Engineering Conference
UNIVERSITY OF CALIFORNIA, IRVINE

Tall Farm

by The Green Giants

2nd Annual UCI Engineering Conference
February 16-18, 2019

Members:

Starberry Farm

Violeta Castillo
Juan Carlos Guzman
Aurora Jael Rocha
Sonoma Saito
Janet Song

Famine Fighters

Mohammed Almudhry
Blake L. Byrnes
Omar Casarrubias
Nick Gurnard

PH4

Samantha Drake
Pablo Javier Esquivel
Stanley Oliver Radic
Vincent Thomas Vang

IOP

John Aki
Maximiliano Flores
Mugared Khalifa
Jacob Laxamana

Table of Contents

Design Prompt

In order to produce high-quality food and feed a growing world population, new methods of sustainable farming must be developed that are designed to increase yields and reduce ecological impact. Unlike traditional cultivation, vertical farming has the potential to reduce the need to create additional farmland and increase the productivity of a farm by a factor of 4 to 6 depending on the crop due to year-round productivity. Our goal will be to establish a robotic-centric approach to agriculture that takes advantage of modern engineering simulations, mathematics, the revolution in sensor technology, controlled environment agriculture, fertigation, and indoor farming techniques to transform modern food production. The spire will have an 18-floor, 256.5 x 114 ft farm located around the UC Irvine campus, and our goal is optimizing it to produce 15,000 tons of food annually.

Overview

The planet's current population is around 7.53 billion and will only continue to grow. In order to keep up with the increasing demand for food new and efficient farming methods must be developed. One of the larger limitations regular farming has is its current need for a large surface area, resource consumption, and labor. The Agrispire aims to maximize the amount of crop that can be produced per horizontal area by building an 18 story vertical farm on the University of Irvine Campus. 15 of these floors will together yield a minimum of 1500 tons of crop. The system will diminish the need for human labor by creating a completely autonomous farming system which will be controlled through a wireless sensor network. The network AI will collect data throughout the whole farming process into an NoSQL database. The data collected within the database will allow optimizing and controlling all mechanized functions such as:watering,sowing,weeding,fertilizing,and harvesting with a robot equipped with SmartShift. The building will retrieve its water from two primary sources such as the San Diego Creek and rain. The water will be filtered onsite with a simple and efficient filtration method comprising of coagulation, flocculation, sand filtration,and ozone disinfection. The facility is cost-effective, environmentally conscious, and technologically controlled.

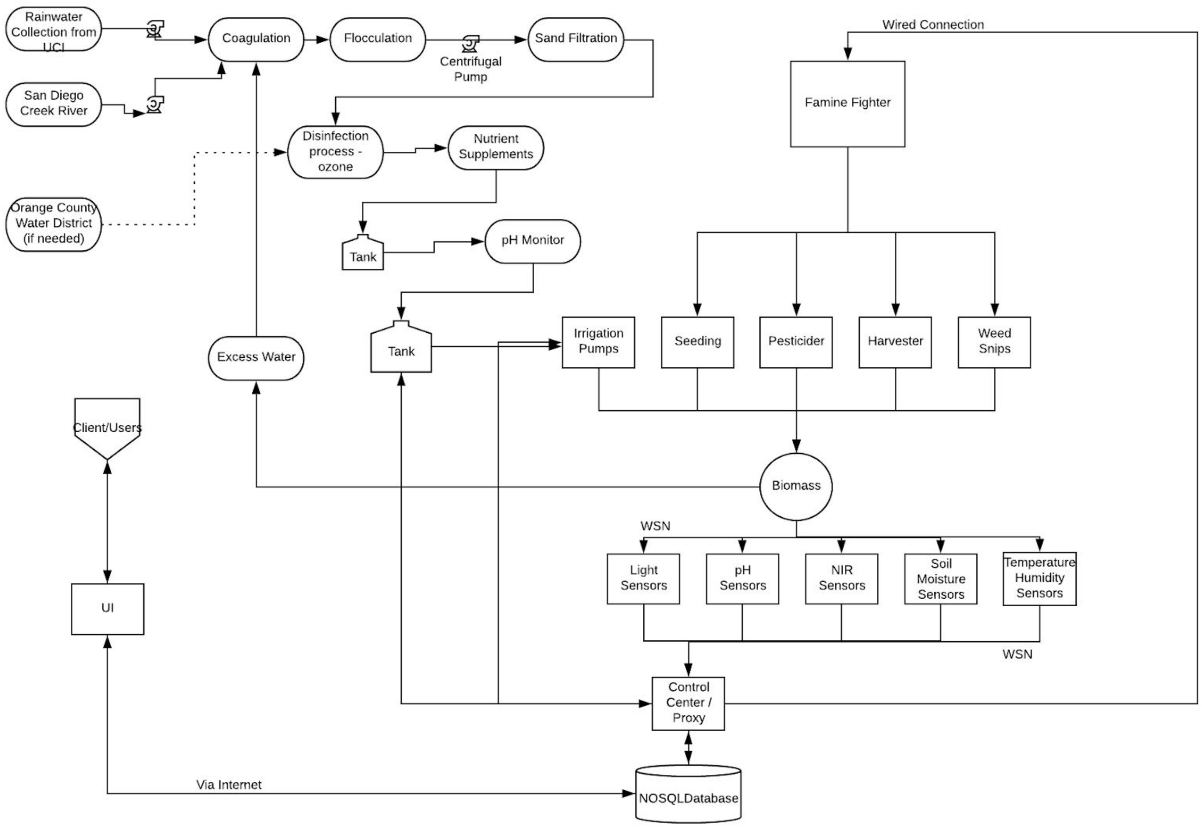
Goal

Our objective is to design an 18 story vertical autonomous farm with a water filtration system, an autonomous crop farming mechanism, and utilization of AI to optimize the different structure. All the systems within the farm will be utilized to ensure an optimal growth and picking of a minimum of 3.6 million pounds per year of our target crop, strawberries, within the building.

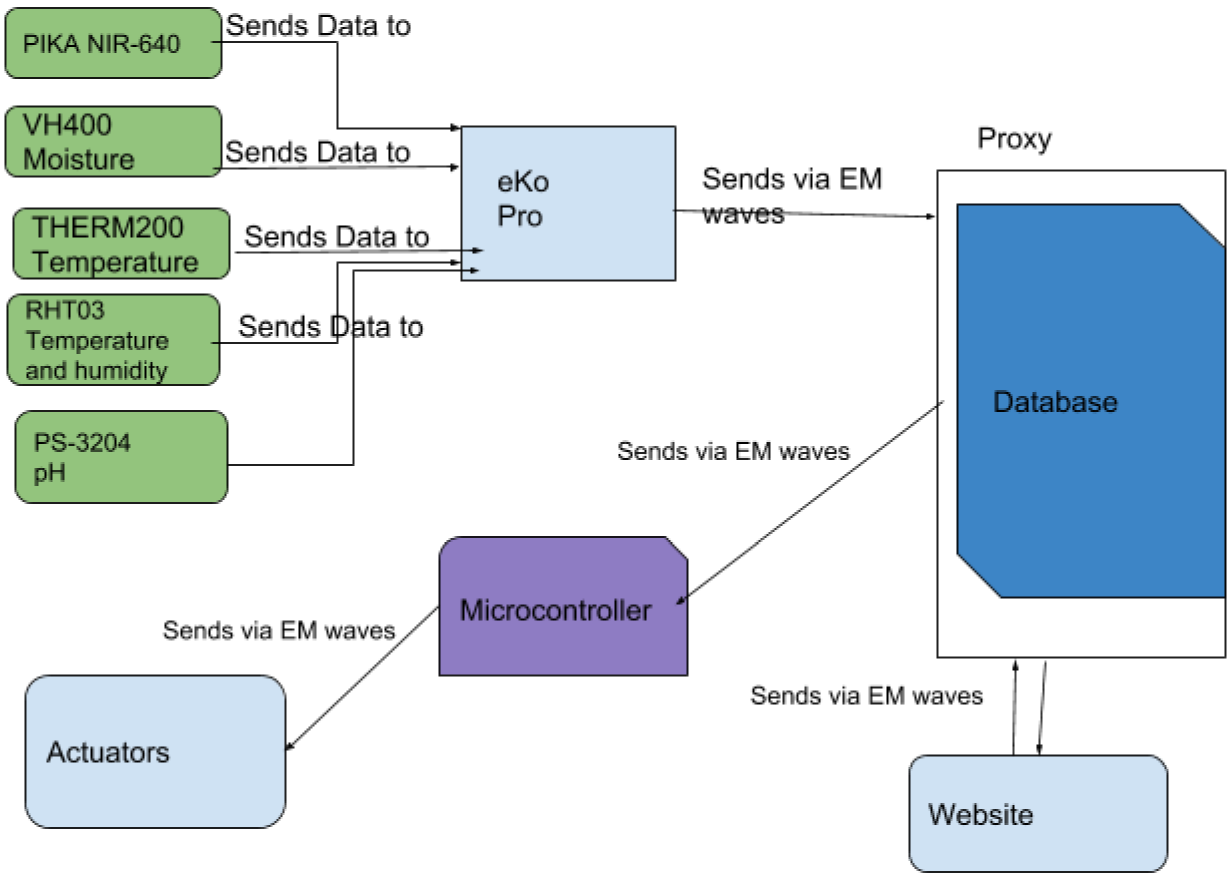
Objectives

- Create a system and web application to monitor a farm through sensors to collect data and store it on a network where an AI will generate responses for optimal crop growth and determine when specific crops are ripe.
- Provide a water filtration system with the ability to purify water effectively in a economical methods in order to support strawberries in an 15 story Green Skyscraper, keeping in mind the pH and nutrient levels of the water.
- Produce an autonomous crop farming mechanism that can be integrated both vertically and horizontally designed to optimize the balance between cost, functionality, performance, and practicality.
- Design the structure of an 15 floor vertical farm with the purpose of minimizing environmental impact, determining best material, and the structural design.

