CO2 levels, and other adjustments. These vertical farming towers host a variety of vegetation, herbs, and greens. The layout is arranged to maximize space by stacking the growing crops and categorizing them into zones, based on the time length of their growth cycle. The Smart Farm is designed to scale as the settlement expands and is the foundation for a low labor agricultural system.

**2.1 Farming Systems:** The Smart Farm combines several “soil less” crop growing techniques to increase production, reduce water-usage and provide a steady farming system.

**2.1.1 Hydroponic Racks:** The Hydroponic Racks consist of multi-level shelves that hold growing trays, filled with nutrient-rich water. Crops are either partially or fully submerged delivering required nutrients directly to the roots of the crops. Each shelf has overhead LED lights and sensors that monitors

Crops	Time Taken to Grow
Tomatoes	40-55 days
Cucumbers	50-70 days
Banana	270-330 days
Eggplants	100-120 days
Lettuce	28-35 days
Microgreens	7-12 days

water quality, temperature and solution nutrient strength. This stacked layout increases production quantity and ensures uniform lighting and air flow across all levels. This system uses two-part nutrient solutions providing all the essential nutrients for plants to grow. Namely, Solution-A & Solution-B, these two different groups of nutrients and when combined with water, will create a mixture that provides nitrogen, phosphorus, calcium, magnesium, and other micronutrients. Details in Appendix2.



**2.1.2 Aeroponic Towers:** The Aeroponic Towers are long cylindrical structures that will hold the plants in slots around themselves, while the roots of those plants will extend into a dark interior chamber. In these towers a mist solution will be sprayed on them at regular intervals.

Crops	Time Taken to Grow
Strawberries	35-50 days
Blackberries	40-60 days
Tomatoes	25-30 days
Bell Peppers	60-90 days
Bok Choy	21-35 days
Kale	28-35 days

Table2: Crops grown in Aeroponics towers

The internal chambers will remain closed to reduce damage to the crops as well as ensure control of humidity and nutrients. Maintaining proper pH and electrical conductivity is a vital part of this whole process because the mist must stay within the correct acidity and nutrient strength for the roots to absorb it. Sensors track these levels, allowing the system to adjust and keep the solution stable,

**2.1.3 Bioreactors:** Technological advancements are reshaping how we cultivate Algae for a range of industries from biofuels to pharmacy to food & waste treatment, producing oxygen and other useful substances. Algae growth for such purposes is optimized under controlled environments using special advanced photobioreactor technology. These photobioreactors leverage light facilitating photosynthesis for algae cultivation along with utilizing the organic carbon sources which are best suited for maximum productivity. Such controlled closed loop systems assist in algae growth and help prevent contamination and limit the transfer of bacteria between the systems. Further research for microalgae grown in closed environments can help facilitate their rapid adaptability to harsh space environments establishing agriculture ecosystems in space.

**2.2 Zonal Arrangement:** The Smart Farm growing area is divided into a three-part growth cycle zonal system which categorizes plants based on how long after they are planted, they are ready to harvest. This structure focuses on timing to segregate instead of crop types, which makes it easier to manage and speed up the production process. Here's the zones and their classification:

- Zone A (1-30 days) – This contains fast growing crops that can be harvested and replanted quickly. This includes crops like microgreens (7-12 days), lettuce (28-35 days), Bok choy (21-35 days).
- Zone B (30-60 days) – This contains crops with moderate growth times. This includes crops like berries (35-60 days), tomatoes (40-55 days), cucumbers (50-70 days).
- Zone C (60-90+ days) – This contains crops that take the longest time to grow. This includes crops like eggplants (100-120 days), peppers (60-90 days), bananas (270-330 days).

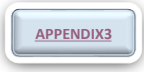
**2.3 Food Storage Unit:** The FSU in Smart Farms ensures harvested crops and seeds remain preserved.

**2.3.1 Nutrient and Seed Storage:** The Smart Farm includes a dedicated area for the storage of the essential nutrients and all the seeds that are used in our agricultural system. Salts and nutrient mixes for the hydroponic & aeroponic farming systems are kept in sealed, airtight containers, stored in dry and temperature-controlled conditions. Alongside, a compact seed storage drawer holds airtight packets of seeds of all varieties and crops. This drawer has extremely controlled conditions as these storage seeds are vital in case of an emergency. These seeds would be replaced with the ones from a new set of crops every time harvest takes place.

