STAR Programs Climate Tracking Network

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CONCEPT OF OPERATIONS

REVISION – 1
4 October 2017

Concept of Operations
for
STAR Programs Climate Tracking Network

Team STAR Programs

Approved by:

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1. Executive Summary

The purpose of this project is to address the need for regional climate and environmental data to improve agricultural performance. The solution specified is to develop a network of climate sensor stations distributed across a cultivatable area and the surrounding region to monitor relevant climate factors over time. Specifically, the climate factors that will be recorded are rainfall, solar irradiance, air temperature, soil temperature, soil moisture content, wind speed, and water levels. Each sensor station will operate on solar power and take measurements hourly. The stations will then transmit the information to a base station. The central network station will upload all of the data to the internet twice a day where the data will be presented in a user interface that is accessible to the agricultural end user through the web. The scope of this project is a proof of concept for a prototype climate sensor station, prototype stock pond depth sensor station, and central node which will be networked to gather and to upload the information so that it is accessible through a website on the internet.

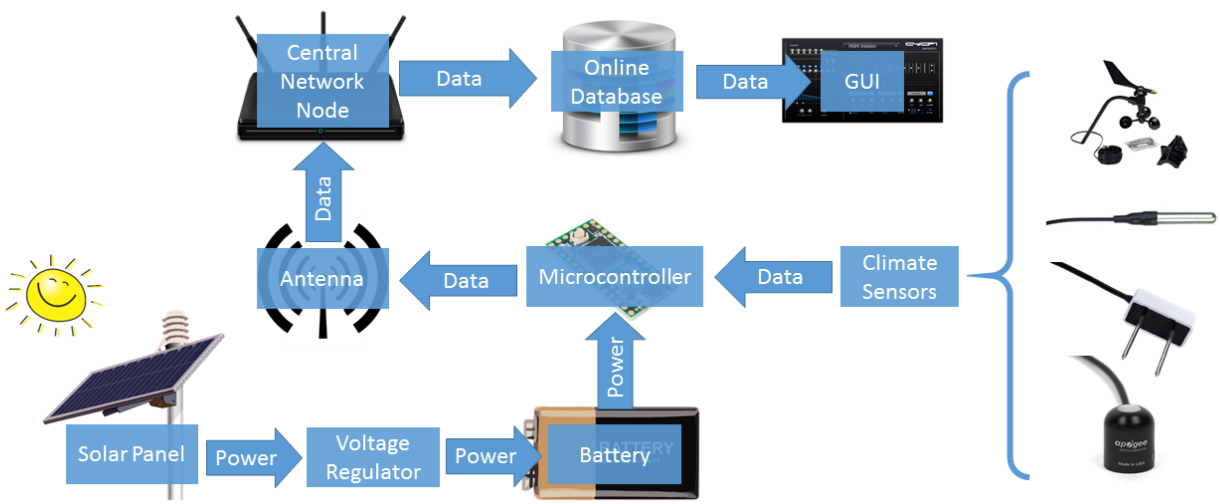

Figure 1: Functional System Diagram of Climate Tracking Network

2. Introduction

The purpose of this document is to present the Climate Tracking Network, a distributed network of agricultural sensors that monitor relevant climate parameters in order to assist farmers with crop selection and management techniques. This project has the potential of improving agricultural performance and enabling agricultural in areas where it has not yet been tried by providing additional and necessary information.

2.1. Background

There is an increasing worldwide demand for food that requires new farming techniques and paradigms [1]. STAR (South Texas Advancement Resource) Programs believes Southwest Texas could be a new region where agriculture needs can be met. Southwest Texas is a harsh environment where farming has not been developed, and ranching is the predominate means of food production. In order to develop a system of agriculture which is profitable in Southwest Texas, additional local climate and micro-environmental data will be needed. The Climate Tracking Network will help support the initiative by providing data to aid in the crop selection and management programs STAR Programs is pursuing.

The Climate Tracking Network has an additional goal of providing data to supplement already developed agricultural systems. The profit margins in agriculture are usually very narrow, which leaves very little room for uncertainty [2]. Success is often dependent on the accuracy of information about specific variables, many of which are related to the climate of the region. Although public weather information is commonly available across the country, this information is tailored to specific sensors across a wide region, and it is possible that none are located anywhere near the agricultural property in question. It also does not typically include parameters that are useful for a particular farmer. Therefore, it is frequently inaccurate or not useful for agricultural purposes, especially when crop yield is trying to be optimized.

There are systems available on the market that can be implemented to aggregate climate data for a specific area of land. These systems import data from sensors into units that store the information and transmit it back to a centralized location. However, these systems tend to be very expensive and offer little flexibility for expanding the functionality of the system or for using it in conjunction with sensors produced by other manufacturers. When the profit margins are already very narrow in agriculture, an affordable solution is necessary if widespread use of these networks is to become common practice in agriculture. Therefore, the Climate Tracking Network will leverage technology that is widely available and comparatively cheap to that used by the tailor-made equipment in other systems.

The system will also be environmentally friendly since it will be powered entirely from solar energy and will enable farmers to conserve resources when the system indicates there is no need for them. It has been shown that agriculture consumes about 75% of all human water use, and the ability to conserve water without endangering the crops will increase water usage efficiency [4]. Such an increase in water efficiency will be accompanied by optimized fuel and chemical usage, serving to help the environment and improve sustainability in agriculture.

2.2. Overview

The network will consist of several sensor stations that are comprised of sensors interfaced into a microcontroller. Each station will continuously record measurements and send them to a central location, which will upload all of the information through the internet to a database. A web application will show recent and historical data pulled from the database. Over the course of several years in order to show the historical averages and general trends will build up within the database. This will allow farmers to select crops that are known to do well in that environment and use techniques to compensate for those parameters that are limiting the yield of their crops. The schematic in Figure 1 below shows the flow of information and feedback control that the system will leverage.

