NORTHERN ARIZONA UNIVERSITY

To: Wilbert Odem, Ph.D., P.E., Client & Professor

CC: Bridget Bero, Ph.D., P.E.; Mark Lamer, MEng, P.E.; Alarick Reiboldt, MEng, E.I.T.; Dianne McDonnell, Ph.D., P.E.;

From: Vertical Farmers: Matthew Schraan, Samuel Just, Zebulon Davis, Chalmer Bitsoi

Date: 5/4/2017

Subject: Vertical Agricultural Design Proposal

Attached is our Proposal for an indoor vertical agriculture system in Northern Arizona.

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1.0 Introduction

This document discusses the scope and potential schedule of the vertical agriculture project. The purpose of this project is to develop a design for a vertical agriculture prototype that can be patented and available for public use. Many tasks must be completed in order to design and build the vertical agriculture product. These tasks can be split into the selection of components, design, building, and testing of the product. Each of these major tasks can be broken down into sub-tasks that will be discussed in the following sections.

2.0 Project Understanding

This proposal is prepared and presented by a team of qualified engineers to license and patent an indoor structure for the purpose of growing vegetable green. The design must be suitable for the Northern Arizona climate and must either be suitable in size for a neighborhood or a family. The team will build a prototype and incorporate materials and equipment from past capstone projects. The team anticipated building and maintaining the project in the environmental lab for its ease of access, ability to grow plants, and storage.

2.1 Exclusions

In order to complete the vertical agriculture project, our group will not carry out some tasks. Due to limitations on time and expense, our design team will only be able to design and construct one prototype; therefore, the effectiveness of alternatives cannot be assessed through trial and error. These limitations will also not allow our team to extensively evaluate how well our design can grow more than the plants that we are able to test with one trial.

2.2 Technical Considerations

In order to successfully design an effective indoor vertical agricultural system, extensive research by the team is required. Research for functionality of viable components includes lighting, watering, and the structure of the system. The technical considerations for the lighting and watering component depend on the source while ensuring it maintains minimal power consumption, operating cost, and performs at optimum capacity for crop yield. Crop yield ensures sustainability therefore proper nutrient solution and the amount of water circulated in a hydraulic system involves technical work [1]. It is important that the crop, light and water loads are properly supported for safety and reliability to the stakeholder.

2.3 Stakeholders

The project stakeholders include the customer, client, grocery stores, large agriculture companies, farmers, and the environment. The final design is geared towards a customer that wishes to reduce their carbon footprint in the Northern Arizona climate, is concerned about where their food comes from, and concerned about minimizing the health risk from store bought food. It is required that the customer has suitable living arrangements and is capable of growing gardens in a compact environment. Such people will enjoy the fresh greens to their dinner table by eliminating waste and improving their environment.

The client is the main reason for this project and identified the main ideas for the outcome. The vertical agriculture design entails specifications set by the client. The client will be the initial recipient of the design and possible prototype.

Grocery stores will be affected by this project because the vertical agriculture product will possibly take customers away from the stores. The owners of the vertical agriculture product will be able to grow their own vegetables and will not need to go to the store to purchase vegetables. This will then affect the large agriculture companies and the farmers that grow the vegetables for the grocery stores or to be sold elsewhere. With less demand for store bought vegetables, the prices will go down and some formers or companies may not be able to keep a steady income [2].

The vertical agriculture product will affect the environment in a positive way. Large agricultural operations require a lot of water, ruin natural arable land, and have been shown to be big producers of pollution [3]. The pesticides and fertilizers they use get into natural water systems and affect the ecosystems within. With less large agricultural operations, there will be less pollution, water use, and arable land destruction.

2.4 Potential Challenges

Potential challenges and constraints always arise during the implementation of projects and must be integrated into the project design. The design of the vertical agriculture prototype will consist of many components and each component will provide possible challenges. These challenges and constraints include parts failing, power supply, water supply, and cost.

The design may need to incorporate the technology around lights and choices need to be made of how much is adequate. The amount of light in light-emitting diode (LED) needs to be carefully considered, as the cost needs to be relatively low for the Do-it-yourselfer. At the same time, the power demand needs to be kept to a 110-volt supply [4]. These criteria need to be sufficient for the growth of the plants in order to maintain survival.