Project Outline



IntelliCulture (IOP)

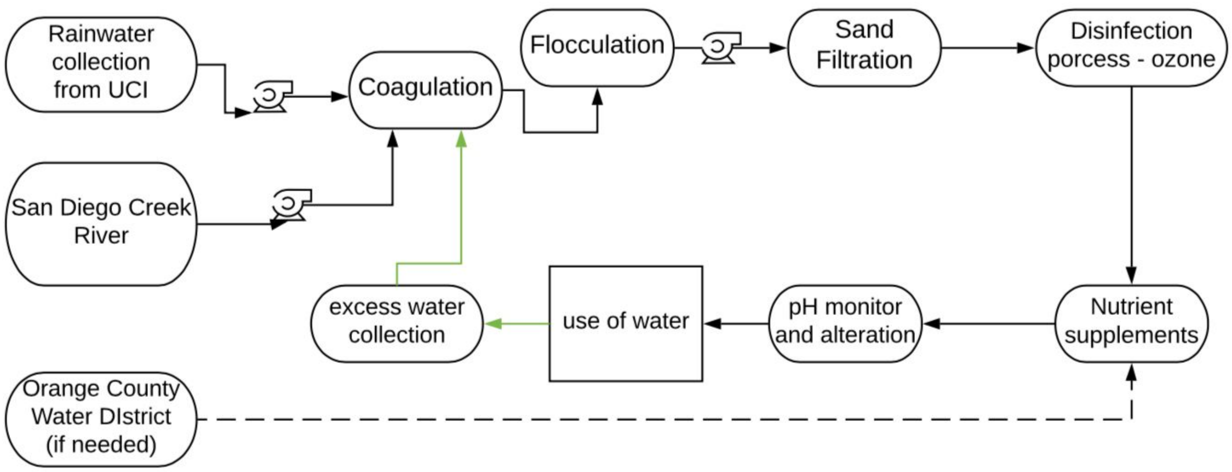


We have multiple sensors to measure variables such as temperature, moisture, humidity, and pH in the farm. That data will be sent to a network of eKo Pro systems. These systems have the capability to relay data from one eKo to the next keeping the data separate from its own. Because of this, as long as one eKo system can reach the next, data can be transmitted to the main server.

Once the data reaches the server, a proxy will cue the given data in a cue structure, which will increase the consistency of the data transfer. After that, the data will be given to a program running on the server that will store it in a database available for analysis and for the client.

Our Neural Network will analyse the data and find a correlation between them to optimize the yield of the crops, and detect which crops are ready to harvest. Then based on the optimum values found by that Neural Network, the proxy will send these values to the actuators controlling the environment to make it optimum for growing the crops.

AquaRefine (PH4)

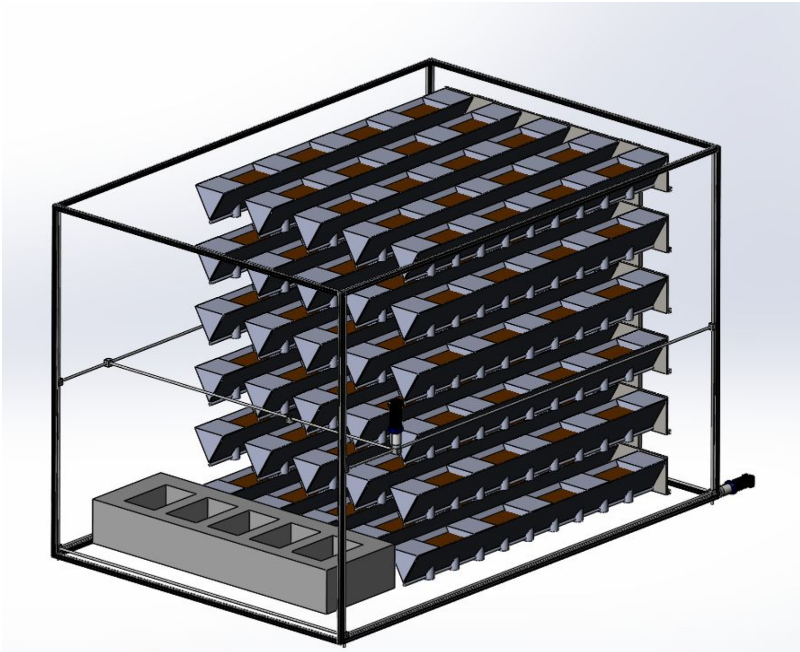


Using rainwater, and river water as water resources to optimize the local resources such as The San Diego Creek river and rainwater that can be collected from buildings across the UCI campus. The water will go through multiple processes beginning with coagulation followed by flocculation then sand filtration, disinfection, infiltrated with nutrients and lastly pH balanced.

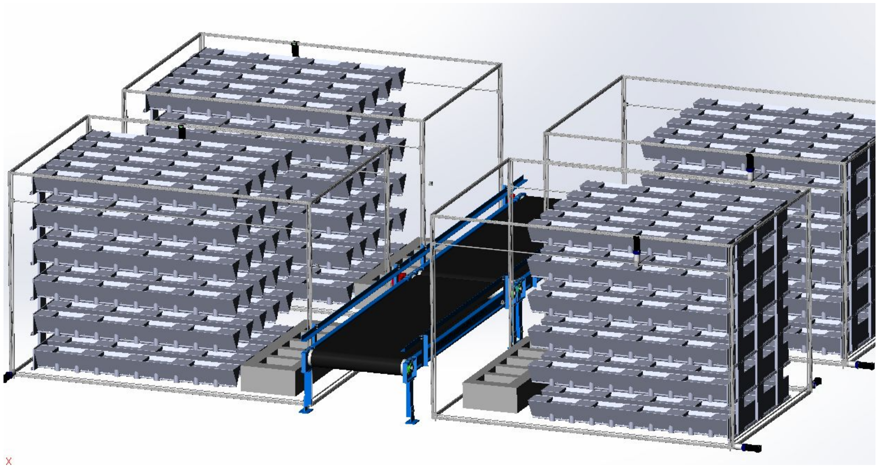
Within the Green Skyscraper the water collected from the excess water usage, we would collect the unused runoff water to return to the filtration system that will go through and reduce the amount of total water needed for sustaining the growth within the gardens.

Agri-BOT-any (Famine Fighters)

When it comes to the design of most agriculture robots and systems, the design relies on the use of wheels and multiple arms attached. In order for a system to be most efficient in an enclosed area, this can not be the case. In order for the system to be completely autonomous, the robot is able to move both vertically and horizontally. To accomplish its tasks, the robot is able to change the tools by use of the SmartShift. The SmartShift is a tool changer and will change the robot's in use tool/component to do the necessary task autonomously. The components deal with the task of seeding, sowing, spraying fertilizer and pesticide, removing weeds, and picking out the crops.



SkyFarm (Starberry Farm)



Ground Floor

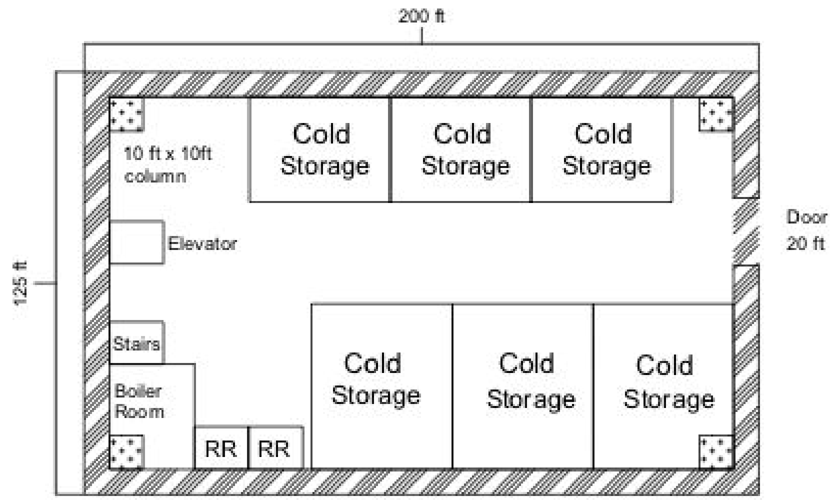


Figure 1: The main function of the ground floor is for crop storage and transportation. Six cold storage tanks are available to preserve the strawberries produced by Starberry Farm. There is a door large enough for a truck to drive in and out of the facility. Our strategy for minimizing load on upper levels is to store strawberry yields to the ground floor.

Floors 2-4

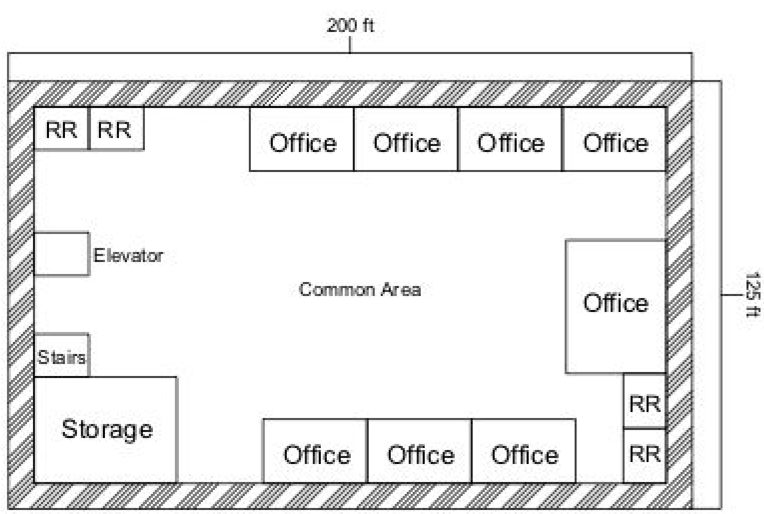


Figure 2: Floors 2 to 4 are used mainly for office space and administrative purposes.

Floors 5-18

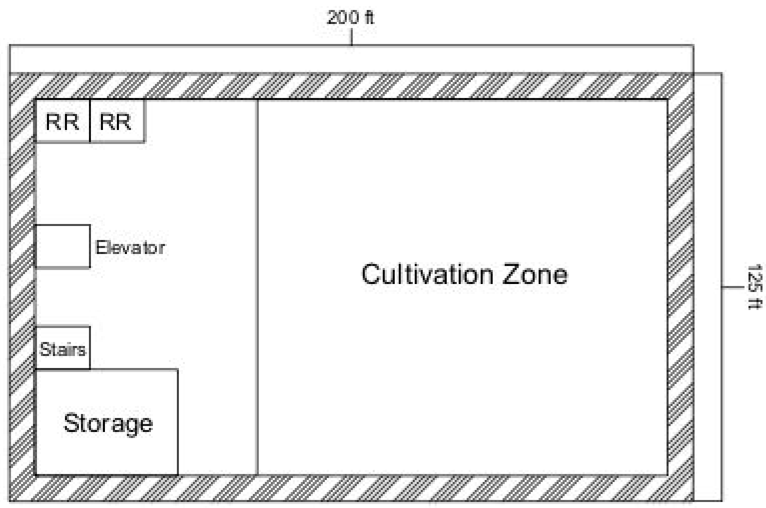


Figure 3: Floors 5 to 18 are where the strawberry plants are grown. A 120 ft by 125 ft section on each floor is cordoned off as a cultivation zone.

