Hardware and Software Prototyping of 5G-and-Beyond Wireless Systems and Rural Broadband

Documentation and Educational Website Final Design Document

Team Number: 31

Client: Dr. Hongwei Zhang

Advisers: Dr. Hongwei Zhang

Team Members/Roles:
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Executive Summary

Development Standards & Practices Used

List all standard circuit, hardware, software practices used in this project. List all the Engineering standards that apply to this project that were considered.

Summary of Requirements

- Create and host an Elegant Website
- Educate Junior and Senior Engineers on LTE and 5G to work on with the system
- Compile and organize relevant websites
- Complete a lesson plan for Students knowledgeable with STEM
- Create 10 Quality Videos on LTE and 5G topics
- Create Experiments ISU Juniors and Senior can perform with the equipment in Durham(WiCi Lab, and Basement Lab)
- Create learning resources
- Assess learning tools with real Juniors and Seniors during the last 6 weeks

Applicable Courses from Iowa State University Curriculum

- SE 319
- Com Sci 309
- Com Sci 363
- SE 339
- Com Sci 352
- CPRE 489

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1 Team Composition

1.1 Team Members

Team Members	***Majors***
Adam Kruger	Software Engineering
Benjamin Riemersma	Software Engineering
Danny Cao	Electrical Engineering
Ethan Gabriel	Electrical Engineering
Zachary Miller	Software Engineering

1.2 Required Skill Sets & Member Coverage for Project

HTML Development
- Adam Kruger
- Zachary Miller
- Benjamin Riemer…

Website Design
- Zachary Miller
- Ethan Gabriel

Willingness to learn about 5th Gen Wireless Networks
- All team members

Tech Writer Skills
- Danny Cao
- Ethan Gabriel

Experiment Design
- Benjamin Riemer…
- Danny Cao

Git
- Benjamin Riemer…
- Zachary Miller

Surveying Experience
- All team members

1.3 Project Management Style Adopted by the Team

By committee decision, we decide on meeting times and assemble online or in person to complete crucial tasks or decide direction based on established project timeline.

Communication initiation takes place via group text and will carry over in Discord when discussing larger file documentation.

There are biweekly meetings with our project advisor, Dr. Hongwei to discuss project status and client requests.

1.4 Initial Project Management Roles

Adam - Technical Director

Benjamin - Communication Initiator and Lead Linux knowledgebase

Danny - Timeline Manager and Risk Manager

Ethan - Experiment Consultant

Zach - Milestone Evaluator and Task Overseer

2 Introduction

2.1 Problem Statement

There is a need for wireless technologies that provide affordable, high-capacity connectivity to rural communities and industries. Or more specifically:

- Increase wireless connectivity, especially in rural areas
- Provide advanced wireless coverage for locations within about 6 miles range from any of the ARA (Agriculture and Rural Community) sites
- Enable the research and development of rural-focused wireless technologies
- Cross community collaborative research, education and innovation

For the purpose of our project, we hope to provide resources and educational advancement for those who are in need, or for those who are interested in utilizing resources of the ARA project.

2.2 Intended Users and Uses

Those who are interested in 5G networking or may be involved with the ARA project and products are the target audience and intended users for our case. While specifically intended for Iowa State undergrads and perhaps owners of the ARA user equipment, it may be beneficial to understand the basics and procedures for understanding and applying 5G network fundamentals.

This will allow for a more streamlined process for getting introduced to 5G networking and allow for users to start experimenting and testing 5G network applications much faster compared to being self-taught and trying to find resources online to learn from.

Those who will use the ARA product who may benefit from our documentation process are located in Iowa State University (ISU) campus, City of Ames (where ISU resides), and surrounding research/producer farms as well as rural communities in central Iowa, spanning a rural area with a reach of over 60km.

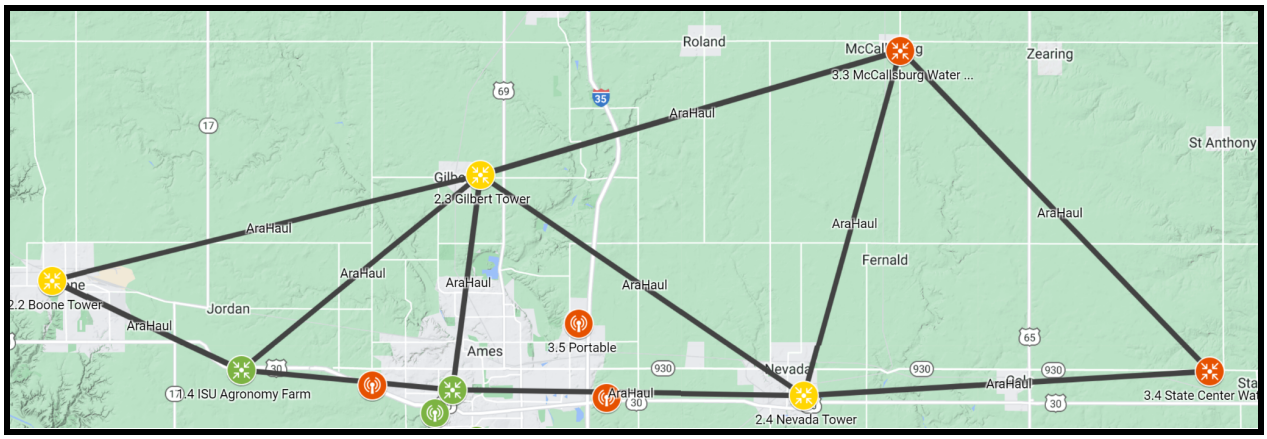


Figure 1. *Map of deployed towers and ARA connections*

Who benefits from or will be affected by the results of your project?