Another important constraint arises from the watering component of the structure. Misting or cycling water through the plants with the aid of carefully chosen pumps would assure that adequate balance of oxygen assures plant growth [5]. The amount of water with supplemental nutrients assures the healthy growth of plants. Of course these water components need to be maintained for the Do-It-yourselfer.

These challenges will be addressed throughout the design process and overcome through research and possible testing.

3.0 Project Tasks

3.1 Task 1: Research and Selection

All vertical agricultural systems, large-scale and small-scale, utilize three main components to operate successfully. These three main components are watering, lighting, and structural [6]. These components must be carefully selected in order for the vertical agriculture product to operate successfully.

Vertical Farmers (VF) will perform a selection process in deciding each component for the prototype by conducting research on current operating vertical agriculture systems. The research will evaluate and compare components of existing systems in order to select the optimum lighting type, watering type, and structure for the prototype. Based on the results of the analysis and upon selection of the components for the preferred prototype structure, VF will prepare 30% design plans that specify structure type, watering type, and lighting type.

Deliverable Selection Report September 14, 2017

3.1.1 Research

To begin the process of component selection, VF will begin by conducting background research on existing methods of indoor/vertical farming. Through understanding existing technologies, VF may then identify potential components that could be used for each aspect of the design. It is important that research is the first task in the selection process; however, research will continue to take place throughout the entire project's timeline.

3.1.2 Product Scale

The types of components selected by VF will depend largely on the scale and space that the design will occupy. During this process, the design team will identify and narrow down specific objectives of the prototype. This will include the affordability and applicability of the product. There are great differences between independent vertical farming practices and large-scale commercial practices [7]. The design team will continue to narrow down the target market as part of the component selection process.

Based on the determinations for the scale of the product, VF will then determine a building site for the prototype. The scale of the prototype will also be constrained by access to building space and materials.

3.1.3 Structural Component Selection

VF will determine the appropriate structure type to support racks of multiple levels for growing nutrient rich vegetables. In addition to supporting the vegetables, it needs to support the required artificial lighting and watering system. The structure dimensions will be minimal for the medium size family while achieving the ultimate yield per square foot.

This part of the process will also include selection of materials for the construction of the base structure of the prototype. The selection of materials will be important, as they will influence the price and ease of assembly of the product.

3.1.4 Lighting Component Selection

VF will determine the appropriate lighting as this technology is driving down cost and discovery of a mixed lighting optimizes photosynthesis. Photosynthesis is key to a healthy growing environment and ensuring that each plant received an equal amount of light per day [8]. VF will determine adequate lighting from LED technology and whether LED should be supplemented with natural light. The selection of lighting will be determined through research on the effectiveness of potential light sources. The availability of natural light may also be constrained by the site of construction.

3.1.5 Watering Component Selection

VF will determine the appropriate watering system in order to successfully provide enough water and nutrient solution to the plants. This may include analysis of water demand, weight of water created on structure, and power needed by a pump to operate the watering system [9].

3.2 Task 2: Design

Once each component is selected, they need to be put together in an optimum design to create a successful system. VF will design a prototype consisting of the chosen components from each selection process. In designing how each component will fit together, research will be conducted on current operating vertical agriculture systems. The research will evaluate and compare designs of existing systems in order to design a successful system for the client. Based on the results of the analysis and upon completion of the design of the prototype, VF will prepare 100% design plans that specify structure dimensions, watering demand, and lighting demand.

Deliverable Design Memo October 13, 2017

3.2.1 Structural Component Design

VF will determine the appropriate structure material and size to support racks of multiple levels for growing nutrient rich vegetables. This component design process will consist of analyzing loading on the structure and determining a design that will successfully support the loading created by the plants, artificial lighting, and watering system. The structure dimensions will be minimal for the medium size family while achieving the ultimate yield per square foot.

