Plantmosphere Technologies

September 22, 2014

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 305W/440W Project Proposal for an Automated Greenhouse System

Dear Dr. Rawicz,

The following proposal document outlines the Plantmosphere automated greenhouse system for ENSC 305W/440W. Our project is to design a gardening solution that requires no prior knowledge or technical experience to operate.

The proposal will outline the purpose of our product, as well as the system design and functionality. Additionally, our sources of funding, worst-case budget, company information, scheduling, and team organization are included.

Plantmosphere Technologies is a team of six diverse and highly qualified engineers: Faisal Emami, Terry Hannon, Jane Horton, Alex Naylor, Jeffrey Shum, and Mike Thiem. For additional information about our product, please contact me via email at jhorton@sfu.ca

Sincerely,

Jane Ashley Horton
Design Engineer
Plantmosphere Technologies

Plantmosphere

Project Proposal

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Executive Summary

Imagine a world where your survival depended on the food you grew in your backyard.

In comparison to other third world regions, Sub-Saharan Africa in particular battles an ongoing hunger crisis due to its unpredictable climate. Food supplies are consistently struggling against an increasing population. These conditions, coupled with infertile land and poor agricultural practises, are resulting in widespread malnutrition and death. Instead of exporting food to these struggling regions, Plantmosphere Technologies aims to provide a sustainable solution.

With our solution, residents of impoverished areas can grow food locally, generate sources of nourishment and actively reduce malnutrition and hunger. Subsequently, inflated prices due to imported food items will decrease.

The Plantmosphere is an easy to use automated greenhouse system that controls the physical environment surrounding a plant's growth cycle. Our product combats the harsh sub-Saharan climate by removing it from the equation entirely. With a water capturing and comprehensive control system, crops within the Plantmosphere can flourish anywhere.

Plantmosphere Technologies is a team of six intelligent and capable engineering students, devoted to the betterment of human life. Our diverse skill sets and collective experience combined with our enthusiasm and ingenuity increases the likelihood that the Plantmosphere will triumph over world hunger.

Introduction

In sub-Saharan Africa 38% of children below five years of age suffer from chronic malnutrition [1]. In some of these countries, more than 90% of the population, predicted to grow from 925 million to 2 billion people by 2050, depends on small-scale farming for survival [2]. However, if Africa's current agro-ecological conditions persist, there will only be enough food for 13% of this population [3].

The lack of investment in the agricultural sector contributes to hunger and food insecurity in sub-Saharan Africa [1]. Despite popular belief, abundant natural water supplies suitable for crops do exist, but are not properly utilized or distributed [1]. Due to unsteady climate conditions, most farms are either under or over-irrigated. Less than a quarter of soil suitable for rain-fed crop production is even used. Solutions for Africa's hunger crisis involve the implementation of sustainable land management and reliable water control systems, and improving agriculture technology dissemination and adoption. These solutions align with Plantmosphere Technologies' initiatives. Our goal is to develop a sustainable agricultural solution for use in sub-Saharan Africa.

The design solution we propose will make gardening more accessible to users without previous training by automating the most tedious, difficult, and critical tasks. Plantmosphere Technologies proposes an affordable, microcontroller-based automation system that will optimize the environment within an enclosure for plant growth and nourishment. The system utilizes sensors to continuously monitor a controlled environment. A rainwater harvesting, storage, and distribution system will provide an efficient and sustainable means to irrigate the enclosed plant life. The user interface will be simple enough that even those unfamiliar with gardening will be able to effectively utilize the system.

Project Overview

Our proposed solution has the potential to provide food to residents of developing countries, specifically sub-Saharan Africa. Charities and Non-governmental organizations (NGO) can support the development of an automated greenhouse system in order to further their vision of eradicating world hunger. Similar to sponsoring third world children, volunteers can decide to sponsor the building and maintenance of the Plantmosphere for communities in need of agricultural support.