- ARA
  - Local place for learning and refreshing knowledge
    Provides a shared area for definitions
- Senior Design Students
  - Students need a way to quickly learn as ARA will likely be worked on by many more SD teams
- SD Advisors
  - SD Advisors can better assess students by looking at the experiments from the website that SD students have completed
- National Science Foundation
  - NSF does periodic assessments of the projects they fund. Having documentation about what is achievable and what isn't is valuable to this foundation

Who cares that it exists?

ARA - First and foremost, the ARA team members. In our experience there are tons of resources available, but organization, and access to these resources is difficult. A central location for knowledge with priority given to provable methods in 5G innovation is a crucial resource

Cellular Network Companies - As ARA members work on bleeding edge Wireless Com protocols and strategies, Cellular Network Corporations will need tools to learn about the ARA Engineers projects, hence the desire for documentation and learning exercises

Senior Design Students - This may seem narcissistic, but SD students will greatly benefit from

this resource as this project aims to onboard undergraduate students in 1.5 months to work with 5th Gen Tech

2.3 Requirements & Constraints

Functional Requirements

- Education website needs provide useful and relevant information to the public
- Provided resources must be applicable and in-use of the ARA project
- Inexperienced users must be able to reflect their learning after being exposed to the educational website

Educational Website, Wireless Network Experiments, and Student's Usability

- The Educational Website will have a collection of well sourced documents and hyperlinks to College Textbooks, Public Domain Educational Visual Media (Videos, PDF's,) a major glossary of Acronyms and Wireless Network jargon definitions.
- Wireless Network Experiments should be engaging and be capable of being performed with little set up time from supervisors. Examples include creating a POWDER account, Setting up a software defined network on an Ubuntu Virtual machine, compiling and running srsRAN, building a local network with routers - network switches – Cat5 ethernet cables, and MAC spoofing.
- Virtual Experiments should also be provided such as following the information from a transport block through the PHY Layer to Antenna Mapping.
- Finally, our resources should be tested by some Engineering Juniors and Seniors in the EE/SE/CPR E/CYB E majors. Their information acquisition time and personal feelings on the resource should be recorded

Resource Requirements

- Dedicated Web-Server on ISU's campus which is up most of the week for deployment testing
- GitLab for providing a shared codebase
- Access to the WICI Laboratories
- 5G Wireless Network Wireless Access Hardware (aka a big part of a UE)
- srsRAN Testing Equipment

- POWDER Server Accounts
- Permission to Reach out and Survey ISU college students (via email)

Physical Requirements

- Reasonably low latency website
- Comfortable viewing on a 12”+ screen
- Incorporates embedded videos for additional assisted learning
- Any information quoted or referenced must be cited for credibility purposes

Aesthetic Requirements

- Website must be structured in a way that promotes ease of learning (i.e. incorporations of many graphics and attempts to avoid long text)
- Website used to host documentation and experimental practices must be user friendly in terms of user-interface design
- Dates on all information must be provided

UI Requirements

- Looks good for the colorblind fellas
- Accessible Homepage with collapsible dropdown menu. Menu contains labels which redirect to more specific information
- Should place emphasis on key topics
- Vocabulary words and key ideas should have the same style and highlighting
- We should make a style guide
- Here is a preliminary list of topics to be included:
    - MAC, RLC, PDCP
    - MAC Experiments
    - PHY Layer
    - PHY Experiments
    - PHY Layer Quiz
    - Glossary
    - Acronym Glossary

Economic/Market Requirements

- No more than 10 hours of work per member per week
- Must be completed by April 14, 2023 (so within 5 months)
- Website must continue to be up post completion of project

2.4 Engineering Standards

3GPP
3GPP is the collection of standards organizations which are responsible for developing protocols and guidelines for mobile telecommunications such as 3G, 4G, and 5G. ARA is focused on providing rural areas 5G network access and thus would follow the 3GPP engineering standard.
IEEE:
IEEE is a standards association which ensures balance, openness, fair procedures and more among a broad range of industries. Our project oversees the process of utilizing many different kinds of electronics, electronic equipment, and methods of data analysis, each of which is governed by the previously mentioned standards. These standards are also enforced among the different companies that are invested with the project.
RoHS:
The Restriction of Hazardous Substances Directive, adopted by the European Union, restricts the use of specified chemicals for use in electronics and electrical equipment. Our senior design will be utilizing electrical and electronic equipment and must adhere to this standard if the product was to be implemented in the EU.
ISO/IEC/IEEE 23026:2015:

Defines the requirements for the life cycle of websites which promotes the usability of informational websites, ease of locating relevant and timely information, and informs users of practices for consistent and efficient web development.