3.2.2 Lighting Component Design

VF will determine the optimal lighting design for the prototype in order to drive down cost and optimize growth of the plants. The lighting design will ensure that each plant receives an equal amount of light per day while using the smallest amount of energy required doing so. This component design process will consist of analyzing the lighting amount needed to optimize growth and the power required by the lighting.

3.2.3 Watering Component Design

VF will determine the optimal watering system design for the prototype in order to successfully provide enough water and nutrient solution to the plants while minimizing the water demand and power needed by the pump. This component design process will consist of analyzing the water demand of the designed system and the power needed by a pump to operate the watering system.

3.3 Task 3: Construction

After the design process is completed, the vertical agriculture prototype will be built. Building will take place only after the design components have been decided. Construction of the prototype will begin by collecting required materials. It will then occur in three phases starting with construction of the structural component, followed by the lighting and watering components. After the prototype is completely built, the final stage will be testing the product by using it to grow produce. This task will culminate with a Construction Memo summarizing the construction process that took place.

Deliverable Construction Memo October 25, 2017

3.4 Task 4: Testing

VF will perform an assessment of the prototype and evaluate its functionality for public use. The study will evaluate the time to construct the prototype and its performance to sustain a medium size family. The evaluation will take into consideration [10]:

- Daily Food Intake
- Water
- Environmental impacts

Based on the results of the analysis, VF will compose a report summarizing the findings of the assessment of the prototype. The report will also discuss the feasibility and marketability of the prototype for use by a medium size family.

Deliverable Testing Memo November 1, 2017

3.5 Task 5: Final Presentation

VF will update the 30% and 60% project report and update the cost estimate for a 90% project deliverable. Immediately upon review all comments will be incorporated and 100% submittal will be prepared. The final presentation will be presented to the client.

Deliverable 90% Project Report November 21, 2017

Deliverable Final Presentation December 7, 2017

Deliverable Construction Memo December 14, 2017

4.0 Project Schedule

Throughout the course of this project, the PM spends time every Monday reviewing and summarizing the tasks completed in the previous week, outlining the task planned for the current week and reviewing the project schedule. This practice helps the PM to track and monitor scope activities, document when tasks were completed, allows for the preparation of detailed progress reports to the Client and identifies any needed adjustments to resource allocations. In addition, the PM obtains weekly hours reports from staff and tracks hours spent on the project. This attention to detail helps ensure that scope items are fulfilled and the budget stays on track.

4.1 Project Meetings

The PM coordinates meetings with staff every Monday reviewing and summarizing the tasks completed in the previous week through an agenda. Throughout the 15 week project, VF will provide meeting notices, prepare meeting minutes, provide meeting materials and facilitate weekly meetings. VF will consult with the Client to get input regarding the agenda.

4.2 Project Reports

Vertical Farmers will prepare and provide technical resources necessary to ensure that the deliverables meet the requirements of the Client. Independent reviews will be conducted by staff involved with the design or preparation of the deliverables. The deliverables are discussed in the tasks above in the tasks.

4.3 Project Schedule

Figure 1 shows a detailed project schedule with critical path tasks and duration:

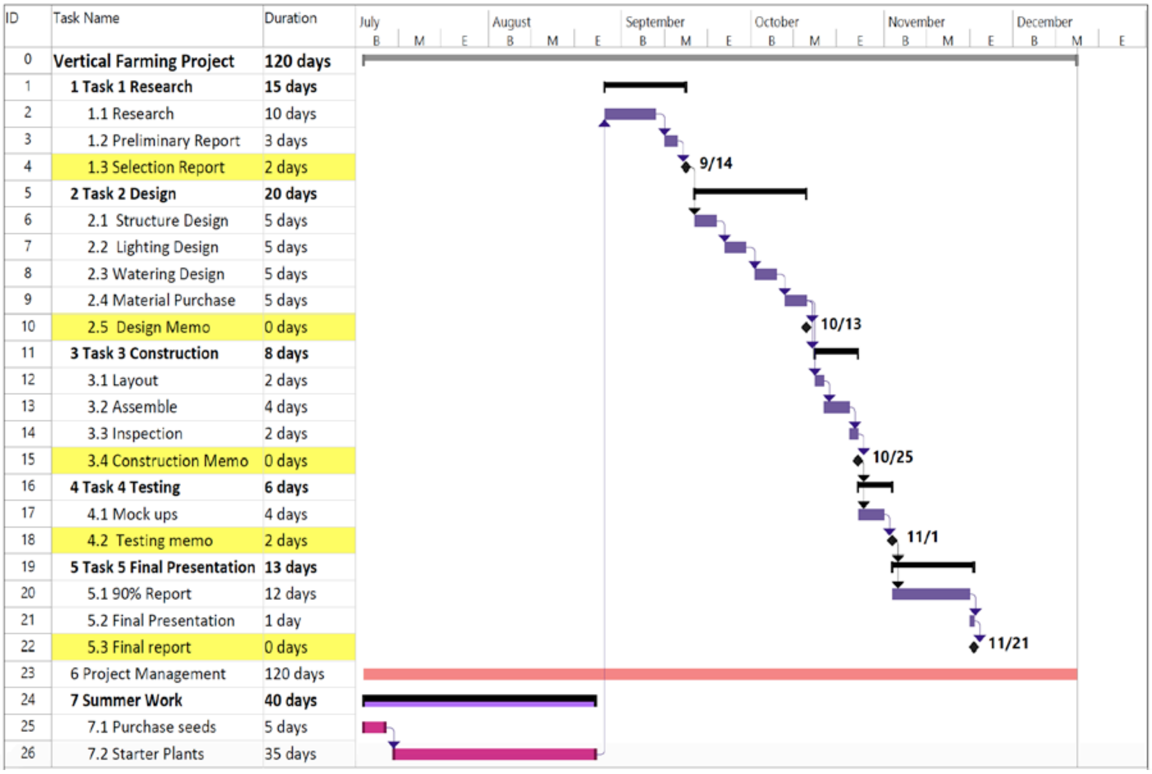

Figure 1: Project Gant Chart

5.0 Staffing and Cost of Engineering Services

Vertical farmers will be comprised of a small team of engineers working to design and construct our product. The tasks required to complete the project will be divided between four separate positions.

5.1 Staff and Qualifications

Table 1: Positions and Qualifications

<table>
<tr><td colspan="2">Matthew Schraan – Principal in Charge</td></tr>
<tr><td>Civil Engineering Major, Northern Arizona University

Over three years of experience as an intern for civil engineering consulting firms. Gaining valuable time management, document preparation, and team leadership skills.</td><td>Three years of experience leading to the knowledge of and experience with:
● Drafting software including AutoCAD, Civil 3D, Revit, and Terramodel
● Design software including WaterGems, FlowMaster, CulvertMaster, HEC-RAS, and HEC-HMS
● Surveying practices, such as topographic and as-built surveys, and construction staking</td></tr>
<tr><td colspan="2">Samuel Just – Project Manager</td></tr>
<tr><td>Environmental Engineering Major, Northern Arizona University

Two years experience with AutoCAD and Civil3D. 3 years management experience. Has some horticultural background.</td><td>● Has some background as a TA in AutoCAD, Revit, Civil 3D as well as some geotechnical engineering.
● Has management experience outside of the field of engineering that has helped developed organization and communication skills.
● Has some experience working on ecological restoration projects.</td></tr>
<tr><td colspan="2">Zebulon Davis – Project Engineer</td></tr>
<tr><td>Environmental Engineering Major, Northern Arizona University

Three years of engineering at NAU. Management experience in several fields.</td><td>● AutoCAD, Civil3D, Culvert Master, and HEC-RES modeling software
● Survey training and practice including using a total station
● Previous participation on environmental engineering design projects
● Some horticultural experience</td></tr>
<tr><td colspan="2">Chalmer Bitsoi – Engineering Tech</td></tr>
<tr><td>Civil Engineering Major, Northern Arizona University

Over 15 years of experience in Oil and Gas exploration, production and transportation.</td><td>● Served as a project engineer on hazardous liquid transportation projects from feasibility studies and environmental documentation to preliminary and final design
● Organization, communication, and detailed-oriented skills that help successfully deliver numerous multi-discipline projects on schedule and within budget.
● Served as project manager, assistant project manager and/or lead engineer on the following relevant projects:
o Chaco Trucking Service, Farmington, NM
o AST remediation, Montezuma Creek UT
o HDD for 1000 feet of pipe reroute.
o Facility electrical upgrade with MCC</td></tr>
</table>

5.2 Breakdown of Tasks and Subtasks

Each task and sub-task needed to complete the project will require work from each staff position through the course of the project. The following table shows how these tasks will be distributed among the team and provides the expected hours required for completion.