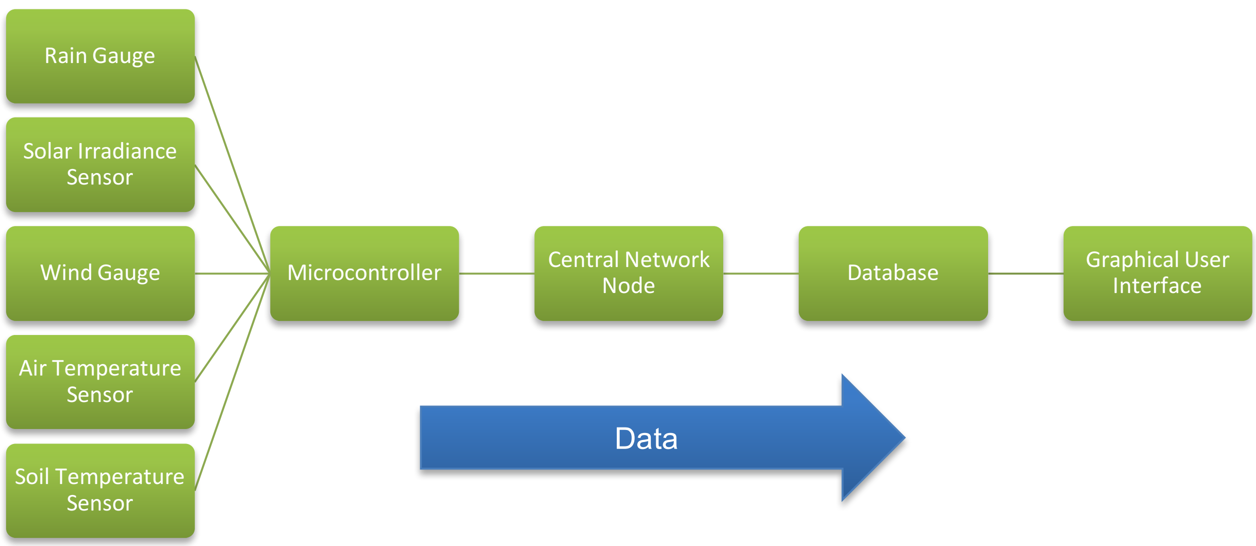

Figure 2: *Flow of information through Climate Tracking Network*

Additional functionality, which may be added to the design as stretch goals for the scope of this project, is described in further detail later in this document.

2.3. Referenced Documents and Standards

[1] "Global agriculture towards 2050". *Food and Agriculture Organization of the United Nations*, October 2009 Accessed at http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf

[2] Hoppe, R. "Profit Margin Increases With Farm Size". *United States Department of Agriculture*. Accessed at https://www.ers.usda.gov/amber-waves/2015/januaryfebruary/profit-margin-increases-with-farm-size/

[3] "Climate Education for Agriculture – Instruments". *North Caroline State University*. Accessed at http://climate.ncsu.edu/edu/ag/instruments

[4] Wallace, J. "Increasing agricultural water use efficiency to meet future food production". *Elsevier,* Vol 82, Iss. 1-3. December 2000. Accessed at http://www.sciencedirect.com/science/article/pii/S0167880900002206

3. Operating Concept

3.1. Scope

For the scope of this project, a proof of concept system is being designed that will be able to confirm all of the relevant operating parameters that the full Climate Tracking Network would need to be employ. The exact deliverables for the scope of this project are as follows:

- Standard Climate Sensor Station
- Depth Sensor Station
- Central Network Node
- Database with GUI

Documentation for the design, construction, and programming of the units will be provided for all parts of the project.

3.2. Operational Description and Constraints

The Climate Tracking Network is intended for use in the agricultural industry in areas with sufficient sunlight for the solar panels to power the units. It is also intended for open areas with direct lines of sight to the places where the climate sensor stations will be placed. The environments in which it is to be used must meet all of the following criteria:

- A year-round temperature range of -20 - 140° Fahrenheit
- Sufficient solar exposure to power the units
- Direct lines of sight between the central network node and all sensor stations
- Small enough radio interference for units to communicate effectively

Furthermore, the system is not designed or intended to operate in and/or survive extreme natural events, such as earthquakes, tornadoes, hurricanes, lightning, etc.

More specific details on the operational description and constraints are recorded in the FSR, which takes precedence in the case of a conflict between with any operational description or constraints detailed here.

3.3. System Description

The Climate Tracking Network will consist of multiple climate sensor stations, a centralized network node, a database, and a graphical user interface. This can be broken down into five different subsystems, described in detail below:

Sensor Subsystem: The five parameters that are most important for developing systems of agriculture are gathered by the sensors connected to the microcontroller to obtain the needed information. Additional sensors and subsystems that support the acquisition and storage of the data are detailed below.

Pyranometer: A pyranometer measures solar irradiance. The values measured by the pyranometer will vary throughout the day and can be affected by shadows produced by nearby plants or sensors. The pyranometer will be placed well above the ground and in such a manner that no shadows will be cast on it. These sensors typically output a small voltage associated with the wattage per square meter incident upon it.


Figure 3: Pyranometer

Rain gauge: The rain gauge will measure precipitation. Rain gauges typically operate with a tipping bucket design. A tipping bucket collects water and tips when a certain amount of water as fallen. This tipping triggers a pulse which can be recorded and used to determine the total amount of rainfall in a given amount of time.


Figure 4: Rain Gauge

Anemometer: An anemometer measures wind speed and direction. A common anemometer design is a cup anemometer. The cups capture the wind and begin to spin. The faster the cups spin, the higher the voltage provided by the data output. This voltage can be used to determine the wind speed.


Figure 5: Anemometer

Thermometer: Two different types of thermometers will be implemented. One thermometer will measure air temperature at each climate sensor station, and another type of thermometer will measure soil temperature at each climate sensor station. These thermometers modify the resistance seen from the microcontroller, which can be measured by a simple voltage divider circuit.


Figure 6: Thermometer

Soil Moisture Sensor: A soil moisture sensor measures the volumetric content of water in the soil. It measures the dielectric permittivity of the soil by acting like a capacitor. By measuring the performance of the capacitor, the dielectric permittivity of the soil can be found, which is directly proportional to the water content in the soil.


Figure 7: Soil Moisture Sensor

Pressure Transducer Depth Sensor: A pressure transducer depth sensor calculates the pressure it is under by its changing resistance as the pressure changes. The transducer can also be vented to help calibrate for changes in barometric pressure.

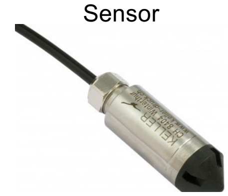
Figure 8: Pressure Transducer

Microcontroller Subsystem: The microcontroller will interface with and manage each of the components in the climate and depth sensor substations, including the power subsystem, sensor subsystem, and communication subsystem. In the central network node, it will manage the communication subsystem and ensure all of the data is routed to the proper place.

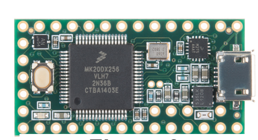
Figure 9: Microcontroller

Power Subsystem: The power subsystem will consist of a solar panel, a voltage regulator, and a battery at each of the climate/depth sensor stations and central network node. It will be the sole source of power for the physical components of the system.