3 Project Plan

3.1 Project Management/Tracking Procedures

Project Management Style:

The agile project management style has been adopted as the team needs the ability to revise different steps along the way. With different function groups and majors, it may be best to adapt an agile project management style to insure productivity for different specializations.

With the adoption of the again project management style, the following applications and software will be utilized:

- Discord, GitLab, Google Drive, and Clickup

3.2 Task Decomposition

Task 1: *Research and excavate through several educational resources to find relevant information*

We have been supplied with countless resources within the field of 5G to get a better understanding. What we need to do is: find the information that is applicable to us, and not random factoids.

Task 2: *Sort which of the relevant information is specific to ARA project and its use cases*

Once we have identified which information is relevant to us, we must discern which of this information is applicable to the ARA project, and how one can begin using and testing within the ARA landscape.

Task 3: *Demonstrate and teach how to test 5G servers via srsRAN and powder wireless*

We test servers using SRSran and Powder Wireless. Powder wireless is an end-to-end wireless research platform that can be used for mobile research. This will be included in our documentation and we will teach users how to use these resources.

Task 4: *Have college undergraduates (Juniors) to use and test our resource and website*

In order to make sure that these resources work well, and actually help the users be able to get a desired level of understanding, we will be testing the educational resources on Juniors and then receive feedback from them based on the performance of the website and the information presented by the documentation and educational aspect.

Task 5: *Code/organize website structure*

We have to make sure that the website is user friendly and easy to navigate.

To complete this task and make the website useable, we have to organize our documents and resources into specific categories so that users know what the information is for

Task 6: *Add all resources to website*

We must then compile all of the resources that we selected and collected, and then place them in the designated organized locations.

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

Task

- ***Milestone***

- Research and excavate through several educational resources to find relevant information
  - We have been supplied with countless resources within the field of 5G to get a better understanding. What we need to do is find the information that is applicable to us, and not random factoids.
- Sort which of the relevant information is *specific* to ARA project and its use cases
  - Once we have identified which information is relevant to us, we must discern which of this information is applicable to the ARA project, and how one can begin using and testing within the ARA landscape.
- Demonstrate and teach how to test 5G servers via srsRAN and powder wireless
  - We test servers using SRSran and Powder Wireless. Powder wireless is an end-to-end wireless research platform that can be used for mobile research. This will be included in our documentation and we will teach users how to use these resources. Successful 5G server testing will include a latency ping test.
- Get Juniors to use our resource and website
  - In order to make sure that these resources work well, and actually help the users be able to get a desired level of understanding, we will be testing the educational resources on Juniors and then receive feedback from them.
  - In terms of teaching effectiveness, quizzes monitoring the user's score will be analyzed and should be expected to be above 70%.
- Review feedback from testing
  - Once we have reviewed the feedback from the Juniors about our resources, we can determine which ones will be implemented into the website, and then begin designing it.
  - After reviewing feedback, we will hoist another test with a small sample size of users and hopefully expect an increase in quiz scores of about 5%.
- Code/organize website structure
  - We have to make sure that the website is user friendly and easy to navigate.
  - To complete this task and make the website usable, we have to organize our documents and resources into specific categories so that users know what the information is for.
- Add all resources to website
  - We must then compile all of the resources that we selected, and then place them in the designated organized locations.