Additionally, the Plantmosphere will benefit anyone who wants to grow plants without the added time commitment required for traditional gardening. Once installed, the system will allow users to select the plant they wish to grow. Based on the optimal environmental parameters for the specifiedplant, the system will perfect the climate within the enclosure. Gardeners of all skill levels will be able to grow unfamiliar or exotic plants with ease.

Risks associated with developing the automated greenhouse involve time constraints, cost, and potential part failure. Building a fully automated greenhouse system requires purchasing the expensive greenhouse structure, as well as sensors, pumps, plant troughs, heating cables, and gutters. The design includes many closed-loop control systems with interdependencies which may necessitate redundancy in order to mitigate component failure. For example, the irrigation system depends on the output of the soil saturation level sensor.

Another potential risk for the project is climate. Although we are designing the greenhouse system for the warm climate of sub-Saharan Africa, we will be demonstrating the product in a cold, winter climate. In order for the plants to survive cold weather, we will be forced to include soil heating and the enclosure must be thermally insulated. These features will make the product more marketable to clients who live in colder climates. However, adding components increases cost and the risk for system failure.

Our goal in this project phase is to simplify the proof-of-concept design as much as possible. Therefore, the Plantmosphere will initially be designed to sustain one type of plant. Also, we will utilize the minimum number of components to ensure that the selected plant flourishes. We will aim to select non-proprietary, easily accessible parts. Further additions to the system will only be included if time permits. These design simplifications will allow Plantmosphere Technologies to generate a functional, yet manageable prototype.

Possible Design Solutions

Famine and severe climate conditions plague the third world. In an ideal scenario, food would be grown locally. But food and water distribution are resource intensive and time consuming. To solve this problem, Plantmosphere Technologies will design a portable, straightforward solution to automate food growth. Similar technologies for streamlining the plant-growth process are described below.

Hydroponics

Hydroponics is a solution for growing plants without the use of soil. An inert medium such as clay pebbles avoids soil-borne diseases, and requires less space and water. Specialized fertilizers produce crops faster, and generate a larger yield [4]. However, the disadvantages of hydroponics directly impact our target market. Initial set up costs are very expensive. Some plants requiring space for their large roots cannot be grown with hydroponics and greatly limits the available food choices. Hydroponic systems are less suited for automation, as they require daily maintenance and user supervision [5].

Automation Systems for Greenhouses

Greenhouse automation systems have been developed by Growtronix, Climate Control Systems Inc., and Argus Control Systems Ltd. These systems are capable of controlling environmental factors such as air temperature, humidity, carbon dioxide, soil pH, and light. Other features include irrigation control and flood detection, security and alarm notifications [6]. However, these solutions are expensive and incorporate complex software management suites which are not suited our target market.

Small-scale Greenhouses

For small-scale gardening systems, the Arduino UNO is a popular microcontroller choice. Among the existing Arduino-controlled greenhouses, Micro Experimental Growing (MEG) makes the only pre-packaged solution, while the vast majority are homemade [7]. The drawback of MEG's design is that the system is restricted to indoor use only. Consequently, the product is too small to grow any significant amount of food. Additionally, no existing solutions boast a closed water system, which is crucial for our target market.

Proposed Design Solution

With our solution, the user's involvement has been reduced to three key steps across the lifespan of their crop:

1. **Inform** the greenhouse of the plant category
2. **Respond** to notifications from the greenhouse
3. **Harvest** the plants when they reach maturity

When the gardener begins a new crop, the greenhouse system will prompt them through a simple user interface (UI). The UI specifies the selected plants and the current stage of life those plants are in, such as seeds, seedlings, or mature plants. The Plantmosphere will use this information to tailor the growing conditions to the chosen crop, and determine the estimated date of harvest.

Following initial setup and planting, the automation system will strive to maintain an ideal environment. Rainwater will be collected and stored in an evaporation-resistant reservoir for irrigation and humidification. Water that drains from the planting troughs will be captured and recycled. Throughout each day, and as seasons change, ambient soil and air temperatures, as well as humidity and light may fluctuate. The Plantmosphere will maintain the perfect growing conditions by monitoring these parameters and adjusting them with affordable, off-the-shelf actuators.