**2.3.2 Harvest Storage:** The Smart Farm includes a dedicated small cold storage section for storage of harvested crops. This section will have shelves with controlled temperature designed for different crops like leafy greens, herbs, fruits and vegetables. Proper storage of these harvested crops will help reduce spoilage and maintain freshness of these foods. This storage unit also helps in inventory control by grouping crops according to harvest cycles and shelf life.

**2.4 AI Modeling of plants health monitoring:** In the Smart Farm, manually inspecting every tray and tower of the hydroponically and aeroponically grown crops would be tedious and easy to overlook, especially as the farm is scaled. To address this, we use cameras integrated with vision-based AI models that continuously scan the plants to detect early signs of stress and address the same. Cameras are installed above the hydroponic racks and along the aisles facing the aeroponic towers. These cameras send the live feed to be processed by vision AI models that can detect each plant, analyze leaf color, size, and shape, compare those to healthy leaves and flag signs of stress such as yellowing, wilting, damages, or irregular growth. These AI models use computer vision tasks like object detection, classification etc. and understand any irregularities. For example, if leaves in one plant or part of the farm start to lose color or show some irregular pattern, the system will recognize that this may indicate nutrient deficiency, pH imbalance, or some disease.

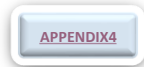
This system doesn't just flag issues but also works towards analyzing and implementing solutions for it. Since we mostly have plants requiring quite similar if not the same conditions, each hydroponic rack and aeroponic tower has a set lighting system, mist solution, and mist flow schedule. After a problem is discovered, the AI will adjust the necessary nutrient concentration, pH levels, light intensity & duration etc. This not only helps early detection and response, but also reduces labor workload and leads to healthier, faster and stable yields. Reference model details in Appendix3.



**2.5 Genome Editing for Crops to improve sustainability in CSS-v2:** There are many factors that can affect plant growth and development which could eventually lead to reduction in crop yields. With the advancement of technology, tools like CRISPR- Cas9/Cas12a and Cas12b genome editing now make it possible to help resolve these problems precisely. CRISPR can be used on many different crop species, and it allows scientists to improve plant traits. For our settlement, we can use CRISPR on main crops before launching on Earth so that their genes are optimized to undergo conditions they will face while growing on the settlement. By directly editing the plant's DNA, we can help crops handle limited water, salinity in nutrient solutions, temperature swings and potentially low gravity, radiation etc. We can also improve yield per square meter in vertical farms through this and increase its nutritional value. In addition, CRISPR would make our crops more resistant to accidental viruses, fungi, and bacteria, such that we always have healthy and stable crops. For example, genome editing in Tomato with precise elimination of hybrid proline protein (SIHyPRP1) helped achieve protein manipulations of tomato hybrid proline rich protein 1 (HyPRP1) led to high salinity tolerance of tomatoes at the germination. Further research in CSS by leveraging CRISPR/Cas on gene editing for plants by generating indel mutations and nonhomologous end joining could help food crops to cope with many potential space issues. Overall, performing CRISPR on the initial batch of crop seeds would create "CSS-ready" seeds that are more reliable, productive and stable for long-term food production.

**2.6 Growth Environment Control System (GECS):** The GECS is a system that regulates the environment within our Hydroponic & Aeroponic farming zones. Instead of relying on people to constantly check and adjust equipment, the GECS uses sensors and control rules to manage four key variables that affect plant health - temperature, humidity, CO<sub>2</sub> levels, and nutrient solution pH. In the design the GECS aims to keep air temperature between 58-86 degrees Fahrenheit, humidity between 40-60%, CO<sub>2</sub> levels of 1000-1500 ppm, and nutrient solution pH between 5.5-6.5. Sensors collect the data for these variables continuously and compare them to these ideal values. Based on that comparison, they either turn on/off a relative device that helps stabilize and idealize the readings of that variable. This creates a sort of feedback loop that stabilizes the environment and reduces any amount of manual monitoring or adjustments required.