3.4 Project Timeline/Schedule

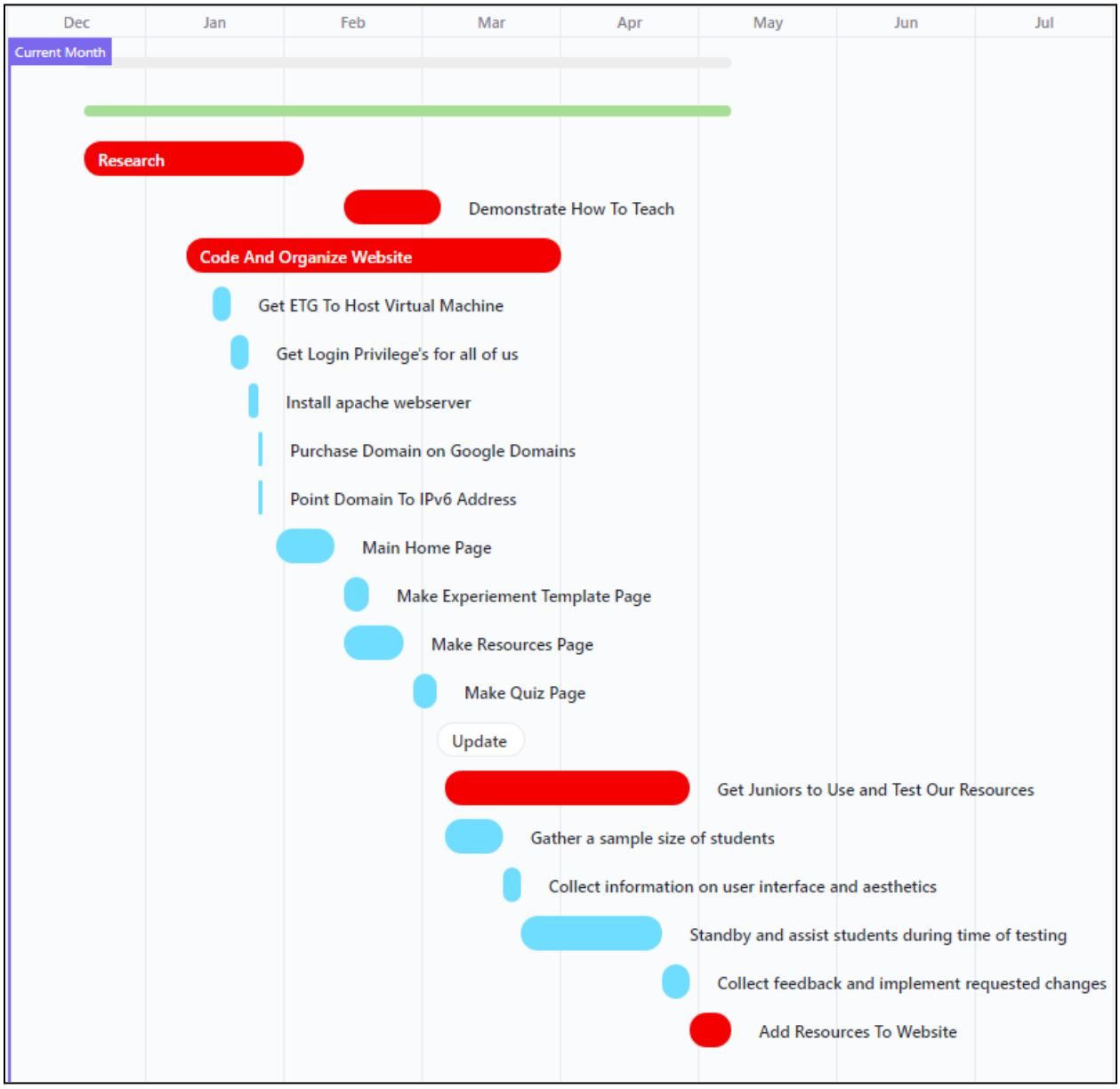


Figure 2. *Gantt chart representing timeline structure for project development*

3.5 Risks And Risk Management/Mitigation

Task 1: *Research and excavate through several educational resources to find relevant information*

- We are at risk of finding information and determining resources valuable when they are actually not
- Risk Probability 0.3

Task 2: *Sort which of the relevant information is specific to ARA project and its use cases*

- We are at risk of finding information and determining resources relevant to the ARA project when they are actually not
- Risk Probability 0.3

Task 3: *Demonstrate and teach how to test 5G servers via srsRAN and powder wireless*

We are at risk of users failing to understand how to test these 5G servers, and them not being able to set it up

- Risk Probability 0.3

Task 4: *Have college undergraduates (Juniors) to use and test our resource and website*

We are at risk of not having a large enough sample size to determine how our resources will affect the general public, and not just a few individuals

The time it will require for the testing process on college undergraduates may hinder results

- Risk Probability 0.6
- Risk Mitigation Plan:
    - As our project is mainly based on the effectiveness of having users being able to apply fundamental knowledge about 5G networks, there will have to be a large sample size of students to determine effectiveness of the project.
    - There will be an emphasis on gathering potential users months prior to completion of web development in order to have a large sample size of students. Incentives for completion of website learning programs may be in order.

Task 5: *Code/organize website structure*

We are at risk for having bad functionality for the website and not being able to access/use certain features.

- Risk Probability 0.6
- Risk Mitigation Plan:
    - We first are going to make sure our website is functional on localhost before releasing it to a public server. We can do this by utilizing our various tests such as unit tests which will help us develop our website code and functionality.

Task 6: *Add all resources to website*

We are at risk of not being able to add resources to sections based upon our initial organization techniques

- Risk Probability 0.2

3.6 Personnel Effort Requirements

Note: *Specific details regarding task numbers can be found in the above statements. Values used within the table are based on an hour scale.*

Team Members	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Total Hours
Benjamin	2	4	3	3	3	1	16
Zach	2	4	3	3	3	1	16
Danny	2	4	3	3	3	1	16
Adam	2	4	3	3	3	1	16
Ethan	2	4	3	3	3	1	16
Total Person-Hours Estimated to Complete	10	20	15	15	15	5	80

3.7 Other Resource Requirements

Note: We have assimilated a small collection of some of the resource requirements that may be required or of use for the project use and as such, have noted these below.