As the growing period draws to a close, the Plantmosphere will display notifications to the gardener to monitor the plants more closely. A simple, visual guide to various plants will be included with the product to help guide gardeners on topics that the Plantmosphere is not in control of. It will include essential knowledge such as recommended agricultural practices and crop compatibility tables.

If time permits, additional non-essential goals will be pursued, including automated plant nutrient distribution, soil pH monitoring and control, and a water filtration system to prevent recycled water from developing harmful bacterial cultures.

Figure 1 below illustrates the system inputs to be monitored and outputs to be controlled.

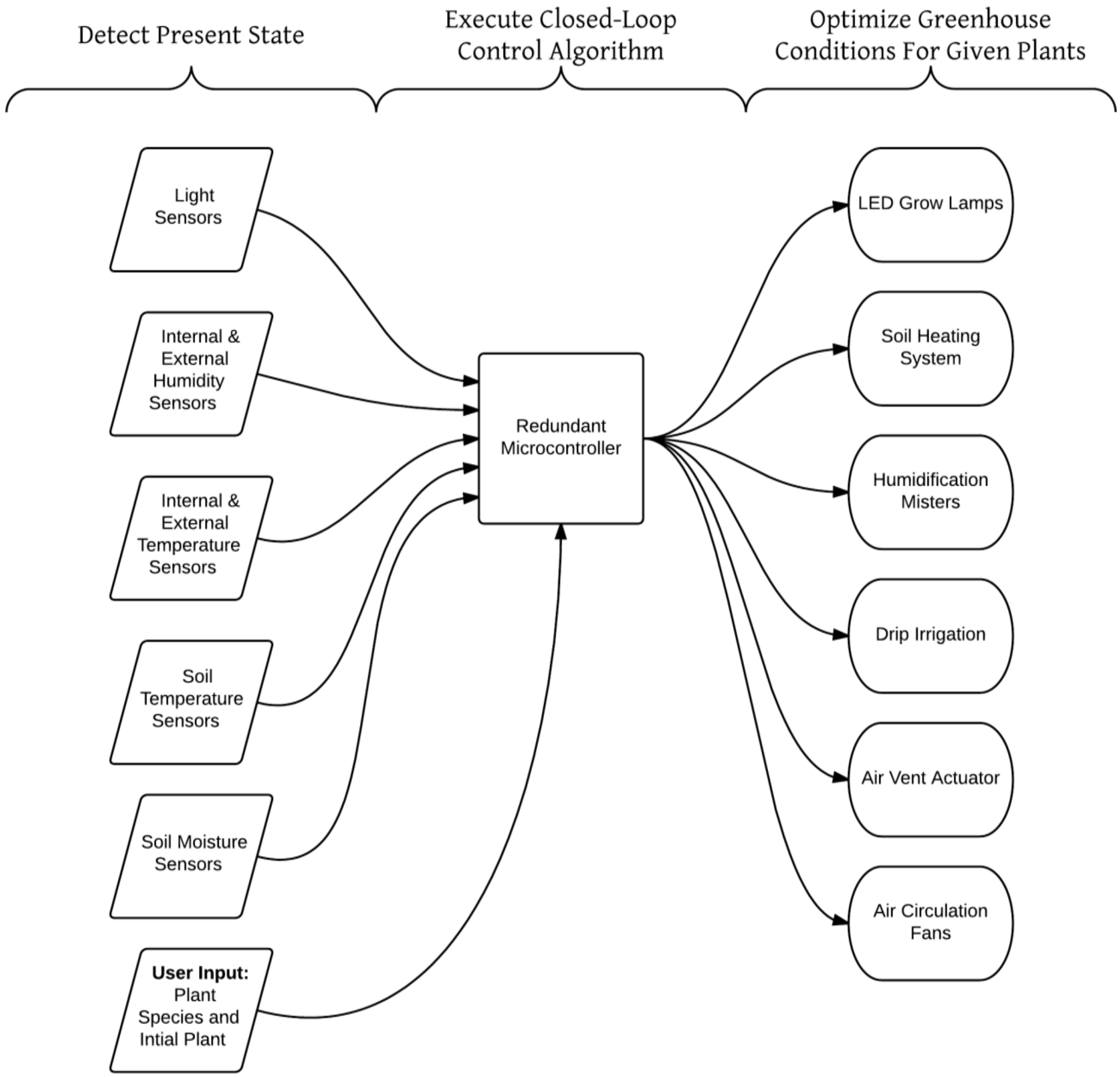


Figure 1 - Inputs, Control, and Outputs of Automation System

Budget

Table 1 below contains the list of essential components that are needed to build and operate the automated greenhouse system. The total estimated costs for our components include shipping and taxes. We have budgeted for additional components for experimentation purposes and to compensate for component failures.

Table 1: Tentative Budget

Component	Projected Cost
Deluxe Twin Wall Greenhouse 6 by 4 feet	$600
Arduino Mega 2560 (2)	$100
P8104-ND Light Sensors (5)	$10
MG-811 CO_2 Sensor	$55
Jebao PP377 Fountain Pump 105 GPH	$40
Gro-Quick Soil Warming Cables	$35
DHT11 Humidity and Temperature sensors (5)	$50
LED Lighting Array	$80
DC Fans	$90
Flexible Vinyl Ducting	$10
Automatic Louver	$60
Soil	$30
Plants	$15
Total	**$1165**

Funding

To mitigate project costs, we will seek funding from several sources. Both the Engineering Student Society Endowment Fund (ESSEF) and the Wighton Fund are being pursued as potential investors. Additionally, we have applied for a grant through Sustainable SFU. Our intentions are to donate the finished product to Sustainable SFU for their upcoming garden space. Any costs that cannot be covered by our funding will be equally shared amongst our members.

Project Plan

The project plan for our project contains the following milestones.