Table 2: Breakdown of Tasks

Task\Position	Project Mgr	Sr Engr	Engr Tech	Engr Tech
Summer Work	2	2	140	140
Sub-Task 0.1: Purchase Seeds	1	1	1	1
Sub-Task 0.2: Starter Plants	1	1	139	139
Task 1: Component Selection	9	19	46	46
Sub-Task 1.1: Research	3	7	16	16
Sub-Task 1.2: Selection Meeting	3	3	3	3
Sub-Task 1.3: Selection Report	3	9	27	27
Task 2: Design	10	19	65	65
Sub-Task 2.1: Structure Design	3	6	21	21
Sub-Task 2.2: Lighting Design	3	6	21	21
Sub-Task 2.3: Watering Design	3	6	21	21
Sub-Task 2.4: Material Purchase	1	1	2	2
Task 3: Construction	2	4	29	29
Sub-Task 3.1: Layout	0	1	7	7
Sub-Task 3.2: Assembly	0	1	7	7
Sub-Task 3.3: Inspection	1	1	7	7
Sub-Task 3.4: Instruction Report	1	1	8	8
Task 4: Testing	3	3	21	21
Sub-Task 4.1: Mock Ups	1	1	11	11
Sub-Task 4.2: Testing Memo	2	2	10	10

Task 5: Final Presentation	5	10	24	24
Sub-Task 5.1: 90% Report	2	7	11	11
Sub-Task 5.2: Final Presentation	1	1	1	1
Sub-Task 5.3: Final Report	2	2	12	12
Total	31	57	325	325

5.3 Cost of Services

The total cost of the engineering services provided by our staff may be broken down in Table 2. As may be seen, these costs are divided between the pay-rate of each staff member. The high pay rate and total cost of each staff member is due to overhead costs included in the personnel costs. The overhead costs take care of travel, prototype materials, and testing materials.

Table 3: Cost of Engineering Services

Category	Total Hours	Rate of Pay [11]	Total
Project Manager	31	$140/hr	$4,340
Senior Engineer	57	$130/hr	$7,410
Engineering Technician #1	325	$75/hr	$24,375
Engineering Technician #2	325	$75/hr	$24,375
Total	**738**		**$60,500**

6.0 References:

[1] J. Quinlan, "Why Do Plants Need Water?", GrowingAnything.com, 2010. [Online]. Available: http://www.growinganything.com/why-do-plants-need-water.html. [Accessed: 31- Jan- 2017].

[2] D. Despommier, The vertical farm, 1st ed. New York: Thomas Dunne Books/St. Martin's Press, 2010.

[3] Garfield, Leanna. "The World's Largest Vertical Farm Will Produce 2 Million Pounds Of Lettuce Every Year". Business Insider. N.p., 2017. Web. 1 Feb. 2017.

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[7] "Hydroponic Tower Production - ZipGrow FAQ", Bright Agrotech, 2017. [Online]. Available: https://brightagrotech.com/hydroponic-farming/zipgrow-tower/. [Accessed: 02- Feb- 2017].

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[10] "Leafy Green Machine™". Freight Farms. N.p., 2017. Web. 1 Feb. 2017.

[11] Salary.com, Site. "Average Engineering Job Salary Range. Engineering Pay Scale. Unemployment, Benefits, And Career Chan". *Swz.salary.com*. N.p., 2017. Web. 7 May 2017.