Center for Wireless; Communities and Innovation:

- WiCI, Projects, and Positions

ARA Project:

- https://arawireless.org

LTE and 5G

- Larry Peterson and Oguz Sunay, *5G Mobile Networks: A Systems Approach*, open-source book
- https://ebookcentral.proquest.com/lib/iastate/detail.action?docID=4603091
- https://www.sharetechnote.com/

Computer Networks

- **https://book.systemsapproach.org/**

Predictable, real-time wireless networking algorithms for control and AR/VR:

- UCS cellular scheduling: https://www.ece.iastate.edu/~hongwei/group/publications/UCS.pdf
- LDP real-time scheduling: https://arxiv.org/abs/2101.01768
- PRKS: http://www.ece.iastate.edu/~hongwei/group/publications/PRKS-TWC.pdf
- pktRT: http://www.ece.iastate.edu/~hongwei/group/publications/pktRT-TII.pdf
- pktR: predictable per-packet communication reliability guarantee (which is a foundation for ensuring sub-ms URLLC services in 5G and beyond)

srsRAN Application and Software:

- Website: https://www.srslte.com/
- srsRAN at Github: https://github.com/srsran/srsran
- Documentation: https://docs.srsran.com/en/latest/

Openair Interface Application and Software:

- Overview: https://www.openairinterface.org/
- Getting started: https://www.openairinterface.org/?page_id=25
- Tutorials: https://gitlab.eurecom.fr/oai/openairinterface5g/wikis/OpenAirUsage
- Emulation: https://www.openairinterface.org/?page_id=791
- Physical layer and MAC layer design: https://www.openairinterface.org/docs/workshop/3_OAI_Workshop_20170427/training/oai_L1_L2_procedures.pdf
- OpenAirInterface PHY abstraction layer: Section of interest starts at slide 66: https://slideplayer.com/slide/10035385/

- Installation tutorials for OAI: https://gitlab.eurecom.fr/oai/openairinterface5g/wikis/home
- large_scale_simulations' branch (includes PHY abstraction): https://gitlab.eurecom.fr/oai/openairinterface5g/tree/large_scale_simulations
    - Once this branch cloned (requires git software) make sure you are in v0.5.2 and not v.0.6.
- Mailing List: https://gitlab.eurecom.fr/oai/openairinterface5g/wikis/MailingList

Open Networking Foundation (ONF):

- Mobile projects: https://opennetworking.org/onf-mobile-projects/

Open RAN:

- https://opennetworking.org/open-ran/

4 Design

4.1 Design Context

4.1.1 Broader Context

Area	Description	Examples
Public health, safety, and welfare	The increased knowledge that we are looking to provide about 5G technologies should serve to better educate a portion of the public and, as such, will better increase the general knowledge of safety and utilization of 5G technologies.	The increased knowledge we look to provide should clear up the confusion that some people may have about the safety of 5G technologies.
Global, cultural, and social	Our website is being created with the purpose of being used for education by the university, and as a result, the site will work effectively in the community it is intended for.	Students that use our website in an educational setting should be able to increase their knowledge of 5G technologies, effectively increasing the potential that the university has to teach new material.
Environmental	While our website and educational materials may not take up or affect the environment significantly, the eventual development of 5G technologies in the area will take up space and require power to function.	The eventual inclusion of 5G technologies will include increased energy usage in the deployment areas. Deploying underground fiber optic cables would also be required.
Economic	As we will be building our website ourselves, the only cost associated should be the hosting of the site and the purchase of a domain name. This makes the project extremely financially viable as the benefit far outweighs the cost.	Since the hosting of our site would be paid for by our client/university, the product would always remain affordable for users, increasing its effectiveness and viability.

4.1.2 Prior Work/Solutions

Similar product: 5G RuralFirst: https://www.5gruralfirst.org/

This product is grounded with some of the same basic elements as the ARAWireless project - one of which is supplying 5G solutions to rural areas. This project concluded in 2020 and as such they have provided a project-conclusion report. This report contains data on what the

project discovered, as well as listing topics such as specific-use cases, the potential of 5G, and what hardware was implemented in their project.

The following list provides some pros and cons which describe the effectiveness of the 5G RuralFirst website as an education source.

Pros	Cons
● The 5G RuralFirst project is complete and contains information describing the project. ● The website is designed gracefully and is user-friendly. ● The 5G RuralFirst project has in-depth test cases describing the deployment of 5G technologies.	● The 5G RuralFirst website does not seek education as its primary goal. ● The 5G RuralFirst website does not include instructional videos/lessons. ● Website does not include resources for users to test their knowledge.

Like our project, this website acts as an extremely helpful tool for us to determine what kinds of information we should be publishing and talking about. While this website mainly focuses on the work that the 5G RuralFirst team was doing, and as such talks more about what they hope to accomplish, it still provides a good example of effective ways to portray the kinds of work that we will hope to teach.

Below are some additional sources which include literature on the topic.

Sources:

- *5G RuralFirst*, 29 Sept. 2020, https://www.5gruralfirst.org/.
- “Ara Wireless Living Lab.” *ARA*, https://arawireless.org/.
- Peterson, Larry, and Oguz Sunay. “5G Mobile Networks: A Systems Approach.” *5G Mobile Networks: A Systems Approach - 5G Mobile Networks: A Systems Approach Version 1.1-Dev Documentation*, 2022, https://5g.systemsapproach.org/.
- “Open Air Interface.” *OpenAirInterface*, https://openairinterface.org/.

4.1.3 Technical Complexity

1. The design of our project not only includes countless hours of research on the topic, but we must understand the content well enough to demonstrate things such as performing complex network tests and teach individuals how to do so.