Figure 10: *Solar Panel*

Communication Subsystem: The communication subsystem is comprised of the antennas and modulation chips that are connected to the microcontrollers of each system for the purposes of communicating between the stations and the central network node, as well as uploading the data from the central network node to the online database.

Figure 11: Antenna

Information Storage and Presentation Subsystem: The online database, with the associated GUI for the user to view the data from the system, is the Information Storage and Presentation Subsystem. This will be the means by which the user is able to consume the data and make decisions to optimize agricultural performance.

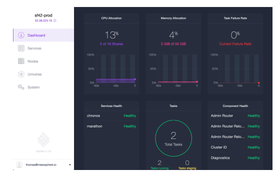

Figure 12: Display Panel

3.4. Modes of Operations

The Climate Tracking Network shall use a primary mode of operation in which the data from the sensors is collected, transmitted to the central network node, uploaded to the online database, and presented to the user for viewing.

The system will also have error notification mechanisms in place to alert the user in the event of any noticeable problems in the operation of the system, such as the voltage to the battery dropping too low. In events that could threaten the long-term survival of the system, a secondary mode of operation will be used in which the system stops transmitting data to preserve the lifespan of the components.

3.5. Users

The Climate Tracking Network is intended for use by farmers and others who have experience in the agriculture industry for the purposes of enhancing crop yield, but will be designed so that the average person familiar with the climate parameters will be able to interpret the data presented to the user.

3.6. Support

User manuals will be provided with details on how the Climate Tracking Network works and interfaces together. The user manual will help provide documentation for each subsystem to help troubleshoot any difficultly that occurs after the project is completed.

4. Scenarios

4.1. Gathering Baseline Weather Data

The Climate Tracking Network will provide point source data about a given local environment. The point source data can be synthesized with a general model to provide a better understanding of the region's environment. This model can be used to establish trends and precedents and to predict future micro-weather patterns.

4.2. Aiding in Crop Selection

The Climate Tracking Network is focused on gathering data which applies to agricultural management and crop selection. Knowing the key parameters of solar irradiance, precipitation levels, and wind speeds will help teams of agricultural engineers select a viable and commercially successful crop for the region. The importance of the network is made more obvious by the lack of historical local data for agricultural engineers in the Southwest Texas region. Providing this data for the historically unfarmed region of Southwest Texas is the central goal of the Climate Tracking Network and directly supports other projects led by STAR Programs.

4.3. Optimizing Crop Performance

Even after a crop has been selected, the use of resources to care for the plants can be optimized by the Climate Tracking Network. Knowledge about the health of soil and crops in different plots of land will allow farmers to conserve resources when utilizing them will not result in greater yield or to expend them when necessary. This reduces cost and increases revenue for farmers leading to an overall rise in profitability.

5. Analysis

5.1. Summary of Proposed Improvements

- The Climate Tracking Network will support STAR Programs efforts for developing an economically successful method of growing a cash crop in Southwest Texas. The data will be used to provide additional source of information for the crop selection and management.
- Success in the development of a cash crop will introduce a new supply of produce into the world market. This will impact not only Texas, but other areas with similar environmental conditions. These new markets will change the face of food production, improve local economies, and help meet the growing need for food around the globe.
- Farmers around the world will be able to improve their use of resources, management of crops, and yields through the Climate Tracking Network. The Climate Tracking Network will provide previously unknown but important and basic climate data for STAR Programs' land in Southwest Texas. The technology developed here can also be used by farmers as a cheap and effective way to introduce data into agriculture a key to better resource management. The Climate Tracking Network should be cheaper than many distributed sensor networks available for agriculture allowing more farmers to take advantage of precision farming.

5.2. Disadvantages and Limitations

The largest barrier and limitation to the climate tracking network is that it will be several years before trends and precedents can be determined based upon the data. The usefulness of the data that is being gathered will be proportional to the amount of data gathered. Therefore, it may be some time before the STAR Programs or others will see a return on investment for the Climate Tracking Network. However, the data that is being gather is valuable, and the time required is reasonable for the long-term goals of STAR Programs.

Since the system is being built at a very low level, it may be difficult for people to implement themselves. The use of these microcontrollers and sensors may be foreign to some users who would benefit from the Climate Tracking Network. Some of this can be overcome with manuals detailing how to construct the system, prefabricated systems, and ready to software that allows for easy installation in the field.

Adding functionality to the system will be very difficult. The system will not be designed to be plug-and-play with other types or kinds of sensors. Thus, those desiring different measurements will be faced with a difficult task of implementing it themselves. In order to avoid the disadvantage of this limitation, the Climate Tracking Network is focusing on the most beneficial data sources for crop selection and agriculture management.

5.3. Alternatives

There are several alternatives to implementing the Climate Tracking Network. The first would be to gather the data manually without a permanent network. This would involve a portable sensor that could be used at each of the various points of interest. The main difficultly with this solution would be the additional labor and clerical work needed during the acquisition process. The Climate Tracking Network would require less time for the user to gather and compile the data by automatically and regularly gathering it. Another alternative would be to contract a company to implement the system. There are companies that specialize in precision agriculture and could implement the system. The primary barrier to this alternative is that the cost to implement a custom solution will be very high. Additionally, nothing will be learned by STAR programs on how other farmers could implement this technology themselves. Finally, there are companies, such as Meter and Davis Instruments, which sell plug-and-play sensors and dataloggers for agricultural purposes. These systems are very expensive and often do not offer the parameters requested at a reasonable price.

STAR Programs Climate Tracking Network

Trevin Cooper and David Fawcett

FUNCTIONAL SYSTEM REQUIREMENTS

REVISION – 1
4 October 2017

FUNCTIONAL SYSTEM REQUIREMENTS
FOR
STAR Programs Climate Tracking Network

TEAM STAR PROGRAMS

APPROVED BY:

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David Fawcett Date

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Prof. S. Kalafatis Date

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Bahareh Anvari Date

Change Record

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1	9/15/17	Trevin Cooper		Draft Release

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1. Introduction

1.1. Purpose and Scope

The climate tracking network is an efficient way to monitor the precise conditions of a microclimate, which is particularly useful for agricultural areas where there is little to no historical data available. It is designed to be implemented by the average person who has an agricultural background, and has the ability to enhance crop efficiency and profit by allowing farmers to fine tune their crop selection and techniques for crop growth to the parameters that their land provides. Figure 1 shows a representative integration of the project in the proposed CONOPS.