Design Breakdown

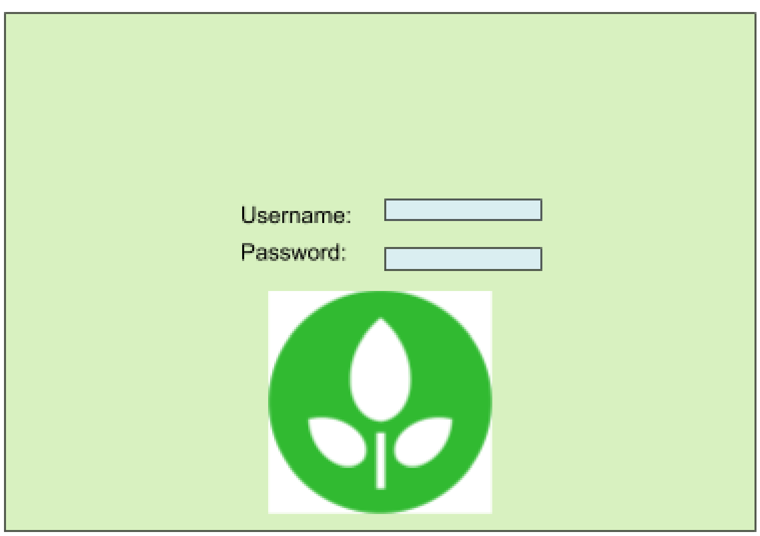
IntelliCulture (IOP)

For the network design we will be using a Bluino Nano Arduino Microcontroller to help send commands from the wireless network to other systems to ensure the crops are being treated in a proper environment. We are using bluetooth to communicate with the sensors because it uses little energy to communicate with other systems making it more efficient than other types of communication. Bluetooth is very universal today and provides data connections to other systems without the use of wires. It also operates on low energy making it efficient for saving money. This specific microcontroller was chosen because of its small size making it mobile as well as its ability to program wirelessly for simpler troubleshooting. The VH400 Moisture sensor, PS-3204 pH sensor, and THERM200 Temperature sensor will measure and record data of the three most significant soil parameters - moisture, salinity, and temperature to ensure crops grow as efficiently as possible. The RHT03 is a low cost humidity and temperature sensor with a single wire digital interface. The sensor is calibrated and doesn't require extra components so you can get right to measuring relative humidity and temperature. The eKo Pro Environmental Monitoring System gathers and transmits data from the sensors. This system can use a nodal hopping mechanism where one eKo system can double as a transmitter of data from sensors around it as well as a hopper that can relay signals from other eKo systems that may not be able to reach the server.

Near infrared radiation causes vibrations in between molecules. If we are able to measure these vibrations, we can find out what a given sample is made out of. Using the Pika NIR-640 we can measure the desired qualities of a strawberry, for example. O-H bonds and C-H bonds vibrate differently. Given their wavenumber of the bonds, we can determine the ripeness of a strawberry based on its sugar and water contents. This sensor is also good at filtering out background noise that can add interfering data to the set. A PowerEdge T30 Tower Server will be located on each floor to process the data of each floor. This will give us the capability to analyze different data sets and train multiple neural networks to analyse each crops' data set, allowing for multiple crops to be planted on each floor.

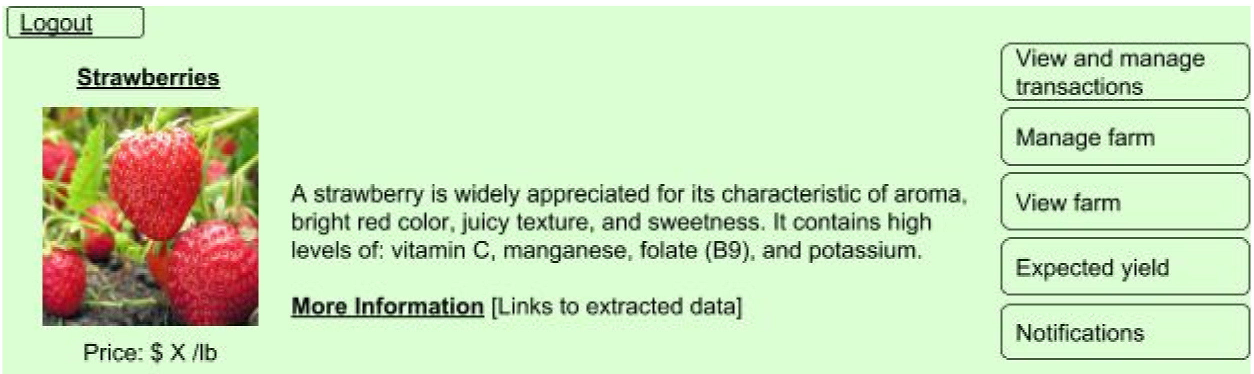
An application needs to be implemented such that it contains use cases: buying/selling crops, logging in/out, observing data analyzed by the implementation, and receiving notifications. The transitions in the application will be smooth and easy to maneuver for the user to use.

USE CASES	**ACTORS (User/Admin)**
Login/Logout	User/Admin
Buy Crops	User
Sell Crops	User
Observe Data	User/Admin
Modify Data	User/Admin
Receive Notifications	User

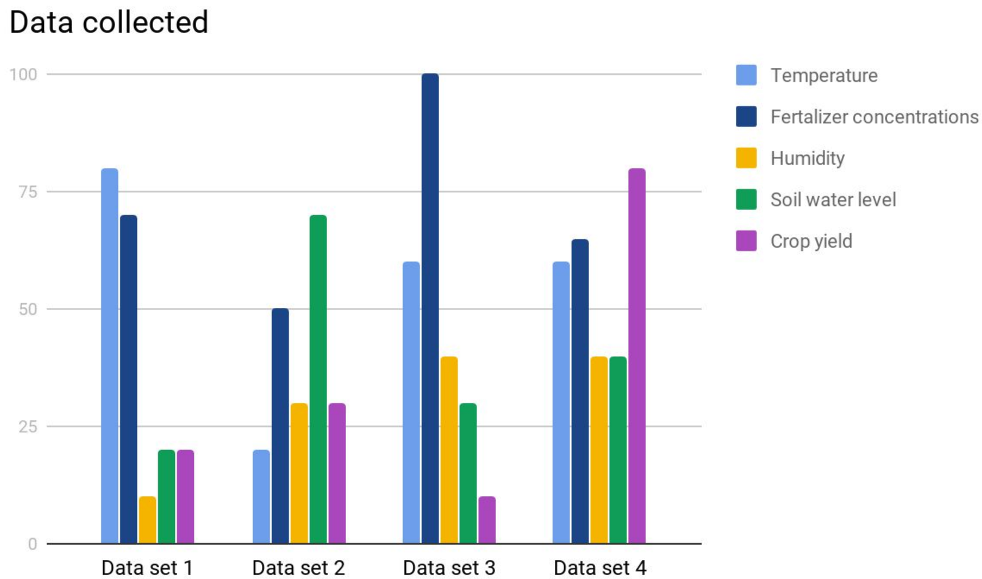


A user should be able to traverse through the application with ease and transparency. The user is able to: login/logout, buy crops, observe data, and receive notifications. Logging in/out is achieved via user input of username and password. The application should have to capability to save the user's username and password to provide quick and easy access.

Buying crops for the user should be intuitive and fast paced. There will be a button on the application that leads the user to page to browse a list of crops. From there, the user can observe each crop's price, description, includes further accessibility such as: adding a quantity to cart and inspecting further information about the crop.

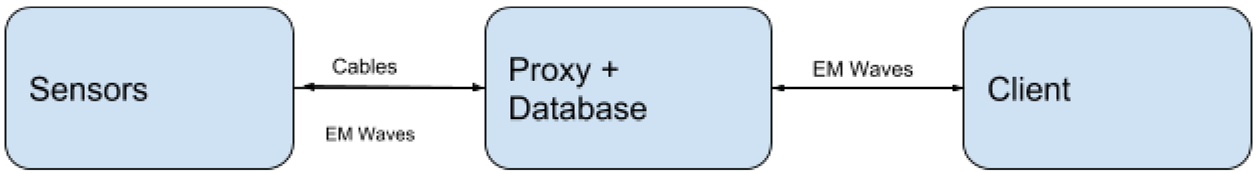


Further information about the specific crop will be the analysis of the extracted data implemented by our integrated sensor system. The data provided will not be exact numbers from our dataset but a finalized analysis form that is visually appealing to the user and is easily interpreted. This will be a simple database schema that include graphs, levels of measured data, and more.



In addition to browsing and buying crops, the user will be able to receive notifications from the application sent by the administrator. Notifications may include information on the restock of a particular item, discounts, or any customer service related messages. They can also include alerts from the sensors if the temperature gets too high or one of the equipment fails.

Data such as temperature, humidity, soil water level, fertilizer levels, PH, and also the content of sugars and water inside the strawberry will be collected from a set of sensors and hardware on the farm and get sent to a server on the farm via bluetooth. This server will then sort that data and put it in a NoSQL database. A total of eighteen servers located on each floor will be used. The use of NoSQL will help implement this horizontal scaling. Each server will store the data for a specific floor, and will implement an isolation protocol that will lock all writes and only allow reads to make sure the data it is retrieving is accurate and make only synchronous reads, since feeding the neural network wrong or corrupt data will affect it adversely. Most NoSQL databases are known to have low consistency, but by implementing isolation it will be able to raise consistency. This will decrease availability; however, consistency in this case is more important as feeding the Neural Network wrong data will make it less accurate. After that, that data can be sent to any client and use that data to run the UI. The advantage of using a NoSQL database is that all the information and fields will be stored in a single document, which means the programs will spend less time trying to access the data as compared to a relational-database. This will all be stored on a PowerEdge Tower server with a one terabyte capacity and a quad-core processor. Having eighteen servers will give us the ability to have different data sets for different crops. Furthermore, this decreases the load on each server; hence, decreasing the heat produces in each server, which increase its durability.