Milestones

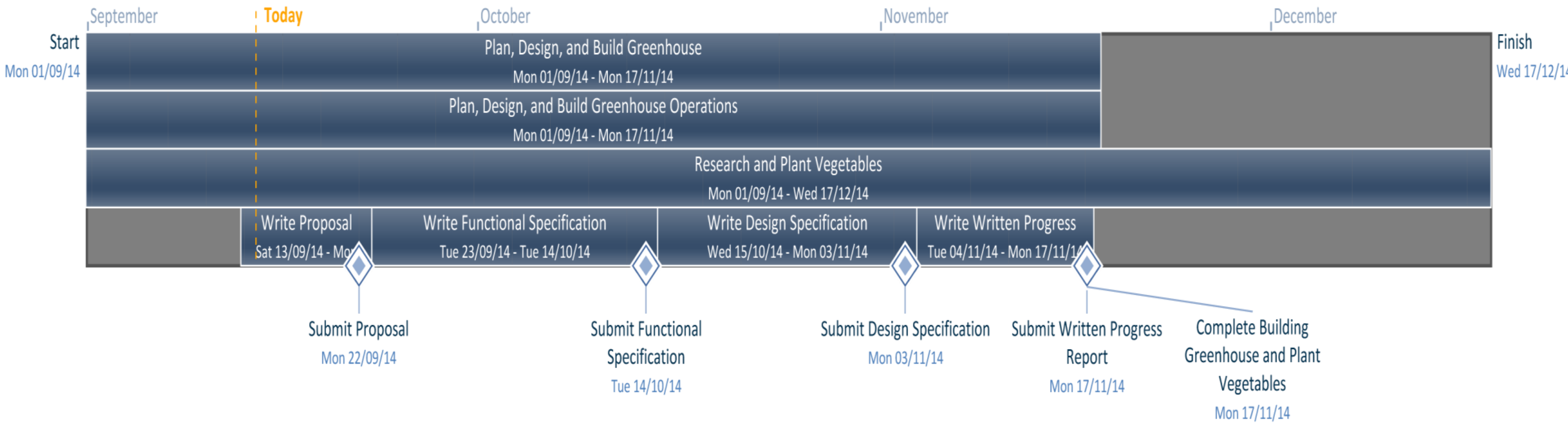