To demonstrate this, a digital prototype was prepared using an Arduino board and various sensors. DHT22 is used as temperature & humidity sensing device, MH-Z19B measures CO<sub>2</sub> levels, and analog pH sensor measures the pH of the nutrient solution. The stimulated actuators for these are a heater/fan output which turns on and off based on temperature readings, humidifier which turns on/off based on the readings of the humidity sensor, CO<sub>2</sub> pump which turns on/off based on the readings of the CO<sub>2</sub> sensor, and an Acid & Base pump which turns on/off based on the readings of the pH sensor. An Arduino code was written to read all sensors continuously and apply conditional if/else logic controlling the output result of on/off stage. Reference Arduino design in Appendix4.



**2.7 Robotics Automation in Smart Farms:** Advancement in the field of sensor technology and Robotic automation has been successfully implemented for multiple agricultural tasks which were traditionally done by manual labor. This has not only enhanced productivity but also led to precise execution for tasks round the clock and helped in gathering real-time data assisting in fine-tuning the growing environment. Leveraging such advanced technology for our space mission agriculture will help in sustainability and easy scalability with time. Robots will assist in seeding, transplanting and harvesting

the final grown crops. With the advanced in-built cameras and sensors robots can readily identify the signs of stress in plants and track their growth.

**2.8 Farming tools and equipment:** For agricultural activities in space settlement under controlled environment, it is very important to use a vast variety of sensors to monitor the environmental conditions, data from which will then be fed to automated control systems which can then adjust the conditions dynamically. Leveraging infrared technology, cameras for real time plant health monitoring. LED lighting systems, advanced water management and recycling systems and other technologies for best performance and maximum output. Robots for precision seeding, constant plant health monitoring, harvesting and recycling the plant waste will be used. We will leverage advanced AI technology for predicting the crop yield and assistance in crop rotation.

**2.9 Oil Extraction Using Microalgae:** Oil is essential part of our everyday cooking. Traditional methods of pressing seeds/nuts to extract oils are extremely resource intensive, making them less suitable for our settlement. Microalgae, on the other hand, presents a high-efficiency alternative to produce edible oils. The microalgae would be grown in closed photobioreactors with controlled conditions. Selected species of microalgae produce large amounts of oils within a small span of land area. Some of these include *Nannochloropsis*, *Schizochytrium* sp. & *Nitzschia* sp. *Nannochloropsis* can produce up to 60% oil by its dry weight and is especially rich in Omega-3 fatty acid. *Schizochytrium* sp. can produce 50-77% oil by its dry weight and is known for having high levels of DHA, a type of Omega-3 fatty acid which is crucial for brain and eye health. *Nitzschia* sp. can produce 45-47% oil by its dry weight and is a great source of EPA which is a type of Omega-3 fatty acid essential for heart health. A combination of the oil produced by these three algae would be made to be used in the preparation of food, thereby including all possible benefits. All these species are easy to grow and harvest, and oil can be extracted through various methods including mechanically pressing the dried microalgae harvest. The remaining biomass can be used as a source of protein, leading to a minimal waste creating system.

**3. Importance of Nutrients:** The residents of CSS need a diet that keeps a stable metabolism, causes low inflammation and keeps the gut healthy. The focus is to have a diet rich in clean proteins, slow-burning carbs and antioxidant rich fruits and vegetables. High fiber is also essential as the gut loses microbial diversity, thus it is necessary to include legumes, fruits, vegetables and probiotics to maintain gut balance. Additionally, herbs and spices are a great addition as they help reduce inflammation. Processed sugars, meats, and foods are avoided to minimize stress on the body. Overall, this diet plays an active role in keeping the residents strong, stable and healthy.

Category	What It Includes	Why It Matters
<b>Protein</b>	Bean, lentils, soy, quinoa	Maintains healthy muscles & bones.
<b>Carbohydrates</b>	Oats, quinoa, cooled rice/potatoes	Keeps blood sugar levels stable.
<b>Fruit &amp; Vegetables</b>	Greens, berries, bananas, carrots, beets	Provides antioxidants & helps against damage due to radiation.
<b>Herbs &amp; Spices</b>	Turmeric, ginger, garlic, cinnamon	Supports cellular health & reduces inflammation.
<b>Fiber</b>	Legumes, whole grains, blackberries, peas	Keeps gut microbiome healthy.