{
ID: 1
Crop: Strawberry
Temperature: 30
Humidity: 70
PH: 7.3
Nitrogen: 4
Potassium: 5
Location: “3,4”
}

To maintain optimal conditions for the crop we are growing, we will use a Recurrent Neural Networks to keep the conditions in a negative feedback loop. When the sensors detect the specific values it will send the info into the neural network system. The Recurrent Neural Network will analyze each of the values given and makes suggestions to stabilize the values if it is not in optimal growing conditions. We chose a Recurrent Neural Network because instead of just giving outputs, it propagates the output back through the system until we get the desired output. This translates well into a farm system because we want things to be in a steady state to ensure the optimal growth of the crops. For example, if the soil is too dry then we want our network to tell us when to stop watering the system rather than just telling us to water it.

We will also have another neural network to determine if a strawberry is ripe or not. The NIR sensor gives data in the form of the frequency of waveforms. Water and sugar are what we are looking for most in strawberries so finding when the amount and ratio of water and sugar is the best is what our AI will be trained to find. We will use a feedforward neural network for this because determining ripeness of a strawberry is essentially unchangeable. Training the AI to determine the ripeness of strawberries with the given data can tell us whether or not a strawberry is ripe or not. There is no need to propagate a signal back through as one cannot directly decide to make a strawberry ripe or not.

AquaRefine (PH4)

The decision to use river and stormwater was because of the convenience and practicality, aside from the optional contribution of the OCWD water supply. These two water sources would be cleaned using 3 continuous stirred tank reactors and coagulant to catch pollutants that will reside at the bottom of the tank. The water is then filtered using a multigrade sand filter instead of the reverse osmosis since it is more expensive and that the water does not require to be treated to safety drinking standards. The remaining pollutants (pathogens, viruses, bacteria, etc) will instead be removed using ozone. The use of KCl and fish emulsion is due to the productivity of micronutrients for crops without the formation of any harmful compounds that may possibly affect the environment. Finally a balance in the pH is performed before water is sent to the crops.

- Calculations:

  v0 (river)=5800 GPH

  v0 (rain)=2000 GPH

  V (CSTR)=792 gallons (3x) -> time to fill up all three reactors= 28 min

  V (tank)= 100000 gal

  Fertilizer = 0.0039 gallons of fish emulsion /per gallon of water

  v_out_filter= 10000 GPH

  feed_gas_ozone=10-12 wt%

  Mass_coagulant=50 to 200 mg / per L of water.

  MAX Pressure at bottom of final Tank= 178755 Pa (assuming full tank)

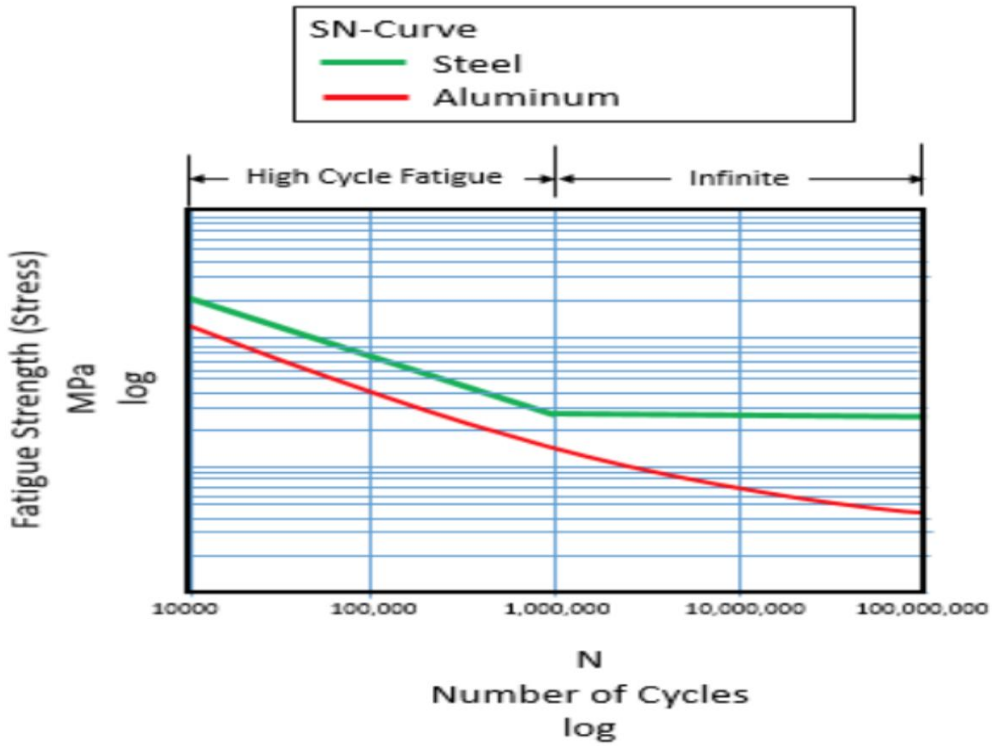
The plant housing uses a system of columns in a matrix to minimize the use of soil and reduce stress/strain by reducing the load on the frame. Each plant bed is a triangular shape that lets the soil sit within the triangle, and a hose runs along the bottom that allows for irrigation to flow to sprinklers that can me mounted in the holes protruding underneath the plant bed.

Agri-BOT-any (Famine Fighters)

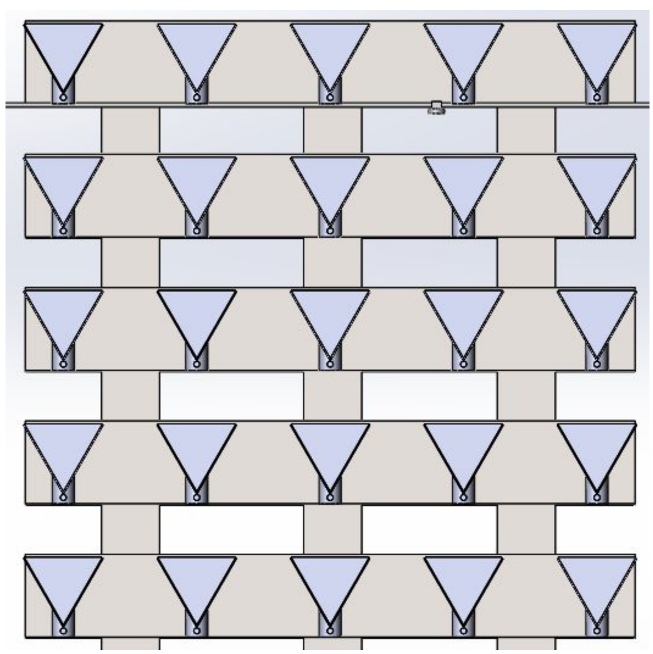
Material selection was optimized thoroughly. Choices of materials keeps in mind and considers various trade-offs and utilize the mathematical and scientific concepts to produce the optimum design. This includes using stainless steel for components undergoing highly cyclic stress load. The choice of stainless steel here prevents these components from failing by fatigue, which is the biggest reason for failing for variety of materials, especially metals.

Aluminum, on the other hand, does not approach an asymptote, which means after a certain number of cycles, fatigue will definitely happen and in a low stress. This is the reason aluminum was used for parts like extrusion, since these parts does not undergo highly cyclic stress loadings, which shows that these parts were used in the optimum place in the design.

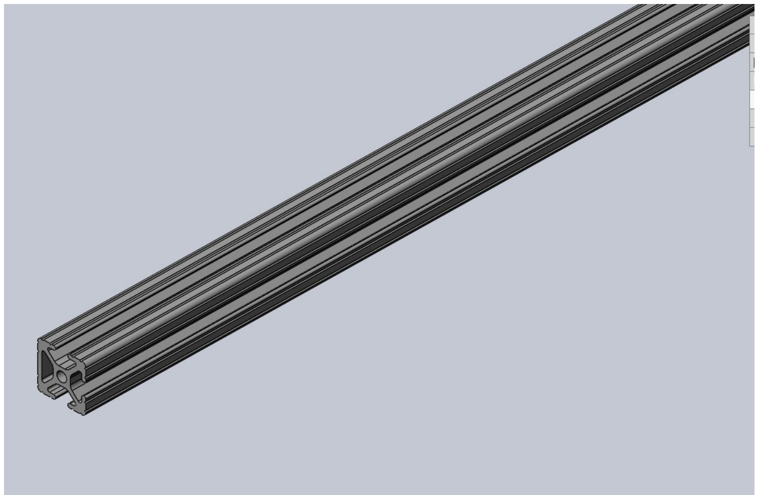
The figure below shows the fatigue curve for aluminum and steel. The lighting needs will be met by providing LED full-spectrum light sources especially made for growing plants. There will be 45 of these light sources in each floor. Each will provide light for the four adjacent units and will alternate a little bit in height in order to provide all of the seed beds with enough light to grow. These units will be in 15 out of 18 floors, which means there are a total of 675 of the growing strawberry light sources in the entire building. Each of these LEDs consume 45 Watts. For strawberries, there is a need for partial light for growth and the strawberries need at least 6 hours and the decided operating time for these LEDs will be eight hours. The amount of energy that will be consumed per day is 243 kW and it will be provided by the power collected from solar cells on the building. For maintenance, these light sources have a lifetime of more than 50,000 hours (more than 17 years), which is the highest number for these kind of lights with this low price.