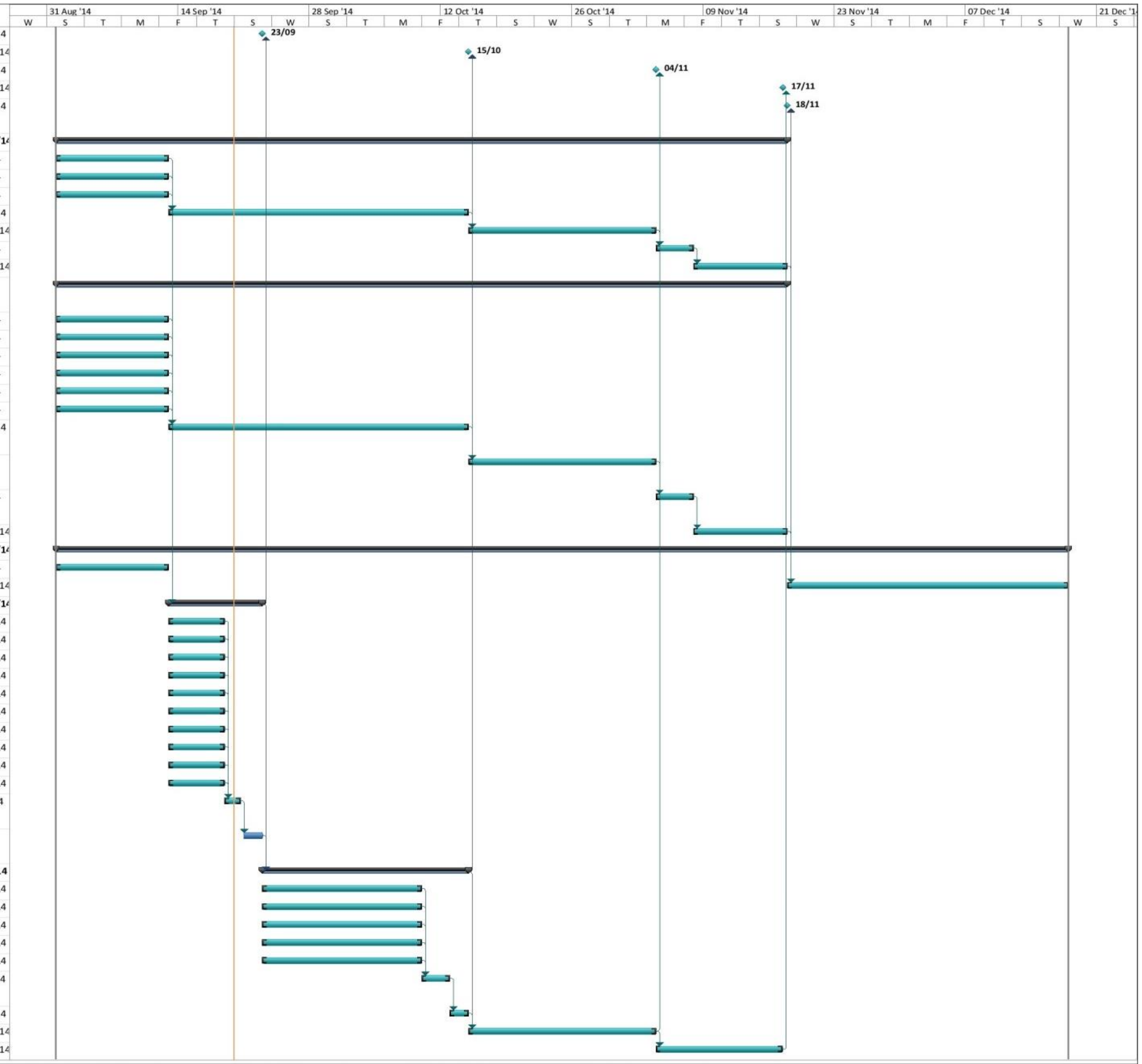