**Nutrients for Bones & Vision:** Living in space for long durations, creates risks for vision as microgravity pushes fluids towards the head. This could lead to vision problems, eye swelling, and retina damage caused due to constant radiation exposure, while limited sunlight exposure can affect bone maintenance. To address this, the residents require a targeted set of nutrients that help counter these. B-vitamins such as folate and B12 support eye-nerve function and may help reduce eye swelling. Lutein and zeaxanthin act as internal filters that protect the retina from harmful light. Vitamin A maintains the eye's light sensing ability, while vitamins C and E provide antioxidant defense against radiation damage. Zinc and the omega-3 fat DHA strengthen retinal membranes, support the visual cycle and help with bone density. Calcium, vitamin D, and magnesium work together to maintain strong bone mineralization. Together, these nutrients work towards ensuring our settlement's residents are not prone to vision damage/challenges. Sample meal plan is listed in Appendix5.



**4. CSS-v2 Bio Beverages:** The CSS Bio Beverages are microbially fermented drinks that use traditional fermentation methods from ancient global cultures adapted for sustainable production within our space settlement. Within these processes, grains, herbs, vegetables, and algae are naturally fermented into drinks dense in nutrients, low in insulin, and rich in probiotics and antioxidants. By integrating these heritage methods in our life support system, CSS can produce a wide range of healthy drinks that support digestion, immunity, hydration, and metabolism.

**Red Booster: Space Kanji-Inspired by Indian Black Carrot Fermented Drink:** The Red Booster is an adaptation of the popular North Indian fermented drink which would be made using our hydroponically grown black carrots (anthocyanin content), beets, mustard seeds, and water. After soaking these, it is fermented for 3-5 days which gives it a deep red colour. This fermentation process generates *Lactobacillus plantarum* which is a mild bacterium, wonderful for gut, digestion & immunity.

**Yellow Booster: Space Chicha de Jora-Inspired by Andean Maize Drink:** The Yellow Booster is a fermented maize drink of communities of the Andes. This golden and cloudy drink is made by sprouting corn, crushing it and letting it ferment gently in water. Fermentation reduces the starch content from the corn which produces a smooth, mildly tangy drink rich in B-vitamins, organic acids and electrolytes.

**Brown Booster: Space Herbal Drink-Inspired by Indigenous Traditions:** The Brown Booster is a herbal drinks made sage, cedar, labrador tea and wild mint. Our hydroponically grown herbs are infused in mineral water and lightly fermented for 12-24 hours into a brown tonic. This drink rich in nutrients, supporting digestion, stress control, & immune health.

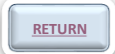
**White Booster: Space Rejuvelac-Inspired by Ancient Grain Techniques:** The White Booster is an adaptation of the Rejuvelac, a sprouted grain fermented drink originated in Romania. White and cloudy in appearance, it's made by soaking sprouted wheat, barley, or quinoa until natural fermentation takes place. The resulting white tonic is rich in digestive enzymes, B-vitamins and mild probiotics.

**5. CSS-v2 Supplement Manufacturing Hub:** For our long-term space settlement, everyone needs a supply of vitamins and nutrients to stay healthy. A practical solution is to make supplements within our settlement. For supplement capsules, their shells would be made using PHA/PHB, a safe biodegradable biopolymer, produced by bacteria, and the nutrients inside would come from algae such as *Dunaliella salina*, *Haematococcus*, or *Nannochloropsis*. This entire product chain would be hosted inside a biomanufacturing module within the agricultural sector in our settlement.