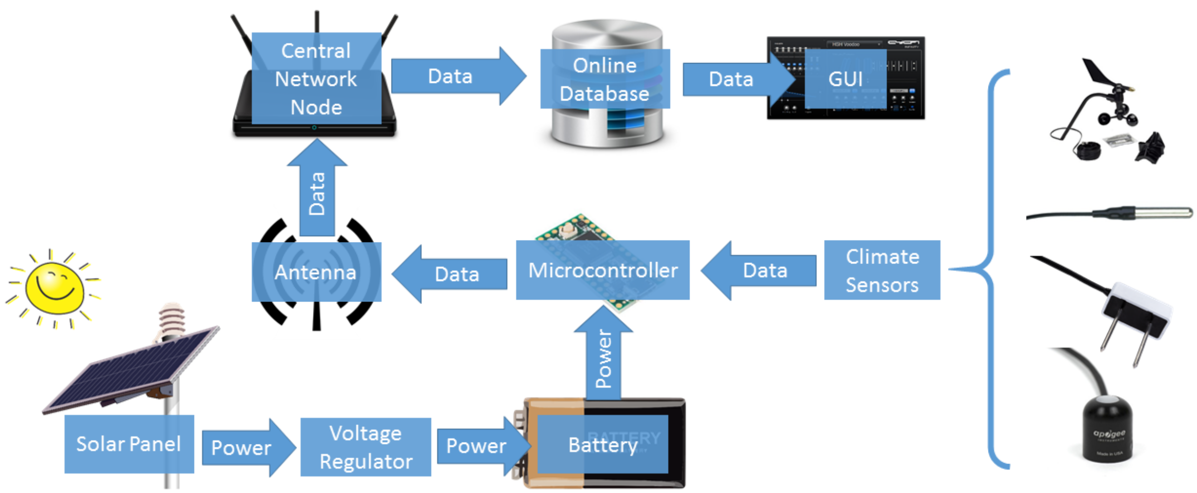

Figure 1: Functional System Diagram of Climate Tracking Network

The system will be powered entirely by solar power, and each sensor station shall record information about the air temperature, solar irradiance, rainfall, wind speed, soil temperature, and soil moisture specific to the area in which the sensor stations are deployed. It may also deliver information about the humidity, air pressure, and soil electroconductivity. A separate kind of sensor shall record the level of water in stock ponds in the area. All of this information shall be transmitted to a central network node, which shall upload it to an online database. The system shall aggregate all the climate data over a period of several years and present it to the user in a convenient, easily understood format.

The system may do analytics on the information collected, such as prediction algorithms, which could forecast general future weather conditions based on historical trends and present conditions. The system may compliment the data gathered by it with information from public weather services.

1.2. Responsibility and Change Authority

The team leader, David Fawcett, is charged with ensuring all specifications of the system are met. Any changes to the specifications or deliverables of the project must be approved by the team leader, David Fawcett, and the sponsor's official representative, Bill Raney.

2. Applicable and Reference Documents

2.1. Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

Document Number	Revision/Release Date	Document Title
IEEE 802.11	2012	IEEE Standard for Information technology—Telecommunications and information exchange between systems Local and metropolitan area networks—Specific Requirements
IEEE 307	1969	IEEE Standard Definitions of Terms for Solar Cells
C2-2017	2017	National Electrical Safety Code(R)

2.2. Reference Documents

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification, and are not controlled by their reference herein.

Document Number	Revision/Release Date	Document Title
Version 1.4	May 2017	SDI-12 A Serial-Digital Interface Standard For Microprocessor-Based Sensors

2.3. Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable document are considered to be for guidance and information only, with the exception of ICDs that have their applicable documents considered to be incorporated as cited.

3. Requirements

In the following section, “climate tracking network” will exclusively refer to the entire system for which the proof of concept is being developed in the scope of this project. This includes all the climate and depth sensor stations, central network node that can interface with the internet, the online database where the information is stored, and the graphical user interface with which the user can view the data being collected. The term “climate sensor station” will exclusively refer to the physical units which record climate data and transmit it to the central network node. The term “central network node” exclusively refers to the device which receives the data from the sensor stations and uploads it to the online database. The term “online database” refers to the web-based storage system where all of the data collected is continuously aggregated. The term “graphical user interface” exclusively refers to the software program which allows the user to view and interpret the data which has been collected.

3.1. System Definition

The Climate Tracking Network will be comprised of 5 subsystems, which are shown in Figure 2. The sensor subsystem is unique to the climate sensor station and depth sensor stations, but the power, communication, and computing subsystems have parts in both the climate/depth sensor stations and central network node. The information is loaded from the central network node to the information storage and presentation subsystem, where it is accumulated over the course of years and presented to the user for viewing.

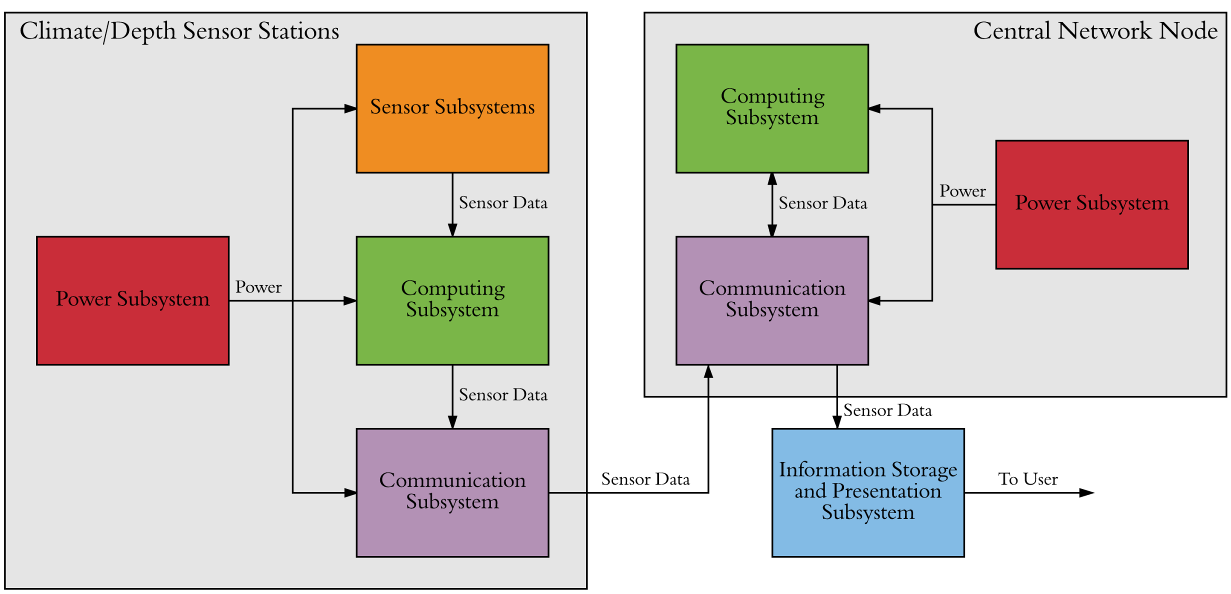

Figure 1. Block Diagram of Climate Tracking Network

In each case, the power subsystem shall consist of a solar panel that harvests energy from the sun, a voltage regulator to provide a constant voltage to charge the battery, and the battery to power the units when the solar panel does not produce enough energy.