Figure 2: Project Milestones

Project Schedule

ID		Task Mode	Task Name	Duration	Start	Finish
1			Submit Proposal	0 days	Tue 23/09/14	Tue 23/09/14
2			Submit Functional Specification	0 days	Wed 15/10/14	Wed 15/10/14
3			Submit Design Specification	0 days	Tue 04/11/14	Tue 04/11/14
4			Submit Written Progress Report	0 days	Mon 17/11/14	Mon 17/11/14
5			Complete Building Greenhouse and Plant Vegetables	0 days	Tue 18/11/14	Tue 18/11/14
6			**Plan, Design, and Build Greenhouse**	**80.75 days**	**Mon 01/09/1**	**Mon 17/11/1**
7			Research Foundation	12.25 days	Mon 01/09/14	Fri 12/09/14
8			Research Greenhouse Structure	12.25 days	Mon 01/09/14	Fri 12/09/14
9			Research Water Reservoir	12.25 days	Mon 01/09/14	Fri 12/09/14
10			Functional Design Greenhouse	33.25 days	Sat 13/09/14	Tue 14/10/14
11			Detailed Design Greenhouse	20.75 days	Wed 15/10/14	Mon 03/11/14
12			Purchase Greenhouse Materials	4 days	Tue 04/11/14	Fri 07/11/14
13			Build Greenhouse	10.5 days	Sat 08/11/14	Mon 17/11/14
14			**Plan, Design, and Build Greenhouse Operations**	**80.75 days**	**Mon 01/09/14**	**Mon 17/11/14**
15			Research Watering System	12.25 days	Mon 01/09/14	Fri 12/09/14
16			Research Sensors	12.25 days	Mon 01/09/14	Fri 12/09/14
17			Research Control Unit	12.25 days	Mon 01/09/14	Fri 12/09/14
18			Research Power Methods	12.25 days	Mon 01/09/14	Fri 12/09/14
19			Research Airflow Systems	12.25 days	Mon 01/09/14	Fri 12/09/14
20			Research Lighting Systems	12.25 days	Mon 01/09/14	Fri 12/09/14
21			Functional Design Greenhouse Operations	33.25 days	Sat 13/09/14	Tue 14/10/14
22			Detailed Design Greenhouse Operations	20.75 days	Wed 15/10/14	Mon 03/11/14
23			Purchase Greenhouse Operation Materials	4 days	Tue 04/11/14	Fri 07/11/14
24			Build Greenhouse Operations	10.5 days	Sat 08/11/14	Mon 17/11/14
25			**Research and Plant Vegetables**	**111.75 days**	**Mon 01/09/1**	**Wed 17/12/1**
26			Research Plants	12.25 days	Mon 01/09/14	Fri 12/09/14
27			Plant Vegetables and Sow Seeds	31 days	Tue 18/11/14	Wed 17/12/14
28			**Write Proposal**	**10.5 days**	**Sat 13/09/14**	**Mon 22/09/1**
29			Proposal - Introduction	6.25 days	Sat 13/09/14	Thu 18/09/14
30			Proposal - System Overview	6.25 days	Sat 13/09/14	Thu 18/09/14
31			Proposal - Possible Design Solutions	6.25 days	Sat 13/09/14	Thu 18/09/14
32			Proposal - Proposed Design Solution	6.25 days	Sat 13/09/14	Thu 18/09/14
33			Proposal - Sources of Information	6.25 days	Sat 13/09/14	Thu 18/09/14
34			Budget/Funding	6.25 days	Sat 13/09/14	Thu 18/09/14
35			Project Schedule	6.25 days	Sat 13/09/14	Thu 18/09/14
36			Team Organization	6.25 days	Sat 13/09/14	Thu 18/09/14
37			Company Profile	6.25 days	Sat 13/09/14	Thu 18/09/14
38			Conclusion	6.25 days	Sat 13/09/14	Thu 18/09/14
39			Proposal - Letter of Transmittal/Executive Summary	2 days	Fri 19/09/14	Sat 20/09/14
40			Proposal - Presentation/Organization/Format/Corre	2.13 days	Sun 21/09/14	Mon 22/09/14
41			**Write Functional Specification**	**22.75 days**	**Tue 23/09/14**	**Tue 14/10/14**
42			Introduction/Conclusion	17.5 days	Tue 23/09/14	Thu 09/10/14
43			Structure System Requirements	17.5 days	Tue 23/09/14	Thu 09/10/14
44			Water System Requirements	17.5 days	Tue 23/09/14	Thu 09/10/14
45			Electrical System Requirements	17.5 days	Tue 23/09/14	Thu 09/10/14
46			System Test Plan	17.5 days	Tue 23/09/14	Thu 09/10/14
47			Functional Specification - Letter of Transmittal/Executive Summary	3.25 days	Fri 10/10/14	Sun 12/10/14
48			Presentation/Organization/Format/Corre	2 days	Mon 13/10/14	Tue 14/10/14
49			Write Design Specification	20.75 days	Wed 15/10/14	Mon 03/11/14
50			Write Written Progress Report	14 days	Tue 04/11/14	Mon 17/11/14