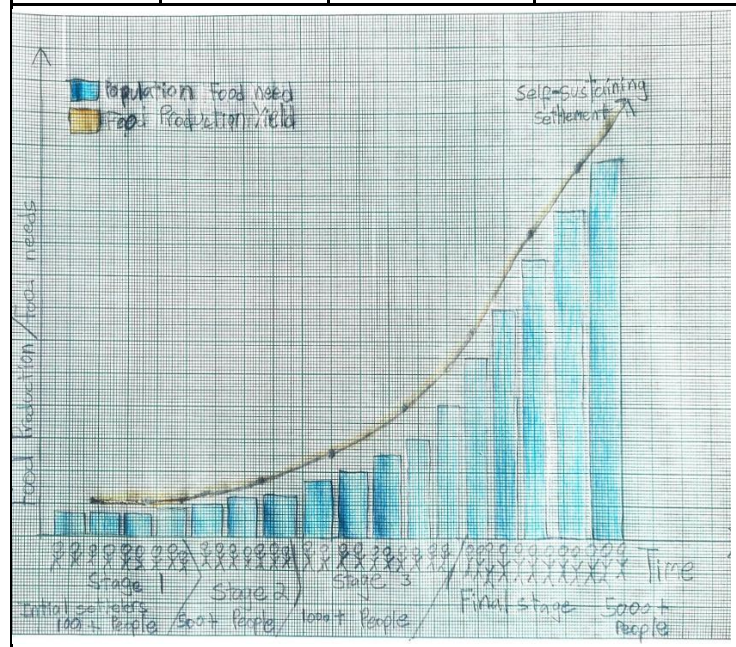
Polyhydroxyalkanoates (PHA) are natural bioplastics made by a specific type of bacteria, and Polyhydroxybutyrate (PHB) is the most common and safest form of PHA. The production process starts by growing bacteria that produce PHA, usually *Cupriavidus necator*, inside a small bioreactor. These bacteria naturally produce PHB when grown in set-controlled conditions. In the first stage, the bacteria are given sugars, as their predominant carbon source. This helps them grow and increase in number. In the second stage, the amount of non-carbon nutrients nitrogen or phosphorus is reduced, which enables a higher PHB production in cells. When the bacteria reach its highest possible concentration of PHB, it is then collected, and cells are broken open to release the PHB stored. The PHB is then processed, during which it is cleaned and grinded into a fine powder. This powder is processed into usable polymer form, by gently melting PHB at controlled temperatures and then shaped into 3D printer filament. For capsule manufacturing, the approach would be to use filament based 3D printing. The 3D printer creates capsule halves by laying down very thin layers of PHB forming light shells with precise shapes. Parallely, a powder is created for the main nutrient component of the capsule. Algae photobioreactors grow different microalgae for their specific nutritional benefits. Once harvested, they are dried are grounded into fine powder and mixed into supplement formulas. Once both parts are ready, the 3D-printed capsule halves are filled with precise amounts of algae powder. Each batch is checked for quality using small spectrophotometers. These supplements are effective in treatment for vision problems bone loss and weakened immunity. Reference details in Appendix7.



Appendix 1: Infrastructure Plan



Stages	Number of Residents	Environmental Conditions	Infrastructure Plan
Stage1 (Initial Habitat)	~20-100	Controlled	<ul style="list-style-type: none"> <li>Vertical Hydroponic racks</li> <li>Algae Photobioreactors panels embedded into settlement walls to regenerate Oxygen and remove Carbon Dioxide</li> <li>Small insect pods for recycling waste.</li> </ul>
Stage2 (Detailed Exploration)	~100-500	Establishing Dynamic Autonomous system	<ul style="list-style-type: none"> <li>Automated monitoring and dynamic atmospheric control systems.</li> <li>Cultivating plants with high water content makes it viable for long term storage. Eg: Lettuce / Tomato/ Basil/ Spinach etc.</li> <li>An automated system having controlled carbon dioxide concentration and optimized lighting using LED systems to generate the needed light spectrum for plant growth</li> </ul>
Stage3 (Habitation Hub)	~500-1000	Dedicated region for Food production	<ul style="list-style-type: none"> <li>Integrated system handling bulk oxygen generation, water recycling, and waste management.</li> <li>Scaling further up the algae based panels across the settlement walls as population increases.</li> </ul>
Stage4 (Full settlement scale)	~1000-5000	Established agricultural zone	<ul style="list-style-type: none"> <li>Multi-tier climate control system to be established with each level providing warm, cool, humid or dry conditions depending upon the crop type.</li> <li>Food storage pods to be set up.</li> <li>Fermentation chambers leveraging kimchi, vinegar, pickles &amp; booster drinks etc for long term preservation without refrigeration will be installed in storage units.</li> </ul>



Quantity	Value
Major Radius (R)	1200m
Minor Radius (r)	200m
Agricultural Sector Angle	72°
Module Radial Height	200m
Modular Circumference (C)	1760m
Number of Tiers	3

Agriculture Module Floor Area:  
 $A = [\pi(R^2 - r^2)]/5$   
 $A = [3.14(2560000 - 1000000)]/5$   
 $A = 980180m^2$   
 where,  
 R is major radius of Torus= 1200m  
 r is minor radius of Torus= 200m  
 pi is approximately 3.1415