The sensor subsystem shall gather the information about the environment and transmits it to the computing subsystem. The climate parameters gathered by the sensor subsystem for the climate sensor stations are air temperature, rainfall, solar irradiance, wind speed, soil temperature, and soil moisture. It may also collect information on the air humidity, air pressure, and soil electroconductivity. For the depth sensor stations, the sensor subsystem collects all of the information a climate sensor station does along with information on the depth of the stock pond. This information is then sent to the computing subsystem.

For the climate and depth sensor stations, the computing subsystem shall take in the data from the sensor subsystem, store it temporarily, and prepare it to be transmitted wirelessly. The computing subsystem for the central network node shall take in data from the communication subsystem that was sent from the climate/depth sensor stations and store it temporarily until it can be uploaded to the internet, through another part of the communication subsystem for that unit.

The communication subsystem shall be the mechanism by which data is transmitted from the climate and depth sensor stations to the central network node, received by the central network node, and uploaded by the central network node to the online database for the user to view.

The information storage and presentation subsystem shall consist of the online database where the data is continuously aggregated and the GUI that the user is able to view. It may also consist of programs that process the data or complement it with public weather service data.

3.2. Characteristics

3.2.1. Functional / Performance Requirements

3.2.1.1. Frequency of Measurements

Each sensor in the Climate Tracking Network will take a measurement every 5 minutes. The only exceptions will be the rain gauge which will take samples continuously, reporting when a discrete amount of rain has fallen.

> *Rationale: This frequency is expected to detect subtle weather events such as light rain showers, but will not provide an excessive amount of data that could become difficult to manage.*

3.2.1.2. Accuracy of Measurements

The Climate Tracking Network will provide climate information using sensors that are rated as being accurate to within the following specification for each type of sensor.

Sensor	Accuracy
Rainfall	+/- 5%
Solar Irradiance	+/- 5%
Air Temperature	+/- 0.5°C
Soil Temperature	+/- 1°C
Soil Moisture	+/- 3%
Wind Speed	+/- 2mph

Table 1: Required Rated Accuracy of Sensors

Rationale: These are standard values that most sensors of decent quality are able to achieve. Further resolution than these values is also not considered to add significant value to the system, and is not within the scope of the Climate Tracking Network.

3.2.1.3. Lifespan and Maintenance

The Climate Tracking Network will be designed with a target life of 5 years. It should operate independently for up to 6 months without needing any maintenance or inspection from the user.

Rationale: Most of the components of the physical side of the system are typically designed to last for about 5 years, which limits the lifespan of the overall system to that time. It is inconvenient to check each climate sensor station more frequently than 6 months, but natural effects could gradually cause damage to the system, which can be prevented if it is inspected occasionally.

3.2.1.4. Communications Requirements

The Climate Tracking Network will require line of sight for all paths of transmissions. Climate and depth sensor stations will be designed for a maximum range of communications with the central network node of 11 miles.

Rationale: Line of sight helps ensure reliable communications over the lifespan of the system, and 11 miles was specified as the length of interest for our customer.

3.2.2. Physical Characteristics

3.2.2.1. Structural

The climate and depth sensor stations will use metal tripods for structural support. The technical components of the system will be bracketed on to the tripod or reach down into the soil or stock pond, depending on the need of the component. The central network node will not use a tripod, but will contain an option for being bracketed onto another structure.

Rationale: The tripod will keep sensitive components off the ground to reduce damage caused by natural effects, and provide the necessary place for the anemometer, air temperature, and humidity sensors to detect the respective parameters from the air.

3.2.3. Electrical Characteristics

3.2.3.1. Inputs

The only inputs the Climate Tracking Network is designed to handle is power from the solar panels and environmental data gathered by the sensors. The input data from the sensors will consist of basic digital and analog values governed by the data sheet provided by the given sensor. The sensor may also communicate with the microprocessor via a standard protocol such as SDI-12, a common communication protocol for agricultural sensors. The design will not allow user to modify or change any of the inputs.

Rationale: There are no parameters of the electrical inputs to the system that would be particularly useful to the user to modify since it is only intended to collect climate information.

3.2.3.2. Power Consumption

The peak power for the physical units in the system shall not exceed the power available from the solar panels. The solar panel will therefore be able to full recharge the battery within a single day in sunny conditions. The units themselves should draw less than half of the battery per day. This will allow the units to run for 2 days without power and the solar panel will be able to restore lost power in about 8 hours of sunlight. All of the sensors utilize negligible current except for the radios which will only operate for small periods twice a day.

Rationale: The power from the battery should be sufficient to power each unit for at least two days, the solar panel should be able to replace lost charge quickly, and a need for another source of power would lower the utility of the system.

3.2.3.3. Input Voltage Level

The input voltage level for each component will be either +12V or +5V.

Rationale: The battery will be a +12V battery, but the microcontroller will need +5V, and considerations for design simplicity make it impractical to allow for any other input.

3.2.3.4. Sensor Station Output

The only means by which data is required to be output from the climate and depth sensor stations is by wireless transmission to the central network node, but the sensor stations may allow for a computer connection to the microcontroller in the sensor stations.

Rationale: The system is intended for automated collection of climate data via continuous transmission of the data wirelessly to the central network node. It is impractical to perform manual collection of the system, but the option to connect a computer to the station to view the data would be helpful for troubleshooting purposes.

3.2.3.5. System Data Output

All data of interest to the user from the system will be output to the user through the GUI. The data will be stored in a database online if more direct access is necessary.

Rationale: The presentation of the data will be most useful and easily digestible via a graphical user interface.