S-N Curve for Aluminum Vs Steel

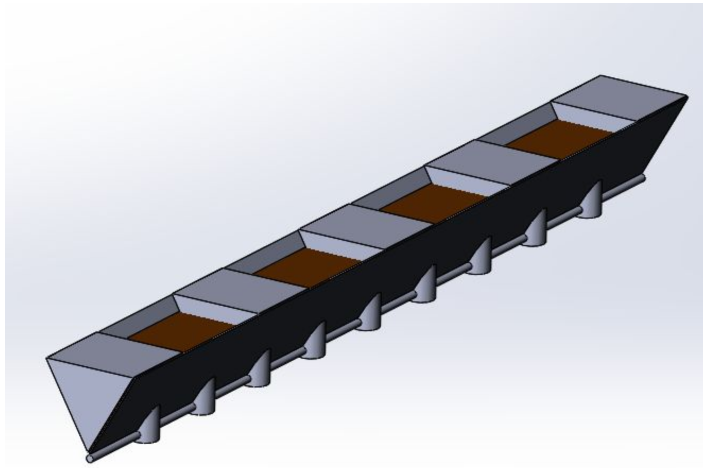


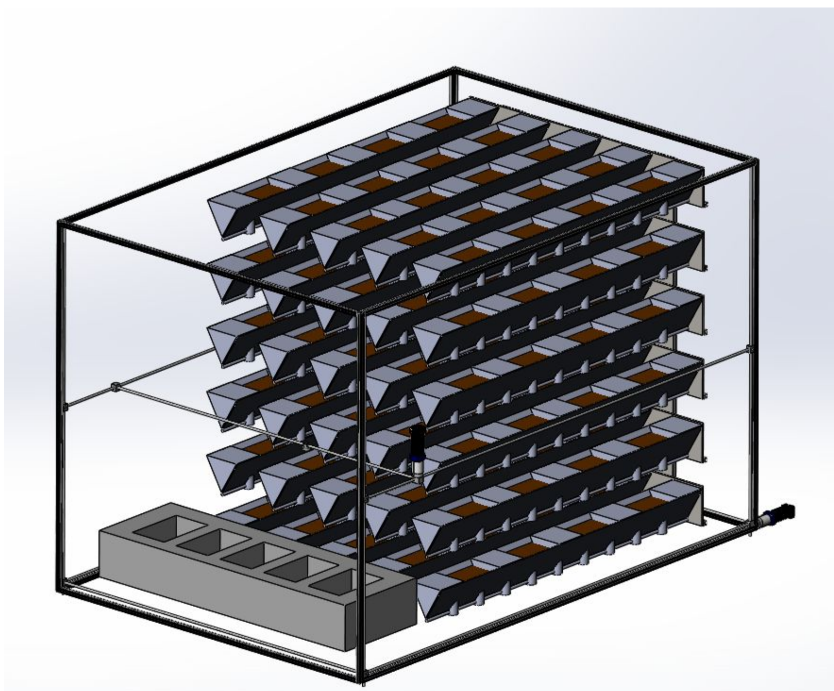
A shelf like structure is used to support the array of plant beds along with the robot mounted on tracks. The tracks are mounted on aluminum extrusions that make up the shelf.



Single Aluminum Extrusion

Two tracks run along opposing sides of the shelf, with a stainless steel connector running between the two tracks. This is where the multipurpose tools that can plant, harvest, and maintain translates across. With this system, three directions of freedom are allowed to be navigated. This is critical because a single tool can manage a large quantity of crops with little hardware. As the scale of production increases, the system can duplicated and reiterated in an array consisting of multiple “units”. Multiple units can fit in a single room and can stack both vertically and horizontally. If speed is essential for a certain crop or farmer, the amount of columns of beds can be decreased (smaller amount of crops per unit size) to increase harvesting/seeding time. A tool changer known as the Smartshift Automated Tool Shifter, can swap out the multipurpose tool in order to decrease clutter and chance of failure due to an increase in mechanical components. One of these is contained in each unit (it lies upon the cinder block looking object in Figure below).





Single Unit Array of Plants Beds and Shelf with Tracks

For the Harvesting tool, a claw mechanism with a sensor is used to detect where the strawberries are. A simple change in code can also make the harvester act as a weed control device to pluck the weeds.

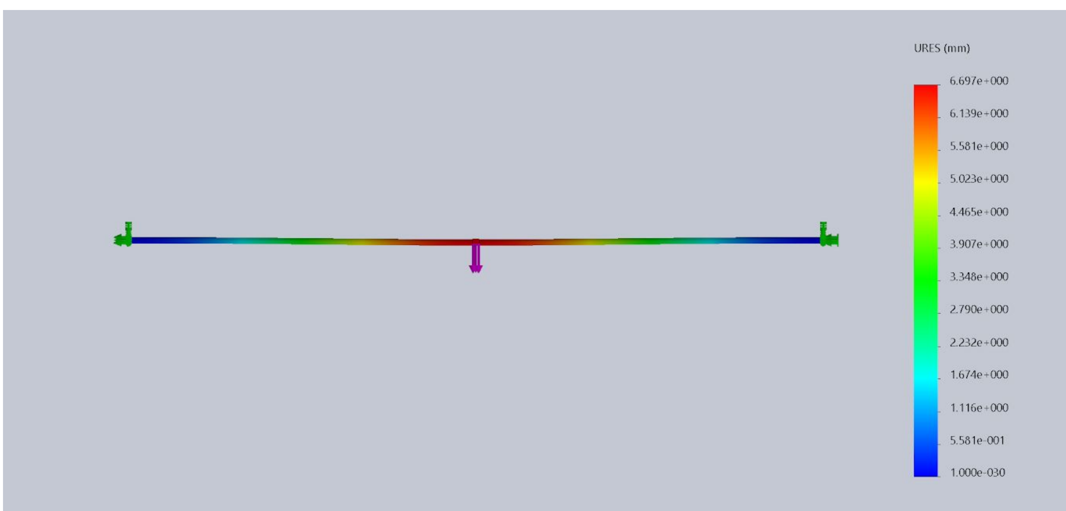
For the seeder, a simple syringe will puncture the soil at a optimal distance between seeds in order to yield the highest amount of healthy strawberries.

Figure 7 - Seeding Syringe

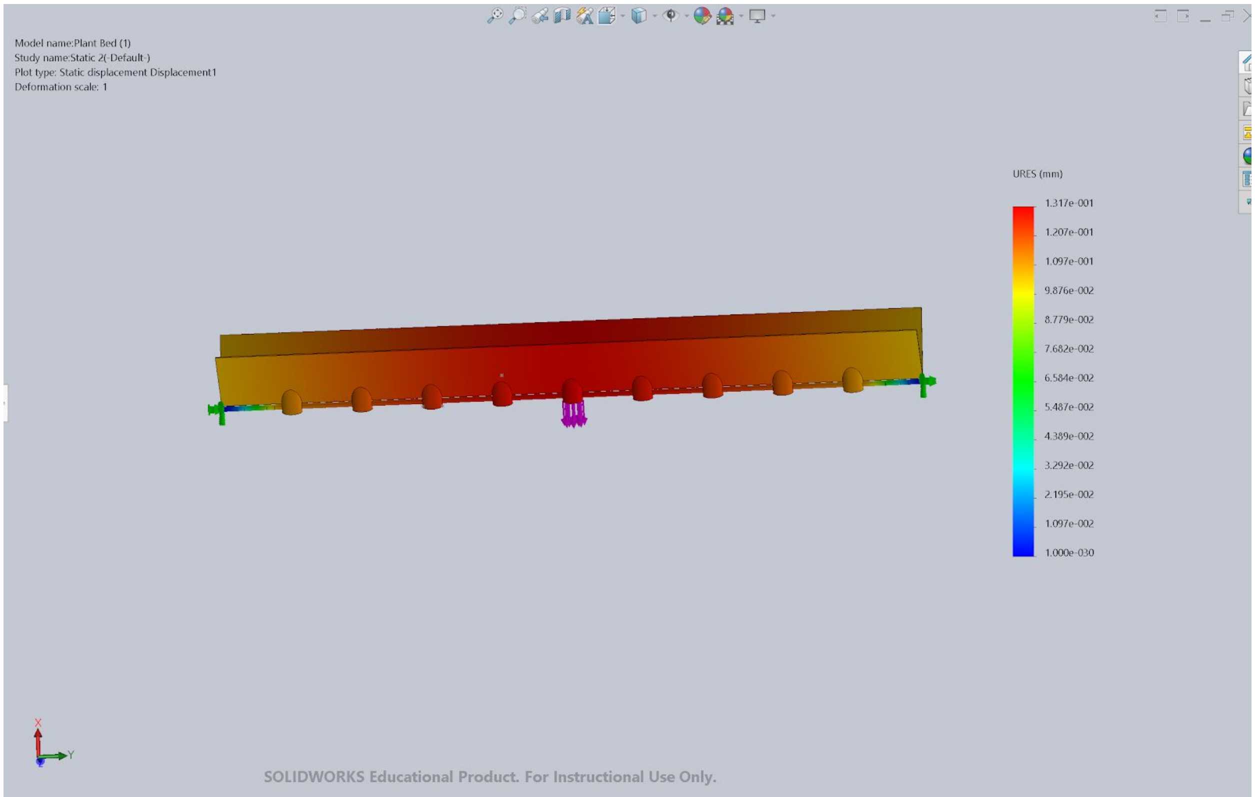
The pesticides can be run through the irrigation or will have a seperate tool to spray pesticides to eliminate insects, rodents, and mold.