## Appendix2: Composition of Solutions A & B for Hydroponics Racks

Concentrated Nutrient Solution—A

Component	Concentration (g L <sup>-1</sup> )
KNO <sub>3</sub>	45.30
Ca(NO <sub>3</sub> ) <sub>2</sub>	26.70
NH <sub>4</sub> NO <sub>3</sub>	1.33
Fe-chelate (6%)	3.00

Concentrated Nutrient Solution—B


Component	Concentration (g L <sup>-1</sup> )
KH <sub>2</sub> PO <sub>4</sub>	20.00
MgSO <sub>4</sub>	20.00
K <sub>2</sub> SO <sub>4</sub>	15.30
KNO <sub>3</sub>	14.70
MnSO <sub>4</sub>	0.16
ZnSO <sub>4</sub>	0.23
B	0.23
CuSO <sub>4</sub>	0.03
Na <sub>2</sub> MoO <sub>4</sub>	0.01

RETURN

## Appendix3: AI Modeling of plants health monitoring

classify\_plant.py image3.png X

images > healthy > image3.png



PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS


```
PS C:\Users\gurno\vision_farm> py classify_plant.py images\healthy\image3.png

Analysis for image3.png:
Green: 93.0%
Yellow: 2.1%
Brown: 0.1%
Status: HEALTHY
Suggested action: No change. Keep current nutrient and light settings stable.

PS C:\Users\gurno\vision_farm>
```

classify\_plant.py yellowimg1.png X

images > yellowing > yellowimg1.png




PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS

```
PS C:\Users\gurno\vision_farm> py classify_plant.py images\yellowing\yellowimg1.png

Analysis for yellowimg1.png:
Green: 22.1%
Yellow: 57.5%
Brown: 23.6%
Status: YELLOWING
Suggested action: Increase nutrient concentration slightly in this zone and verify pH is within target range.
```