2. This design contains many systems and subsystems. First, we must host, test and design the website itself using web programming languages such as HTML, CSS, and JavaScript. We then

must ensure that we understand the complex teachings, testing, and applications of it well enough to instruct users who may have never used important aspects such as linux.

3. The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.

4. There have been many clear examples of students who have been placed onto this project before and were experiencing difficulties with onboarding as mentioned by the advisor and client.

4.2 Design Exploration

4.2.1 Design Decisions

Quantity of Educational Material ***VS*** *Quality of Educational Material:*

Documentation portion of the website will not be purely text based, but will include graphics, embedded videos, and small tests along each core topics of 5G networks. This is crucial to ensure an engaging learning experience and not a regurgitated textbook.

Hands On Experiments to learn 5G ***VS*** *More Digital Experiments, such as Quizlet learning games and Digital Experiments with Cisco Packet Tracer and Wireshark*

For now our mind is on both, if it is within our time constraints. In terms of priority, there is a little more emphasis on digital experiments but there should be implementation of both if the opportunity arises.

Public Server hosted by Amazon Web Services ***VS*** *ISU based Web Server hosted by the ETG and only available while on ISU Network*

There are pros and cons to both. ISU based Web Server hosting has the benefit of having the security provided by the ISU network administrator teams, and ensures a reasonable number of website hits. Public Servers are a little out of our experience but our public IPv4 address will not change and should be accessible to anybody with an internet connection.

*Prioritizing ARA Members **VS** Prioritizing Juniors and Seniors*

We are going to try and make this website a fantastic starting point for college students and as a supplementary or refresher site for members of ARA. It should also be mentioned that the ARA members currently have a form of documentation regarding the ARA network, but this documentation is on a more advanced level.

4.2.2 Ideation

For at least one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). Describe at least five options that you considered.

Hosting website using ISU servers	Build off of existing ARA website	Content Management System
Hosting website using hosting service	Documentation and educational website design	Website builder
—	—	HTML/CSS/JavaScript

In order to identify our potential options, we used a Lotus Blossom Technique. We first started by putting our main task in the center, and then thinking of different aspects and ideas within our project that are connected to the main task. By doing this, we were able to come up with all of the different options that we will have to face.

4.2.3 Decision-Making and Trade-Off

We chose to use the weighted decision matrix that we did so that we could factor in several different aspects of the project that determine whether an option should be used or not be used.

0-10 Trade-off Ranking 10 = GOOD, 0 = BAD	Cost-Efficiency	Feasibility	Man Hours	Expected Performance	Total
Build off of existing ARA website	10	3	4	8	25

Content Management System	1	5	5	7	18
Website builder	1	5	5	7	18
HTML/CSS/JavaScript	9	7	6	10	32
Hosting website using hosting service	5	4	5	6	20
Hosting website using ISU servers	10	7	4	5	22

Agreed Upon Option:

Based on the weighted decision matrix, HTML/CSS/JavaScript using ISU servers will be the main method of approaching Documentation and educational website design. While website building may be cheaper in time and resources, It was ranked lower due to low technical complexity and the ability to design and be creative is not as good. Our client, who is also a professional in this field, recommended coding our own website.

It should also be noted that while building off of the existing ARA website may be the best choice in the long run, due to the difficulty of implementing within the existing website database, it was ranked lower in the decision matrix. The matrix only takes into account options that will most likely have the best performance based on the limited time the group has.