Figure 8 - Smartshifter

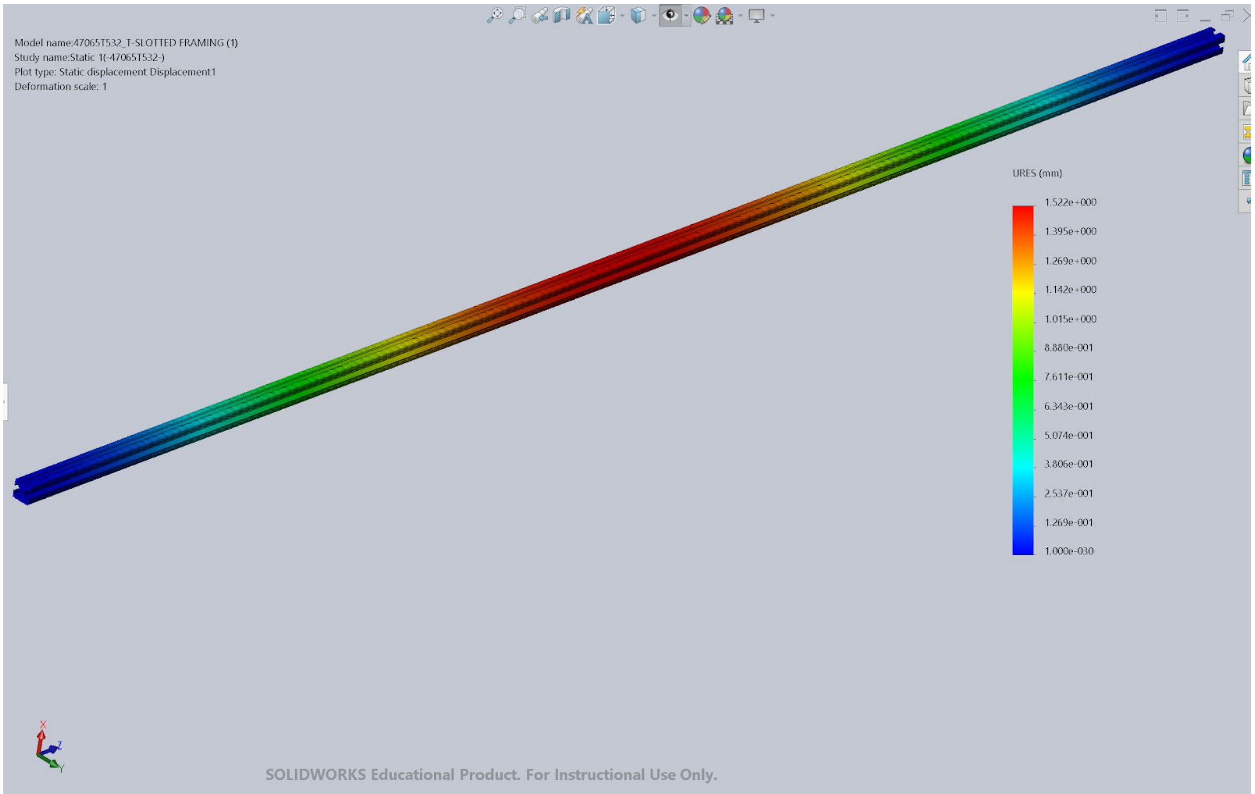
A static analysis on the multipurpose tool track shows that the stainless steel rod can withstand the current design specs without deforming.



Static Analysis of Moving Bars



Static Analysis of Seed Beds



Static Analysis of Extrusion Bars

SkyFarm (Starberry Farm)

Ground Floor

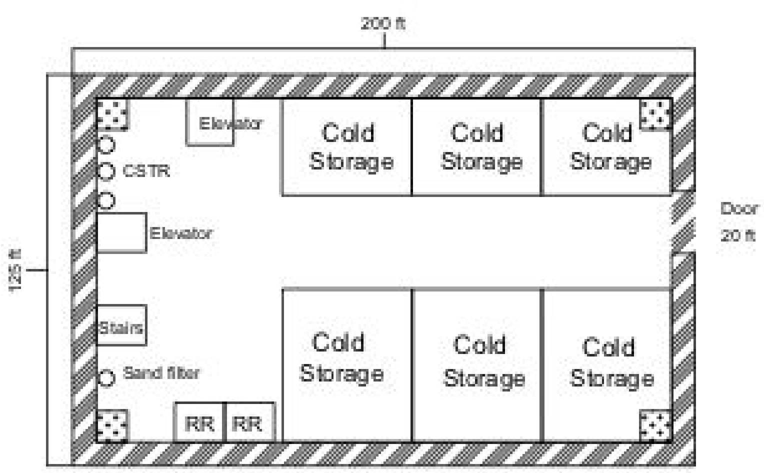


Figure 1: The main function of the ground floor is for crop storage and transportation. Six cold storage tanks are available to preserve the strawberries produced by Starberry Farm. There is a door large enough for a truck to drive in and out of the facility. Our strategy for minimizing load on upper levels is to store strawberry yields to the ground floor.

Floors 2-4

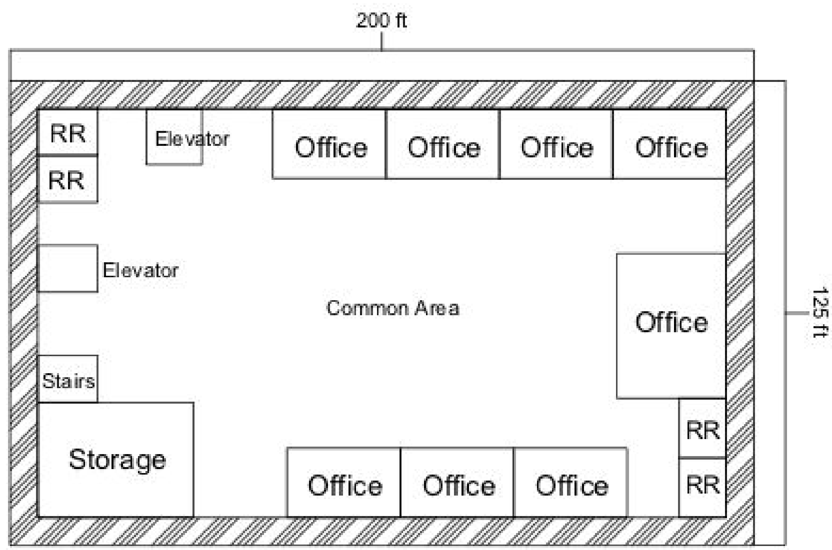


Figure 2: Floors 2 to 4 are used mainly for office space and administrative purposes.

Floors 5-18

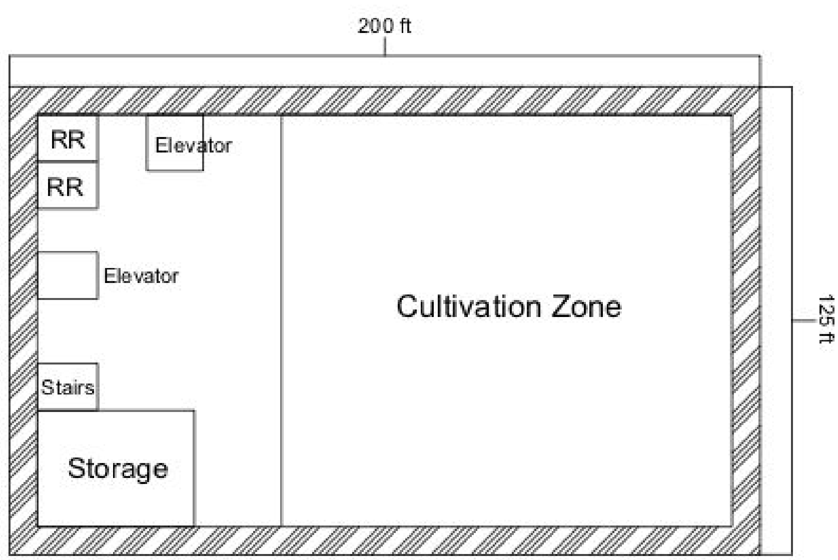
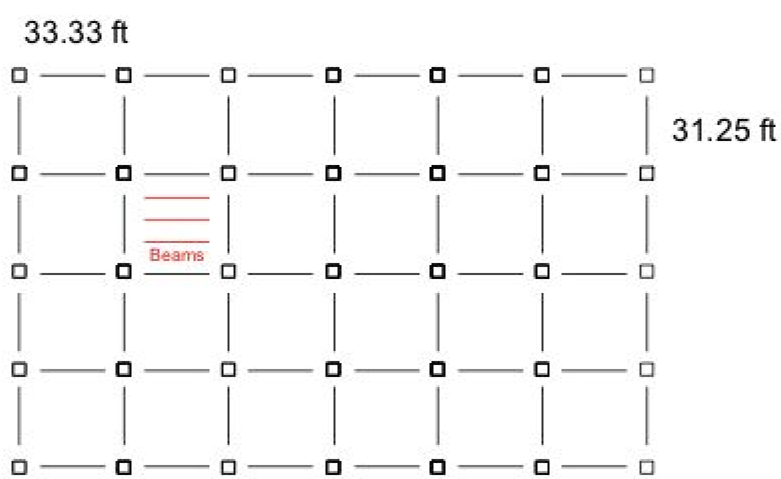


Figure 3: Floors 5 to 18 are where the strawberry plants are grown. A 120 ft by 125 ft section on each floor is cordoned off as a cultivation zone.

The vertical farm is designed to take into account for the 140 psf dead load on each floor. The major factors for the dead load include the floor, the walls, the unit, and the conveyor belt. Following the ASCE 7-10 code, the dead load of the floor and walls were found. The major factors of the live load include maintenance staffs. The value of the live load was taken from the ASCE 7-10 code. In order to support the dead load of 140 psf, the wide flange section used is W18x60.



Recycled Geopolymers Concrete

Recycled Geopolymer Concrete (RGC) was chosen as the primary building material because the CO2 emissions from using RGC is about half that of ordinary concrete. The use of RGC instead of ordinary geopolymer concrete, depending on feedback source location to the location of building, the emissions from geopolymer concrete can be 97% lower than RGC (McLellen, Williams, Lay, Riessen, & Corder 2011). The use of this material reduces waste in the landfills and reduces the consumption of natural resources.

Geopolymer concrete is produced by mixing aluminosilicate material and high alkali solutions. It utilizes by-products such as fly ash or metakaolin as aluminosilicate source to react with high alkali solutions of sodium or potassium based. Fly ash geopolymers have been studied by several researchers and were found to have high early strength, high later age strength (Sata, Wongsa, & Chindaprasirt 2013). In order to reduce costs for cooling and improve compression strength, we are adding ultrafine slag (UFS) to the recycled concrete aggregate, which can reduce the thermal conductivity coefficient to 0.305 W/m*K and raise compressive strength to 46.7 MPa (Wang, 1).

Passive Cooling Systems

Southern California is notorious for hot and dry weather. For our indoor strawberry plants, we want to keep temperatures between 60-80℉. Passive cooling systems are methods of lowering indoor temperatures using natural energy sources. Here we implement two passive cooling systems, a nocturnal convection system and a radiative cooling system.

The nocturnal convection system takes advantage of the natural cooling of air during nighttime. Starberry Farm is ventilated naturally at night with open windows and sealed during the day to keep cold air contained within the building. The combined effects of our insulatory recycled concrete-ultrafine slag aggregate and the natural inertia of heat prevent the cooled mass and air from heating up during the day. Nocturnal convection cooling is preferable in areas with daytime temperatures between 30-36℃ (86-96.8℉) and can reduce indoor temperatures to 7-8℃ (12.6-14.4℉) below the maximum outdoor temperature (Givoni, 9). To improve comfort within the building, we will allow ventilation in between floors.