Project: Greenhouse Project
Date: Sat 20/09/14

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Progress

Page 1

Figure 3: Project Schedule

Team Organization

Plantmosphere Technologies' team comprises six enthusiastic and creative engineering students: Faisal Emami, Terry Hannon, Jane Horton, Alex Naylor, Jeff Shum, and Mike Thiem. Our diverse skill sets and education allows each individual to have a well-defined set of tasks based on their strengths. This wide range of expertise also offers our team members the opportunity to expand their knowledge in areas they aim to improve.

Rather than delegate members purely managerial titles, our positions have been assigned based on our engineering expertise. Terry Hannon, Project Manager, will allocate resources and keep track of our tasks using the JIRA management software, as well as edit product documentation and discover funding opportunities. His extensive technical background will be an asset for product design and implementation. Alex Naylor and Jane Horton, Design Engineers, will design the overall product and handle any part purchasing. Their main tasks will be supplemented by hardware and software support. Faisal Emami, Hardware Engineer, will focus his efforts on the circuit design of our product and creating a hardware interface between the micro-controller and the sensors. Jeff Shum, Software Engineer, is tasked with programming, algorithm development, and implementing the Arduino's software. Mike Thiem, Mechanical Engineer, is in charge of irrigation, humidification, and water distribution, recycling, and storage systems.

To augment overall team productivity, we will use JIRA, a professional issue tracking platform to assign and manage all tasks. Additionally, Dropbox enables the aggregation and versioning of all research and documentation. Each week, we will hold at least one Skype and in-person meeting, with additional team meetings scheduled as required. During these sessions, we will discuss issues, assign action items to team members, and review ongoing work. Designating Alex to lead the meeting and take minutes allows us to complete agenda items before discussing other matters, ensuring that we stay on topic. To accommodate the schedule conflicts of our large group, we will have smaller meetings of two to three members to address task-specific issues.

Numerous engineering students and faculty members have stressed the importance of group dynamics in completing a Capstone project. We believe that our group's strong communication and organizational skills, coupled with a varied technical toolkit will secure our success in this project.

Company Profile

Faisal Emami – Hardware Engineer

Faisal is a fifth year Electronics Engineering student at Simon Fraser University who worked as an electrical engineering co-op student at NavCanada. His experience with AutoCAD and electronic system design will aid him in creating a hardware interface between the sensors and the microcontroller. Recently, he was involved in designing and implementing NTSC video display circuitry, as well as using AutoCAD to plan layouts for repairs and alterations of radio communication outlets. Faisal's superb interpersonal and negotiation skills reinforce his technical skills.