4.3 Proposed Design

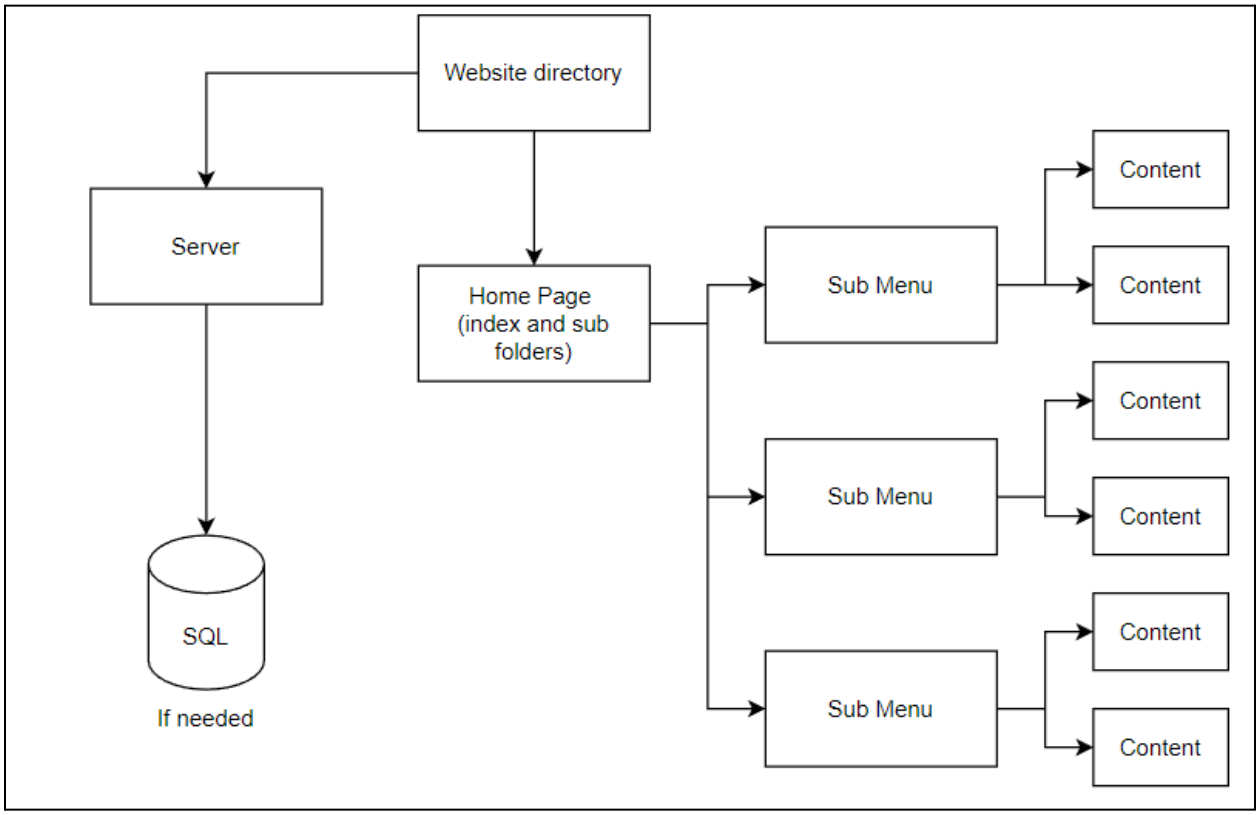
4.3.1 Overview

We are first establishing our goals and determining research relevant to 5G, ARA, and networking and routing. We then have to analyze what we researched and whether it is suitable for relevant academic consumption. After this, we will perform testing on the educational content to gauge how useful it is for 5G applications. Once testing is complete, we begin designing and compiling a website containing our research and findings

4.3.2 Detailed Design and Visual(s)

The website that will be hosted will be able to store the educational content designed in an organized way so that users can easily know what they are learning. The structure of the

website is going to be organized using HTML, this is the most baseline level of the website. Once we have the structure of the website implemented, we are going to implement sub folders and categories placed in an easy to access way to the user using CSS (cascading style sheets). Depending on feedback and our testing from users, we will alter the website accordingly, as well as the actual content of the website itself. Creative implementations of the website will be fueled by the JavaScript programming language. If user feedback is just and we need to implement a database for user data, we are prepared to do so. The domain of our website is TBA, and is yet to be purchased until we are confident that our website will function properly, and is ready to be released to the public. Once the website is finished, and all testing has been done, we will then connect it to the ISU servers, by pointing the domain (i.e. www.ARAdocumentation.org) to the designated static IP address so that users can access the website. Much of the design of the website and content is dependent on our testing, and how each and every element and aspect of the website is organized and implemented. We will carefully cater to our users and this will result in the release of our final product.



Code website layout using mark-up language HTML, design web pages individuals using CSS, add onClickEvents and creative functionalities using JavaScript, and organize the overall design -> Determine which content is to be put on the website -> Organize tested content into the designed website -> Establish a connection to server and database.

Subsystems:

- SQL - If needed a database, we will be able to send data from our website to be validated to our database.
- Sub Menus- A way to organize our data so that users can navigate with ease
- Content- the actual research content for users.

Components:

- Server System - We need available hosting and network access from ISU to enable our website to be accessible to those in ISU campus.
- Domain - We must have a public domain address so that users can access our url.
- Usage of markup language HTML to design the layout of the website.
- Usage of Cascading Style Sheets to alter visuals and tailor the overall design to our users.
- Usage of JavaScript so that users can have a more delightful experience navigating our webpages.

4.3.3 Functionality

Our design intends to operate as a functional website where users can learn about the deployment and science of 5G technology. We would expect that the user would be able to use our site to access well sourced information from documents and textbooks.

We would also expect that our site provides resources to test and perform experiments which include wireless network experiments using resources such as POWDER and Linux, as well as virtual experimentation. We expect to test the responsiveness and effectiveness of our system by testing some of the users on our site.

4.3.4 Areas of Concern and Development

We expect that our design should fully encompass the needs that our project has. Everything that we plan on implementing on our site is within reason, and by using design matrices to decide on how to do our project we feel that we have developed an efficient plan for completing our assignment.

One of the primary concerns for our project is effectively testing our site on real students here at the university. It’s easy for our team to work on the site as we can organize times to meet, but testing with students not only means that we need to adjust to the schedules of said students, but we have to make sure that we have a product that fits our different requirements and will produce good test data.

One of our immediate plans for addressing these concerns is to work with our advisor in order to arrange times with these students. Since our advisor is a professor at the university, we should be able to work with him and his resources in order to organize that part of the project.

4.4 Technology Considerations

Since our design is going to be a website used for hosting information and educating the public, our main technology is the way that we create/host our website.