Radiative cooling is the natural emission of longwave radiation of any material that is exposed to the sky. In most instances, this radiative emission is not enough to offset the absorption of heat from the sun. However, adding large insulating materials on rooftops can reduce heat absorption as longwave radiation cooling occurs. Solar panels can function as insulators, reducing rooftop temperatures by 2.5℃ (4.5℉) in one experiment held in April in San Diego (Dominguez, 1). Covering our rooftop with solar panels results in a ceiling heat sink, which will draw out heat from the lower levels of Starberry Farm. Overall, these passive cooling systems will reduce energy costs for the building and help maintain desirable conditions for strawberry production.

Solar Panels

Solar panels are used as a sustainable way to obtain energy. This is a crucial part of the design because the strawberries will grow with the use of LED lights and aeroponics which requires a lot of energy. The dimensions for each panel is 65 × 39 inches. Each panel produces 15 watts per square foot.

Irvine is a good location for solar panels due to the large amount of exposure to sunlight. The solar panels also act as insulators for the building which helps to keep the building from getting too warm for the strawberries.

Energy cost is increasing (solarnation) as the cost of installation and design of solar panels are decreasing (sunpower). Even though solar panels are an expensive sustainability component in the design, in the long run not only will money be saved but also the environment. In this case the solar panels will also support the stability of the strawberries.

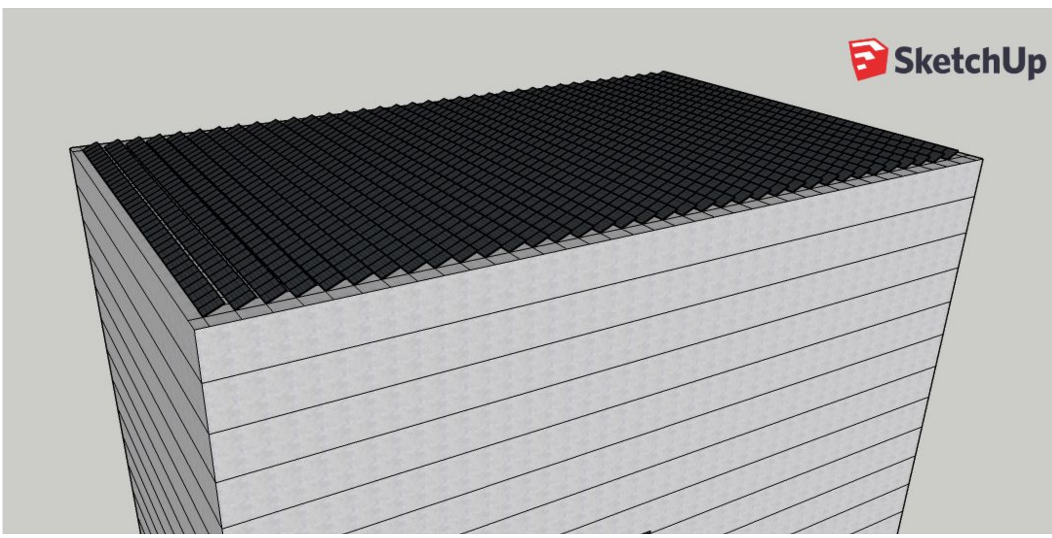


Figure 5: The image above demonstrates where the solar panels will be installed.

Triple Pendulum Isolators

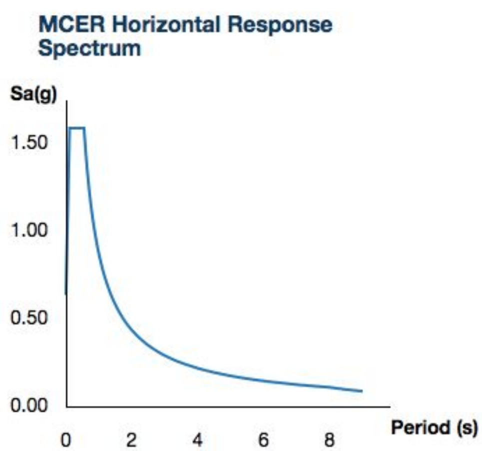
Keeping in mind that Starberry Farm falls under Risk Category III due to enormous height, seismic hazard analysis was calculated according to reference document ASCE7-10 and stiff soil site class. The following parameters and horizontal response spectrums calculated.

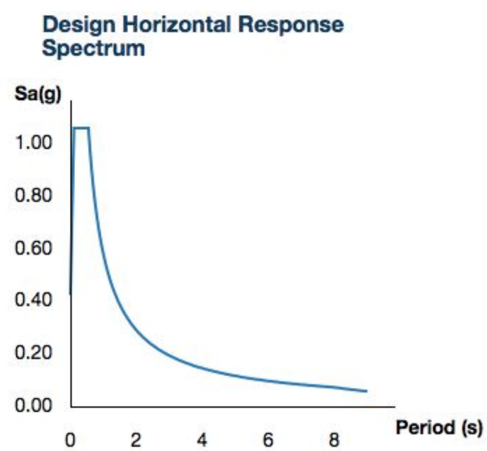
Basic Parameters

Name	Value
S_S	1.585
S_1	0.579
S_{MS}	1.585
S_{M1}	0.868
S_{DS}	1.057
S_{D1}	0.579

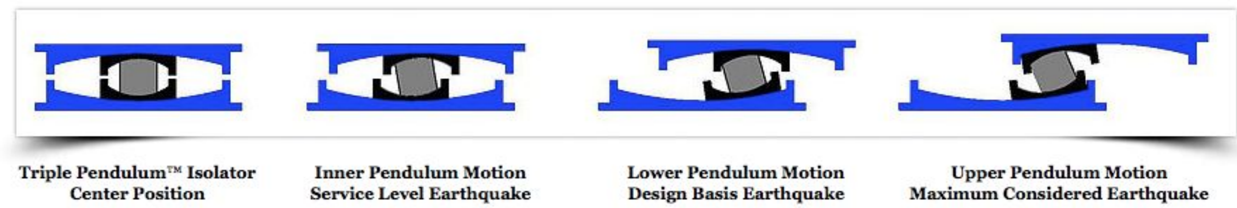
Name	Value
SDC	D
F_a	1
F_v	1.5
CR_S	0.951
CR_1	0.99
PGA	0.622
F_{PGA}	1

PGA_M	0.622
T_L	8
SsRT	1.585
SsUH	1.666
SsD	3.393
S1RT	0.579
S1UH	0.585
S1D	1.212
PGAd	1.272





Our solution to this seismic risk is to install triple pendulum base isolators. These apparatus have three pendulum mechanisms nested on top of one another. When our building is struck by seismic activity, the isolators shift along the same direction. The isolators take the brunt of the motion and relieve lateral load on the farm, significantly strengthening the structural integrity of the building's vertical structures.



(Source: Earthquake Protection Systems 2019)

Bill of Materials

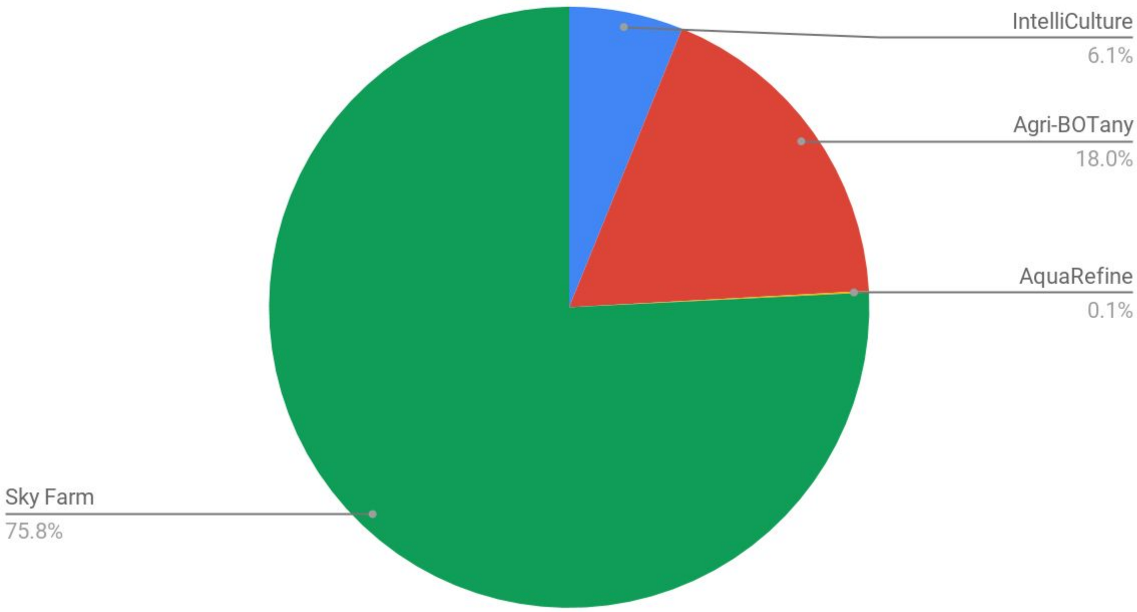
Part	Price	Quantity	Total	URL	Comment	
80 inch 416 Stainless Steel Round Bar 3/4"	$ 36.07	1	$ 36.1	Link		
115 inch 416 Stainless Steel Round Bar 3/4"	$ 49.54	2	$ 99.1	Link		
Mounted Linear Ball Bearing 3/4"	$ 66.60	7	$ 466.2	Link		
1" X 1" T-Slotted Extrusion 115"	$ 30.00	4	$ 120.0	Link		
1" X 1" T-Slotted Extrusion 80"	$ 20.70	8	$ 165.6	Link		
Inline gearbox GBPH-060x-CS	$ 217.00	3	$ 651.0	Link		
Stepper Motor 23MDSI006S-00-00	$ 152.00	3	$ 456.0	Link		
Aluminum Sheets	$ 170.73	30	$ 5,121.9	Link		
Conveyor Belt	$ 1,995.00	270	$ 538,650.0	Link		
				Total Price/Unit		$ 7,116
				Units/floor=		$ 100
				Total Price -	All Units (15 floors)	$ 11,212,425