Terry Hannon – Project Manager

Terry is a fifth year Computer Engineering student at Simon Fraser University and a dedicated I.T. professional with extensive experience in application and data integration, data analysis, design, modelling, and development. His skill at managing multiple projects using Agile, Lean, and waterfall methodologies and his expertise in all system development life cycle phases give him the tools required to allocate resources and edit documentation. Terry's managerial experience and interpersonal skills are bolstered by a vast technical knowledge, enabling him to be directly involved in the product's design and implementation.

Jane Horton – Design and Software Support Engineer

Jane is a fifth year Biomedical Engineering student at Simon Fraser University who had a recent co-op at Lungpacer Medical Inc. as a design engineer. With her many programming courses and experience with data analysis, scripting, and software revision systems, Jane will be tasked with product design, part procurement, and supporting the software engineer. Her recent work includes developing an automated software verification testing suite and writing software for systems requiring microsecond precision. Jane's technical skills are supported by exceptional documentation and interpersonal skills.

Alex Naylor – Design and Hardware Support Engineer

Alex is a fifth year Electronics Engineering student at Simon Fraser University who had an RF engineering co-op with Fastback Networks this past summer. The electronic system design courses he's taken and his product design experience will allow Alex to focus on product design, part procurement, and supporting the hardware engineer. His recent projects include designing and implementing NTSC video display circuitry and developing hardware and software in Python for an antenna test system. Alex's technical skills are supplemented by excellent organization and communication skills.

Jeff Shum – Software Engineer

Jeff is a fifth year Biomedical Engineering student at Simon Fraser University who worked as a research assistant in machine learning at the Rick Hansen Institute. His programming-centric course load and work experience with coding and data analysis will allow him to develop algorithms and create the software interface between the micro-controller and the sensors. Jeff's recent projects involved extending neural network MATLAB code to more accurately analyze data and running simulations for non-linear principal component analysis. His technical skills are matched by a dedication to quality assurance and outstanding communication skills.

Mike Thiem – Mechanical Engineer

Mike is a fifth year Electronics Engineering student at Simon Fraser University who had a recent stack system interface co-op at the Automotive Fuel Cell Cooperation Corporation (AFCC). He will be in charge of irrigation, humidification, as well as water distributing, cycling, and storage. Mike's co-op experience designing and building test fixtures, as well as his prior knowledge in physics and mechanical design will be an asset. His recent projects include designing, building, testing, and documenting a volume measurement apparatus, as well as creating a fixture to visualize fluid flow. Mike's ability to produce quality work in a timely manner and his excellent communication skills complement his technical skills.

Conclusion

Plantmosphere Technologies aims to provide the sub-Sahara African third world with a user friendly and robust automated gardening system for use in a variety of environments. Achieving our goal means providing victims of the hunger crisis with sustainable sustenance.

Although our product is targeted at third world residents, its modular design and open source code makes it attractive to other users as well. Gardening hobbyists may find it useful to add more sensors to more precisely control the environment while others may want to incorporate their own custom modules. The Plantmosphere's versatility gives its users the freedom to easily create the gardening environment they desire.

Comprehensive systems similar to the Plantmosphere simply do not exist. Many automated greenhouses are "do-it-yourself" projects that require the user to have access to the necessary materials and technical expertise. Other solutions provide an automation service for existing greenhouses, but do not provide a complete system. Our product provides a functional platform that requires little technical knowledge to set up and use, while allowing for more advanced users to modify the system to their needs.

Our detailed schedules show that the base product can be completed in the given time frame and the wealth of information both online and offline provides us with plenty of reference material. The outlined financial resources provide the opportunity to obtain the funding we require. Our diverse team can solve any issues we may encounter.

We are confident that the Plantmosphere is the first step towards ending world hunger.

Works Cited

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