3.2.4. Environmental Requirements

3.2.4.1. Pressure (Altitude)

The Climate Tracking Network shall be designed to withstand and operate in air pressures of altitudes from sea level (0ft) to 4000ft. The only sensor required to sustain additional pressure is the depth sensors in the stock pond. If placed at the bottom of the stock pond it will experience additional pressure.

Rationale: This range includes the altitude at which the customer is interested in implementing the Climate Tracking Network, and is typical of many agricultural environments.

3.2.4.2. Thermal

The Climate Tracking Network shall be designed to withstand and operate in temperatures of -20°F to 140°F.

Rationale: This range includes the temperature of the region in which the customer is interested in implementing the Climate Tracking Network, and is typical of many agricultural environments.

3.2.4.3. External Contamination

The Climate Tracking Network shall be designed to withstand and operate in ordinary natural contamination such as dust, pollen, and occasional insects, but is not intended to guarantee survival from insects or animals who frequently tamper with it or use it in part or whole for the place where they live, or from natural events which may cause excessive contamination in a short period of time such as dust storms, tornadoes, etc.

Rationale: Since the system is designed for agricultural purposes, it must be able to withstand ordinary natural contamination, but it is outside of the scope of the project to make it impervious to all possible forces of nature.

3.2.4.4. Rain

The Climate Tracking Network shall be designed to withstand and operate in rain which does not exceed more than 2” per hour and which is not accompanied by flooding or weakening of the soil in which the sensor stations and central network node are located.

Rationale: This is a limit to the level of rain in the region in which the customer is interested in implementing the Climate Tracking Network, and is typical of many agricultural environments.

3.2.4.5. Humidity

The Climate Tracking Network shall be designed to withstand and operate in a relative humidity range of 5% to 95%.

Rationale: This range includes the average humidity of the region in which the customer is interested in implementing the Climate Tracking Network, and is typical of many agricultural environments. Designing the system beyond these ranges would complicate the design and provide little additional utility for the system.

3.2.4.6. Absence of Solar Exposure

The climate and depth sensor substations shall not be designed to withstand or operate in a period of time without sun exposure that exceeds 2 full days. This includes both natural events and physical obstacles blocking the sun exposure of the solar panels.

Rationale: Any further operation would require powering the sensor stations from a source besides solar power.

3.2.4.7. Natural Disasters

The Climate Tracking Network shall not be designed to withstand or operate in any natural disasters, such as tornadoes, dust storms, hurricanes, earthquakes, floods, lightning storms, acid rain, hail, blizzards, etc.

Rationale: It is outside the scope of this project to create a system which is impervious to all forces of nature.

3.2.5. Failure Propagation

3.2.5.1. Wireless Transmission Errors

The Climate Tracking Network will utilize failure checking algorithms to identify incorrect bits and request retransmission of data if information is detected in error. Every transmission received by the central network node will meet reliability specifications as outlined in IEEE 802.11.

Rationale: This will help preserve the integrity of the data being collected.

3.2.5.2. Diagnostic Errors

The Climate Tracking Network will monitor the voltage levels for the power subsystem, whether sensors are reporting or not, and other relevant parameters of the units, and send alerts to the user if any errors are identified.

Rationale: This will allow the user to make any necessary changes to keep the system running if there is a problem.

4. Support Requirements

4.1.1. Computer Terminal with Internet Access

In order to view the data and use the system as designed, the user must use a computer terminal with access to the internet and a web browser to view the application.

Rationale: Other forms of accessing the information from the system are outside the scope of this project.

4.1.2. 3G Reception

The user must have reliable 3G cell service reception in the area where the central network node will be located.

Rationale: This will be the means by which the system uploads information to the database for the user to use.

4.1.3. Maintenance

The user must maintain the stations by visiting them at least once every six months to ensure no equipment has been damaged or tampered with.

Rationale: The system is designed with the premise that the user will be able to access the stations and will be able to address any physical issues at the site that arise.

Appendix A Acronyms and Abbreviations

GUI	Graphical User Interface
MHz	Megahertz (1,000,000 Hz)
V	Volt

Appendix B Definition of Terms

Central Network Node	Network element to which climate sensor stations report information and from which information is uploaded to the online database.
Climate Tracking System	Complete system being designed, including climate and depth sensor stations, central network node, online database, and GUI
Climate Sensor Station	Unit designed to collect climate data from sensors and report it to the central network node
Depth Sensor Station	A Climate Tracking Station with an additional sensor to acquire the depth of a nearby stock pond
Graphical User Interface	Software program designed to display data stored in the online database for the user
Online Database	Software storage system for climate data

Appendix C Interface Control Documents

Interface Control Document is attached as a separate document.

STAR Programs Climate Tracking Network

David Fawcett and Trevin Cooper

INTERFACE CONTROL DOCUMENT

REVISION – 1
4 October 2017

INTERFACE CONTROL DOCUMENT
FOR
STAR Programs Climate Tracking Network

TEAM STAR PROGRAMS

APPROVED BY:

____
David Fawcett Date

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Prof. S. Kalafatis Date

____
Bahareh Anvari Date

Change Record

Rev.	Date	Originator	Approvals	Description
1	9/15/17	Trevin Cooper		Draft Release

Table of Contents

List of Tables

1. Overview

The Interface Control Document (ICD) for the entire Climate Tracking Network will provide more detail on how the subsystems in the Concept of Operations and the Functional System Requests will be produced. The ICD will include physical descriptions of the various elements and the electrical interface, power, and placement of each sensors. The document will also explain how the subsystems will interface together to achieve the goals and requirements mentioned in the FSR and ConOps documents.

2. References and Definitions

2.1. References

IEEE Standard 802.15.4-2015
Standard for Low-Rate Wireless Personal Wireless networks
2015 revision

IEEE Standard 802.11
Standard for Wi-Fi Networks

IEEE Standard 802.16
Standard for Metropolitan Area Networks

2.2. Definitions

GUI	Graphical User Interface
MHz	Megahertz (1,000,000 Hz)
m	Meter
mV	Millivolt
RF	Radio frequency
V	Volt
Ah	Amp-hour
W	Watt

3. Physical Interface

3.1. Weight

3.1.1. Weight of climate sensor stations

The climate sensor stations will weigh less than fifty pounds. This allows for an average person to lift and move the entire station into place and the station will be more secure with added weight near its base. This will become even easier if the design becomes modular.