7.0 Appendix

7.1 Types of Vertical Agriculture

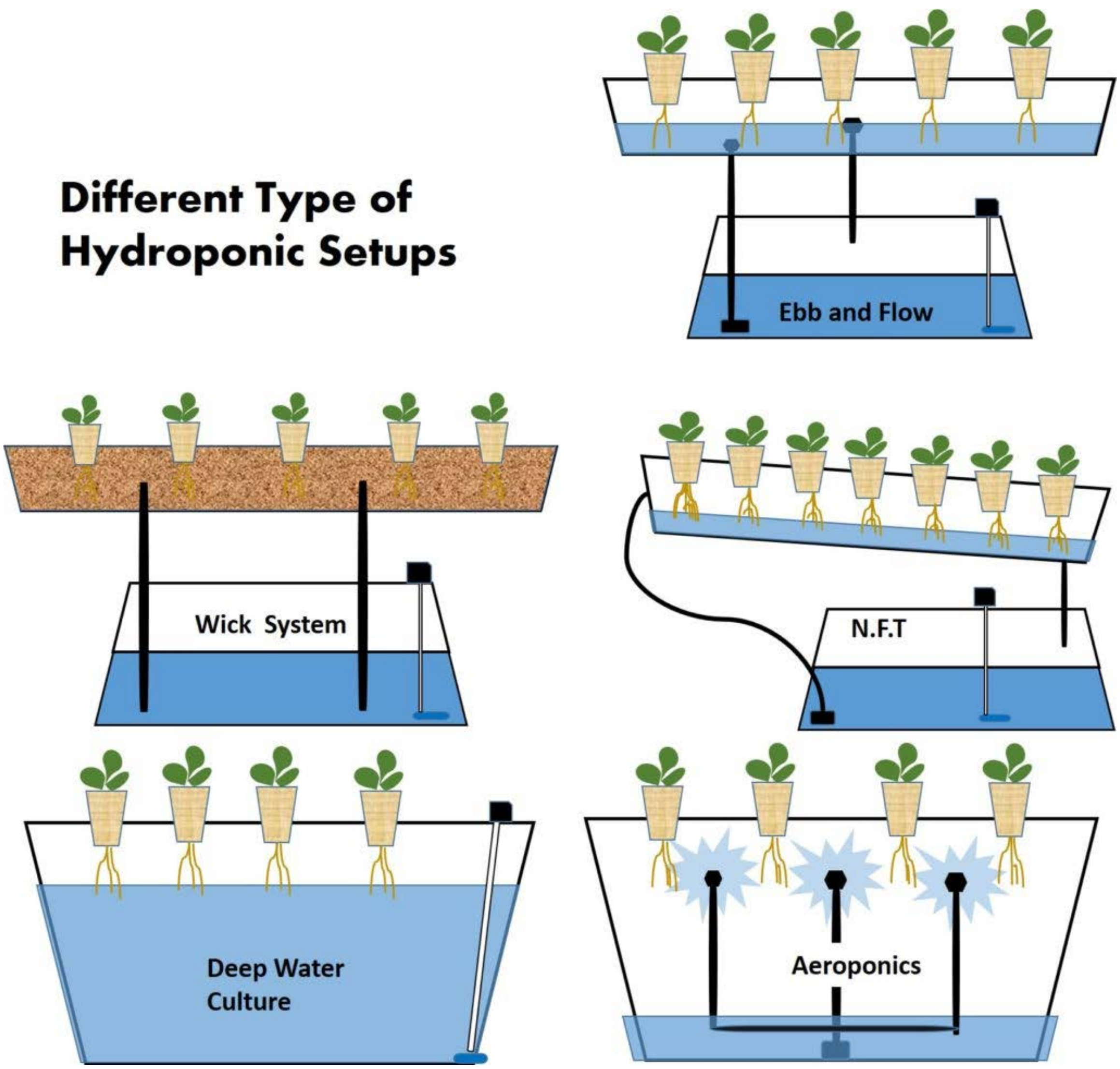

Figure 2: Types of Hydroponic Setups [4]


Figure 3: Deep Water Culture [6]


Figure 4: Hanging Columns [7]


Figure 5: AeroFarm Vertical Farming System [3]


Figure 6: Freight Farm Vertical Farming System [10]

Figure 7: DIY Wall Hanging Vertical Farming System [9]