RETURN

images > dark\_or\_wilted > brownimg2.png



PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS

```
PS C:\Users\gurno\vision_farm> py classify_plant.py images\dark_or_wilted\brownimg2.png

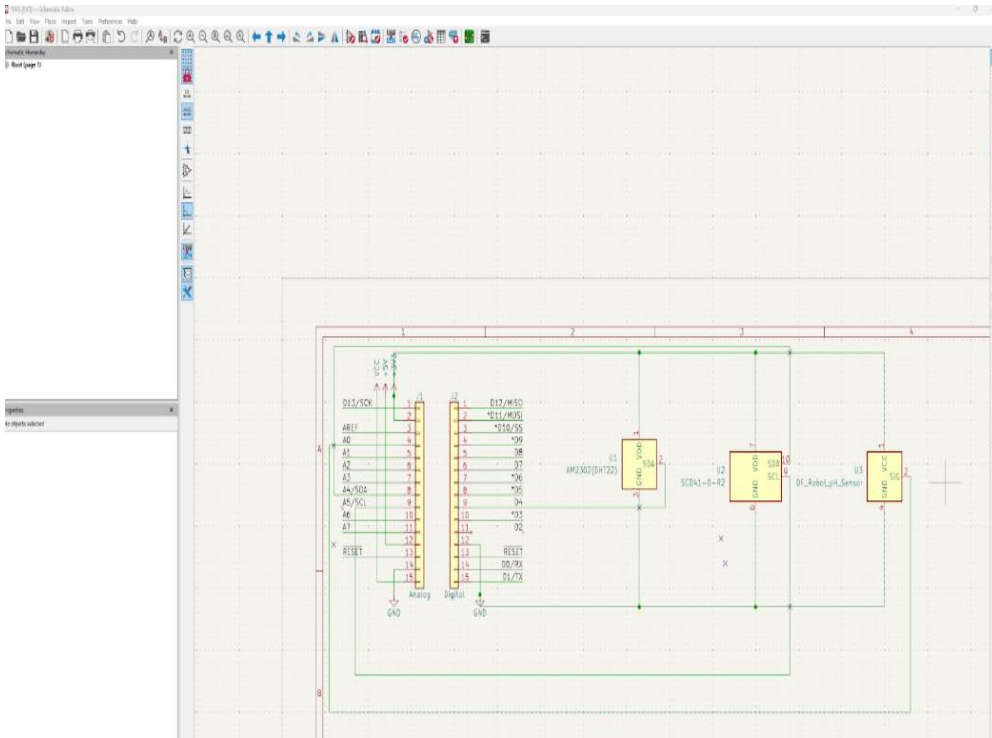
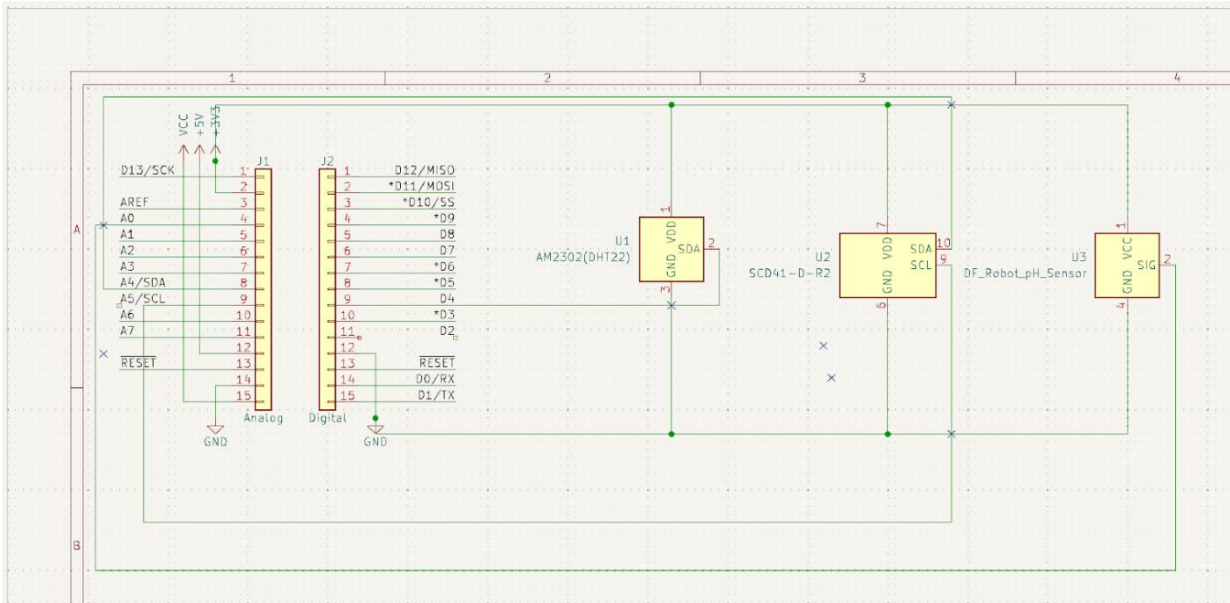
Analysis for brownimg2.png:
Green: 4.0%
Yellow: 6.1%
Brown: 18.3%
Status: STRESSED_DARK_OR_WILTED
Suggested action: Check water delivery and increase light duration or intensity slightly in this zone.
```

Link for GitHub code for AI vision model for plant health monitoring:

<https://github.com/kaur-gurnoor/css-vision-model>

# Appendix4: Growth Environment Control System

RETURN



Code link:

<https://drive.google.com/file/d/1qTamlQGrISIEraTOsuJOQT5ZGo88gijT/view?usp=sharing>