Component	Weight
Thermometer	4.5 oz.
Radiation Shield	Estimate: 1 lbs.
Pyranometer	3.17466 oz.
Davis Rain Gauge	2 lbs. 3 oz.
Anemometer	2 lbs. 15 oz.
Soil Temp & Moisture	Estimate: 0.5 lbs.
Teensy	0.035274 oz.
Xbee	0.17637 oz.
Solar Panel	3.3 lbs.
Battery	4.5 lbs.
Buck Converter	0.035274 oz.
Tripod	Est. 15 lbs
Housings	Est. 3 lbs
Antenna	Est. 2 lbs
Total	34.63 lbs

Table 1: Weather Station Weight Specifications

3.1.2. Weight of depth sensor stations

The depth sensor stations will also weigh less than fifty pounds. The only difference in the depth sensor and the climate sensor station is the addition of a pressure transducer. The additional weight of the pressure sensors is less than two pounds. The reasoning is identical to the one previously in that it allows someone to easily move the station into place and allows the station to be more stable with added weight near its base.

3.1.3. Weight of central network node

The central network node will weigh less than fifty pounds. The only addition to the central network node is a cellular 3G modem which weighs the same as the XBee mentioned above. The reasoning for the weight of fifty pounds is identical to the ones above in that it allows someone to easily move the station into place and allows the station to be more stable with added weight near its base.

3.2. Dimensions

3.2.1. Dimension of climate sensor stations

The climate sensor stations will fit inside a rectangular prism which is 1m in length and width and 3m tall. Table 2 below shows the dimensions of each of the technical components of the climate sensor substations.

Component	Diameter	Length	Width	Height
Thermometer	0.312"	2.5"	N/A	N/A
Radiation Shield	N/A	Est. 5"	Est. 5"	Est. 8"
Pyranometer	0.01"	N/A	N/A	0.01"
Davis Rain Gauge	8.75"	N/A	N/A	9.5"
Anemometer	N/A	18.5"	7.5"	4.75"
Soil Temp & Moisture	N/A	3.93"	1.2"	Est. 1"
Teensy	N/A	1.4"	0.7"	Est. 0.1"
Xbee	N/A	1.297"	0.962"	0.215"
Solar Panel	N/A	10"	16"	.7"
Battery	N/A	7.1"	6.6"	3"
Buck Converter	N/A	12"	0.5"	N/A

Table 2: Weather Station Dimension Specifications

3.2.2. Dimension of depth sensor stations

The depth sensor stations will fit inside a rectangular prism which is 1m in length and width and 3m tall, not including the depth sensor itself which will extend to the bottom of the stock pond.

3.3. Mounting Locations

3.3.1. Placement of Station

The station will need to be placed on a flat square meter section of land. The station will also need to be fixed into the ground with stakes if windy conditions will be present. This will require a mallet and soil with the appropriate conditions for securing the station to the ground.

3.3.2. Mounting of Sensors

The sensors will be placed in the ground or mounted on tripods to provide the optimum environment for the sensor to gather the data. For example, the pyranometer will be mounted such that no shadows are ever cast upon it and the anemometer will be mounted so that nothing is blocking wind around it. There are several options for purchasing mounting equip for each of the sensors mentioned in this document.

3.3.3. Mounting of Solar Panel, Controller, and Battery

The battery solar panel will be mounted such that it receives an optimum amount of sun every day throughout the year. The controller will be underneath the solar panel along with the battery inside a waterproof housing.

3.3.4. Mounting of Microcontroller and Power Converter

The microcontroller and power converter will be placed in a waterproof housing underneath the solar panel. The cabling for the sensors will run into the housing and be processed by the microcontroller. An opening for an RPSMA wire to run to the antenna.

3.3.5. Mounting of Antenna

The antenna will be mounted so that it points towards the central network node. An RPSMA cable will run to the XBee communication chip attached to the microcontroller.

3.3.6. Mounting Locations for Central Network Node

The central network node will have an option for mounting it onto a pole to help establish line of sight with the sensor stations and/or improve antenna and communication performance between the central network node and sensor stations.

4. Thermal Interface

4.1. Thermal Shielding for Air Temperature Sensor

The air temperature sensor on the climate sensor stations will have a radiation shield on it to improve accuracy of the sensor with respect to detecting the exact air temperature without influence from incident radiation from the sun.

4.2. Cooling of Battery

The battery will be air cooled under the solar panel. The heat generated by the battery should be able to dissipate on its own.

5. Electrical Interface

5.1. Primary Input Power

5.1.1. Primary Power for Climate Sensor Stations

All power for the climate sensor station will be supplied by the 10W solar panel, which will be used to charge the 12V battery. The battery will then be used to supply power to the computing, sensing, and communication subsystems. The voltage will be regulated and buck converters will be used to supply acceptable voltage levels to components which cannot use 12V inputs.

5.2. Signal Interfaces

5.2.1. Digital Climate Sensors

The digital climate sensors will communicate to the computing subsystem in their native language. The native language for each type of sensor is shown in table 1 below.

Sensor	Sensor Type	Native Language
Decagon 5TM	Soil moisture & temperature	SDI-12

Table 3: Native Languages for Digital Sensors

5.2.2. Analog Climate Sensors

The analog climate sensors will communicate to the computing subsystem by outputting a voltage in the range specified below in table 2. The specification sheets for each sensors will be used to program the computing subsystem to interpret the output values of the subsystem.

Sensor	Sensor Type	Output Range
Davis 6465	Rainfall	Pulse
Apogee SP-110	Solar irradiance	0 to 2.5V
Davis 6475	Air temperature	~0Ω to ~300kΩ
Davis 7911	Wind speed	Pulse
Omni 2600	Depth	0 to 100mV

Table 4: Output Ranges for Analog Sensors

5.3. Voltage and Current Levels

The current being drawn by the majority of the sensors can be regulated and they will not draw a significant amount of current. However, the XBee communication chip and the Omni Depth sensor will both draw a significant amount of current when in use. The XBee will consume 250 mA during transmission and the Omni will consume 25 mA. The 20 Ah battery and 10-watt solar panel will be more than enough to compensate for the current drain of these two activities.

5.4. User Control Interface

The only interface with the user that the climate tracking network will have is the web-based GUI which will allow the user to view the data being collected by the sensor. No other user interface is required or has been requested by the sponsor.

6. Communications / Device Interface Protocols

6.1. Xbee Communications Protocol

All communications between the climate/depth sensor stations and the central network node will be handled using the Xbee communication protocol on the Xbee RF modules at a range centered at or near 900MHz. This protocol operates in specification of IEEE standard 802.15.4-2015.