Aqua pulse 5200 GPH	$ 170.00	2	$ 340.0	Link		
Large Flow Rate Multigrade Sand Filter For River Water Treatment	$ 3,500.00	1	$ 3,500.0	Link		
Aqua pulse 2000 GPH	$ 125.00	1	$ 125.0	Link		
Stainless Steel Stirred Tank Reactor 3000L with CE certificate	$ 8,000.00	3	$ 24,000.0	Link		
Water Tank	$ 4,510.00	2	$ 9,020.0	Link		
Ozone Gas	$ 50.00	10	$ 500.0	Link		
Fish Emulsion	$ 28.50	312	$ 8,892.0	Link		
Potassium Chloride	$ 98.95	1	$ 99.0	Link		
Fine Pore Diffusers	$ 64.36	6	$ 64.4	Link		

10000L Tank	$ 5,439.95	2	$ 10,880.0	Link		
				Total Price/Unit		$ 38
				Unit/floor=		$ 100
				Total Price -	All Units (15 floors)	$ 57,420
Bluino: Atmega328	$24.90	15	$375	Link		
Pika NIR-640	$2,500	1500	$3,750,000	Link		
RHT03	$9.95	50	$500	Link		
PS-3204	$65.00	400	$26,000	Link		
VH400	$45.95	400	$18,380	Link		
THERM200	$41	400	$16,380	Link		
PowerEdgeT30Tower Server	$399	1	$400	Link		
LED Light Source	$23.99	675	$16,193.25	Link		

				Total Price/Unit		
				Unit/floor=		$ 100
				Total Price	- All Units (15 floors)	$ 3,828,228
Solar Panel (w)	$ 4.25	1296	$ 1,790,100.0			
Steel (per lb.)	$ 22.26	96	$ 10,764,288.0			
Recycled geopolymer concrete	$ 38.50	901080	$ 34,691,580.0			
				Total -	$ 47,245,968.0	
				Grand Total -	$ 62,344,041	

Grand Total: $62,344,041



Conclusion

The problem proposed is to develop an autonomous system capable of creating 1,500 tons of food annually. The final design created is an autonomous system that can produce 1,800 tons of food annually if the food is harvested every 6 weeks as planned. The design offers an alternative to current forms of farming using fields by using advanced farming techniques, technologies, and automation to create the most sophisticated design.

Compare to others possible ways of automating farming, the created design offers a feasible way of achieving the task. While working through the design, the main priority was feasibility. In automating processes, the design is made in the most simplistic manner to support reliability and repeatability in the real world. Compare to most modern solutions to farming, the proposed design is capable of achieving a much greater level of accuracy and repeatability than most.

It is the team's hope that in the future, engineers will look towards the proposed solution when tackling the problem that is feeding the people.

Citations

“2018 New Low Prices Automatic 1000l Reaction Kettle Continuous Stirred Tank Chemical Reactor - Buy Coating Machinery,Agitated Tank Reactor,Reactor Kettle Product on Alibaba.com.” *Www.alibaba.com*, www.alibaba.com/product-detail/2018-New-low-prices-automatic-1000L_60773464966.html?spm=a2700.7724857.normalList.54.566e3b54zaynsF.

Kerslake, J. E. “Iron Salts as Coagulants.” *The Mutual Dependency of Force and Law in American Foreign Policy on JSTOR*, 1 Oct. 1946, www.jstor.org/stable/23349081?seq=1#page_scan_tab_contents.

Purplewave.com. “Used Construction, Agricultural Equip., Trucks, Trailers & More.” *Purple Wave*, www.purplewave.com/auction/120508/item/B6544.

“Determining Amount of Ozone Required for Ozone Water Treatment.” *Ozone Color Removal Textile Wastewater*, www.spartanwatertreatment.com/how-much-ozone-do-i-need-to-treat-water.html.

"McMaster-Carr." McMaster-Carr. 18 Feb. 2019 <https://www.mcmaster.com/>.

"Strawberries Harvester." Agrobot. 18 Feb. 2019 <http://www.agrobot.com/>.

Strawberry, Brandie, Laura, Diane, Mary Belle, Jake, Alex, Kirsty, Jeff, and Katey. "How Tall Do Strawberry Plants Grow? – Strawberry Plants . org." Strawberry Plants . org. 21 Jan. 2019. 18 Feb. 2019 <https://strawberryplants.org/how-tall-do-strawberry-plants-grow/>.

"The largest online community of professional designers, engineers, manufacturers, and students." GrabCAD: Design Community, CAD Library, 3D Printing Software. 2019. 18 Feb. 2019 <https://grabcad.com/>.

Staff, Stouch Lighting. "Lighting Comparison: LED vs Fluorescent and CFL." LED Lighting Distributor and Consulting Company. 18 Feb. 2019 <https://www.stouchlighting.com/blog/fluorescent-vs-led-vs-cfl>.

“Smartshift Automated Tool Changer” <https://www.universal-robots.com/plus/accessories/smartshift-automated-tool-changer/>

“What Is a SN-Curve?” Siemens PLM Community, 2 Dec. 2018.” <https://community.plm.automation.siemens.com/t5/Testing-Knowledge-Base/What-is-a-SN-Cur ve/ta-p/355935>.

Dominguez, Anthony., et. al. “Effects of solar photovoltaic panels on roof heat transfer.” *Solar Energy, Vol 85.* September, 2011. https://www.sciencedirect.com/science/article/pii/S0038092X11002131

Guo, Yi., Ma, Jiwu. “Design of a Sprout Ultrasonic Aeroponic Cultivation Device.” *Advances in Engineering Research, Vol 123*, May 13, 2017. https://www.atlantis-press.com/proceedings/msmee-17/25877939

"Installing a Solar Panel System in Irvine, CA Is Smart!" *Solar Nation*, www.solar-nation.org/irvine-ca-solar-panel-installation.

McLellen, Benjamin C., et al. "Costs and Carbon Emissions for Geopolymer Pastes in Comparison to Ordinary Portland Cement." *NeuroImage*, Academic Press, 22 Feb. 2011, www.sciencedirect.com/science/article/pii/S0959652611000680.

"How Many Solar Panels Do I Need?" *LG Solar Panels | 320 Watt Black Solar Panel | Buy 320W LG Mono NeoN Solar Panels*, https://www.gogreensolar.com/pages/how-many-solar-panels-do-i-need

Sanders, Andrew. "Breaking down Commercial Solar Panel Costs." *Top 7 Types of Renewable Energy to Meet Commercial Sustainability Goals*, 15 Sept. 2018, http://businessfeed.sunpower.com/articles/written-blog-breaking-down-commercial-solar-panel-costs

Sata, Vanchai, et al. "Properties of Pervious Geopolymer Concrete Using Recycled Aggregates."

NeuroImage, Academic Press, 9 Feb. 2013, www.sciencedirect.com/science/article/abs/pii/S0950061812010033.

"Types of Loads on Structures - Buildings and Other Structures." *The Constructor*.https://theconstructor.org/structural-engg/types-of-loads-on-structure/1698/

Wang, Wenjin., et al. "Mix design for aggregate thermal insulation concrete with mineral admixtures". *Magazine of Concrete Research*, *Vol 65.* May 2014.https://www.icevirtuallibrary.com/doi/abs/10.1680/macr.13.00335

Schmidhuber, Jürgen. "Recurrent Neural Networks." KONRAD ZUSE - Inventor of the First Working Computer, 2017, people.idsia.ch/~juergen/rnn.html.

"NoSQL." Wikipedia, Wikimedia Foundation, 14 Feb. 2019, en.wikipedia.org/wiki/NoSQL.

"NoSQL Databases Explained." MongoDB, www.mongodb.com/nosql-explained.

"What Is NoSQL (Not Only SQL Database)? - Definition from WhatIs.com." SearchDataManagement, searchdatamanagement.techtarget.com/definition/NoSQL-Not-Only-SQL.

Castrounis, Alex. "How to Choose the Right Database System: RDBMS vs. NoSql vs. NewSQL." InnoArchiTech Provides Education, Writing, and Speaking Services Focused on Leveraging State of the Art Advanced Analytics to Transform Data into Value| Founded by Alex Castrounis, InnoArchiTech, www.innoarchitech.com/how-choose-right-database-system-relational-rdbms-vs-nosql-vs-newsql/.

An Introduction to Biometric Recognition - IEEE Journals & Magazine, Wiley-IEEE Press, ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6552450.

"Explore Scientific, Technical, and Medical Research on ScienceDirect." NeuroImage, Academic Press, www.sciencedirect.com/.

"Hyperspectral Imaging Analysis for Ripeness Evaluation of Strawberry with Support Vector Machine." NeuroImage, Academic Press, 22 Jan. 2016, www.sciencedirect.com/science/article/pii/S0260877416300024.

"Potential of NIR Spectroscopy for Predicting Internal Quality and Discriminating among Strawberry Fruits from Different Production Systems." NeuroImage, Academic Press, 22 Nov. 2016, www.sciencedirect.com/science/article/pii/S0925521416305920.

"Spectrophotometers." NeuroImage, Academic Press, www.sciencedirect.com/topics/agricultural-and-biological-sciences/spectrophotometers.

"Wireless Sensor Networks for Agriculture: The State-of-the-Art in Practice and Future Challenges." NeuroImage, Academic Press, 5 Sept. 2015, www.sciencedirect.com/science/article/pii/S0168169915002379.

“Isolation(Database Systems”
https://en.wikipedia.org/wiki/Isolation_%28database_systems%29
“CAP Theorem”
https://en.wikipedia.org/wiki/CAP_theorem
“Osunby LED Grow Light 45W UV IR Growing Lamp for Indoor Plants Hydroponic Plant Grow Light." Amazon. Amazon. 19 Feb. 2019 <https://www.amazon.com/dp/B075JFPLY1/ref=sxbs_sxwds-stvp_3?pf_rd_p=03dd84f0-0dd9-4d32-b6cb-02a32e0ba336&pd_rd_wg=bheoV&pf_rd_r=N92Q20NV6VM1Q2773EKK&pd_rd_i=B075JFPLY1&pd_rd_w=w5OUH&pd_rd_r=7c393220-f841-4904-b1c2-b3150c3408e1&ie=UTF8&qid=1550536167&sr=3>.