## Appendix 5: Sample Meal Plan

RETURN

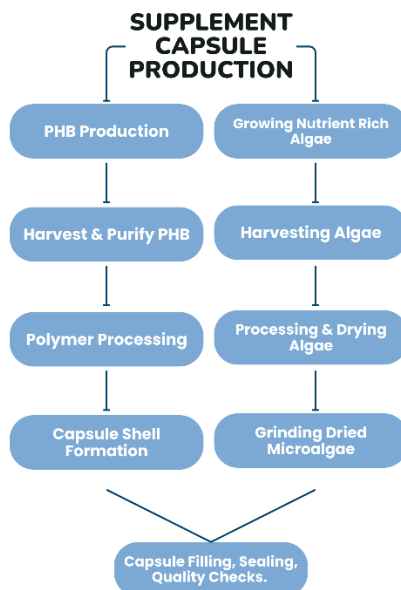
Meal & Time	Food	Nutritional Value
Hydration 6:30 a.m.	<b>Warm Lemon Water</b>	Calories: 20kcal; Protein: 0 g Fibre: 0.8g; Carbohydrate: 0.5 g
Breakfast 8:00 a.m.	<b>Oatmeal &amp; Fruit Bowl:</b> Rolled Oats (cooked): 1/2 cup; Berries (fresh/freeze-dried): 1/4 cup; Soy Milk: 1 cup; Sunflower Seeds: 1/8 cup; Nuts: Almonds, Walnuts  <b>Sweet Potato Breakfast Hash:</b> Sweet Potatoes: 3/8 lbs.; Chickpeas: 1/4 cup; Zucchini: 2 oz; Onion: 1 1/4 oz	Calories: 700kcal; Protein: 20g Fiber: 10g; Carbohydrate: 70g  Calories: 335 kcal; Protein: 8g Fiber: 10g; Carbohydrate: 51g
Morning Snack 11:00 a.m.	<b>Oat Energy Bar:</b> Rolled oats: 1 cup; Mashed banana or berries: 1; Peanut Butter: 2.5 tablespoons  <b>Veggie Sticks &amp; Dip:</b> Carrot/Cucumber/Celery Stick: 5-6; Cashew Dip: Cashews: 1/4 cup; Water: 1/6 cup; Garlic: 1/2 clove	Calories: 100 kcal; Protein: 20g Fiber: 5g; Carbohydrate: 22g  Calories: 55kcal; Protein: 4g Fiber: 4g; Carbohydrates: 10g
Lunch 13:30 p.m.	<b>Tomatoes &amp; Greens Pasta:</b> Rappini: 1 cup; Onion: 1/3; Cherry Tomatoes: 2/3 cup; Pasta: 1/4 lbs.  <b>Black Bean Veggie Wrap:</b> Tortilla: 1; Black Beans: 1/3 cup; Corn: 1/4 cup; Avocado: 1/4; Baby Greens: 1 cup	Calories: 668kcal; Protein: 25g; Fiber: 6g; Carbohydrate: 95g  Calories: 337kcal; Protein: 10g; Fiber: 16g; Carbohydrate: 51g
Evening Snack 16:30 p.m.	<b>Apple/Banana &amp; Nut Butter:</b> Apple/Banana: 1 serving; Nut Butter: 2 tablespoons  <b>CSS Bio Boosters</b> (Highly Recommended)	Calories: 250kcal; Protein: 7g; Fiber: 5g; Carbohydrate: 27g  Varies with drink.
Dinner 19:30 p.m.	<b>Mushroom Stew Over Mashed Potatoes:</b> Onion: 1/4 Mushrooms: 5oz; Green Beans: 1/4 cup; Peas: 1/4 cups Tomato: 1/2; Potatoes (Diced): 1 cup  <b>Vegetable Curry &amp; Brown Rice:</b> Zucchini (Sliced): 1/3 cup; Sweet Potato (Diced): 1/3 cup; Cauliflower: 2/3 cup; Chickpeas: 16oz; Brown Rice	Calories: 360kcal; Protein: 8.5g; Fiber: 7.6g; Carbohydrate: 50g  Calories: 477kcal; Protein: 9g; Fiber: 10g; Carbohydrate: 65g

## Appendix 6: CSS-v2 Bio Booster Drinks

RETURN



## Appendix 7: CSS-v2 Supplement Manufacturing Flow Chart



### Appendix 7: Details of Microalgae and their Nutritional composition details

Microalgae	Nutritional Composition
Dunaliella salina - Known for its ability to produce high levels of $\beta$ -carotene.	$\beta$ -carotene – Converted into Vitamin A by body, providing healthy vision and immune function.
Nannochloropsis - Widely utilized in nutraceuticals, an alternative to fish oil, a common supplement.	Omega-3 Fatty Acid - healthy fat is essential for the body, but it cannot be produced by our bodies.
Haematococcus - Rich in the antioxidant astaxanthin.	Astaxanthin - Powerful antioxidant with benefits for the skin, eyes, and overall well-being.
Spirulina - Rich in proteins, vitamins and minerals like iron, beta-carotene, and B vitamins.	Protein - Spirulina is roughly 57% protein in dry state.
Chlorella - Rich in nutrients and even commercially sold as a supplement.	Proteins, Vitamin B1, B2, B9, B12, C, D, Iron.

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