6.2. Microcontroller Input and Output

The microcontroller has a variety of digital and analog input and output pins. The pins can read and transmit signals from 0V-5V. This meets the requirements of all of the data protocols used by the sensors mentioned above.

6.3. 3G Communication

The microcontroller will also use an Xbee that uses the 3G communication protocol described in the IEEE 802.16 standard. This will be used to connect the central network node to the 3G communications network.

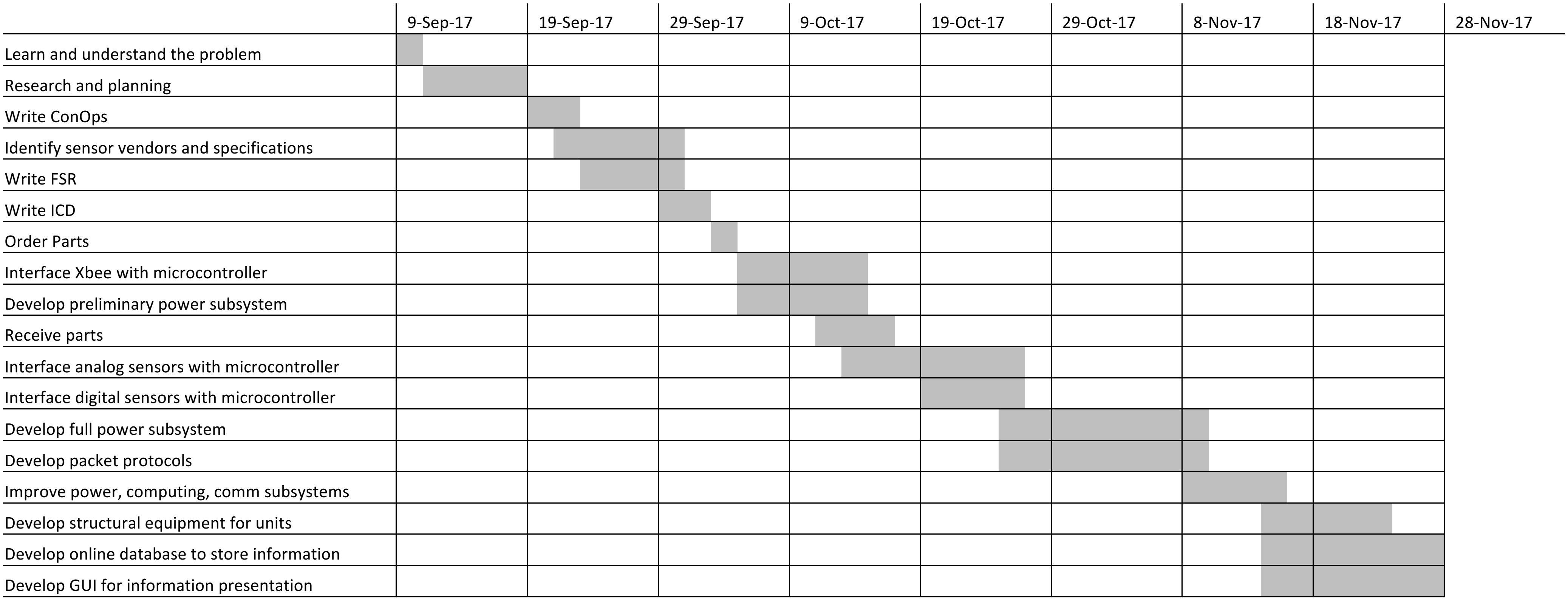
STAR Programs Climate Tracking Network

David Fawcett and Trevin Cooper

SCHEDULE

REVISION – 1
4 October 2017

Execution Plan for STAR Programs Climate Tracking Network Fall 2017



STAR Programs Climate Tracking Network

David Fawcett and Trevin Cooper

VALIDATION PLAN

REVISION – 1
4 October 2017

Validation Plan for STAR Programs Climate Tracking Network

Status Indicators	
Completed	
On Schedule/In Progress	
Behind Schedule	

Task	Deadline	Current Status	
Understand the problem	09/09/17	Completed	
Research and brainstorm	09/19/17	Completed	
First revision ConOps written	09/23/17	Completed	
Sensor vendors and specifications identified	10/01/17	Completed	
First revision FSR written	10/01/17	Completed	
First revision ICD written	10/03/17	Completed	
Parts ordered	10/05/17	Order form sent for parts ordered through Texas A&M. Remaining parts must be ordered through STAR Programs.	
Xbee controller interfaced with computing subsystem	10/15/17	On schedule	
Preliminary power subsystem developed	10/15/17	On schedule	
Parts received		On schedule	
Soil moisture/temperature sensor	10/17/17	On schedule	

Anemometer	10/17/17	On schedule	■
Air temperature probe	10/17/17	On schedule	■
Rain gauge	10/17/17	On schedule	■
Pyranometer	10/17/17	On schedule	■
Radiation shield	10/17/17	On schedule	■
Battery	10/17/17	On schedule	■
Solar panel	10/17/17	On schedule	■
Buck converter	10/17/17	On schedule	■
Microcontrollers	10/17/17	On schedule	■
Xbee chips (3G and 900MHz)	10/17/17	On schedule	■
Xbee modules	10/17/17	On schedule	■
Water depth sensor	11/04/17	On schedule	■
Analog sensors reporting to microcontroller (except water depth)		On schedule	■
Anemometer	10/27/17	On schedule	■
Air temperature probe	10/27/17	On schedule	■
Rain gauge	10/27/17	On schedule	■
Pyranometer	10/27/17	On schedule	■
Digital sensor reporting to computing subsystem		On schedule	■
Soil moisture/temperature sensor	10/29/17	On schedule	■

Full power subsystem developed		On schedule	■
Generates power from sun	11/03/17	On schedule	■
Stores power in battery	11/06/17	On schedule	■
Regulates voltage/current levels	11/07/17	On schedule	■
Operates for 24 hrs with load	11/10/17	On schedule	■
Packet protocol designed		On schedule	■
Error-checking protocols	11/10/17	On schedule	■
Minimize transmit time	11/10/17	On schedule	■
Structural equipment designed		On schedule	■
Supports technical components	11/16/17	On schedule	■
Shields technical components	11/16/17	On schedule	■
Water depth sensor reporting to microcontroller	11/13/17	On schedule	■
Online database created		On schedule	■
Stores information	11/25/17	On schedule	■
Receives transmitted information	11/25/17	On schedule	■
GUI created		On schedule	■
Presents data to user logically	11/25/17	On schedule	■