We decided, using a decision matrix, that creating the website ourselves using HTML/CSS would be the most effective option. One strength that comes from using this technology is that we are able to effectively do whatever we would like with our website as long as we possess the knowledge to actually create it. As a result, one of the weaknesses of this method also includes the possibility of not knowing how to code a feature into our website.

One alternative method to writing the website ourselves would be using a website building service. We would not have to worry about creating the features that our website would have as we could use the given tools to do it, but this comes with an additional weakness - if the service we are using does not have a feature we want there isn't much we can do as a work around.

As a result, we believe that the HTML/CSS method should be the most effective.

4.5 Design Analysis

As our project mainly stems from applying the information about 5G network systems in a learning format on an interactive website, we have yet to build the website. However, there have been several instances of the team experimenting with setting up open source 5G networks and completing successful connectivity tests which will be applied to the project.

Regardless, there is a major emphasis on having to collect relevant information that is both factually correct and the website will hopefully present all of this information effectively with the web development phase as mentioned in the timeline. The main implication for the overall feasibility of our design will be the web development portion as we must be able to implement modern web features as our team consists of mainly three members who are experienced with the web development tools.

There may also be some build issues when implementing experimental practices on the website as the software required to do so operates on a waitlist timer for holding experiments. We

unfortunately have not found an alternative to countering this issue and time will have to be spent in order to address this issue.

5 Testing

5.1 Unit Testing

For our education tools, unit tests need to be done within the infrastructure of our website, or any other media platforms we create. Testing buttons, pages, links, and scroll features to only name a few. In order to do this, small portions of the website will need to be isolated in order to test if these features work properly.

Another part of unit testing that could be important regards the user experience. Since we plan to run this website on Iowa State servers, we need to test whether users outside of the Iowa State network can access this website.

5.2 Interface Testing

We will be hosting a website which should get on average between 50 and 100 hits per day. Usually from the same users, almost all of whom will be on the Iowa State University Local Area Network.

A Linux Virtual Machine and host will need to be acquired, likely from the ETG in Coover. From there we can host it. Git-Lab will likely be used to keep track of the codebase.

Main interfaces consist of: Client Web Browser <-> ISU LAN Server Web Server

YouTube Server <-> JavaScript/ HTML embedding API

GitLab Project Code Repository -> ISU LAN Server Webserver

Ebookcentral <-> JavaScript / HTML API

5.3 Integration Testing

Integration testing will be done after our website is completed. That is, once all the components are designed and tested individually. This will include the testing of buttons, tabs, links, scroll features, and embedded educational material (videos and interactions). We will test all these components by simulating the average user. This means putting ourselves in the shoes of someone wanting to learn about the material, and make sure the website features run seamlessly.

The backend features like server connections will also need to be tested for speed and reliability.

5.4 System Testing

After the above testing is complete and sufficient, we can look at the big picture. We will need to test website reliability in regards to user load and bandwidth restrictions. To do this, we will need to test a large number of users using the website at once to see if the server can handle it. Our main goal is to make the website as reliable to the user as possible, so we cannot afford any crashes or required server resets.

5.5 Regression Testing

In order for us to test regression with our website, we need to make sure that new pages of the website do not break it completely. This will most likely be a simple task, as each new page of the website will cause little to no issue. If we do come across some bugs with adding features, we will need to refactor some backend code to fix the issue.

5.6 Acceptance Testing

Our non-functional testing for the website will be done based on the user. We will create a simple Google Form that will give us feedback from users. Each user that helps us test the website will be asked questions based on the experience using our website, as well as if the website was educational. We will also be monitoring the quiz results and other methodology of collecting scores within the educational website to analyze how well the users are retaining the information.

We will also be in contact with our client to make sure that the educational material is important for further learning of our users. It is important that our website is engaging to the user, but also provides accurate and up-to-date information.

As far as functional design testing goes, there will be a part in the form that the user can indicate where they had bugs, if any. These responses during our testing phase will be really helpful in creating the best user experience possible.

5.7 Security Testing

- We want to make it so the site isn't too abusable if malicious users want to hurt it or deny its use.
- We will have to review our server hoster's operating system security.
- We will have to review GitLab's security.
- We will have to look at who deserves access to modify this website currently and after completion.

5.8 Results

Note: Only successful test results as of currently resulted from network performance and tuning.

Network Performance Test Results:

Testers will also use an iPerf3 setup which is a tool for testing network performance and tuning. We use this setup where the client will run on the UE side with the server on the network side. UDP traffic will be generated. Once we start the iPerf3 server, it will then listen for traffic coming from the UE.

```
---------Signal-----------|-----------------DL-----------------|-----------UL-
↪----------
rat  pci  rsrp   pl   cfo | mcs  snr  iter  brate  bler  ta_us | mcs   buff ␣
↪brate  bler
 nr  500    29    0  -16u |  28  n/a   1.1   9.9M    0%    0.0 |  28    48k ␣
↪9.5M    0%
 nr  500    25    0  -18u |  27   70   1.1    13M    0%    0.0 |  28    61k ␣
↪ 13M    0%
 nr  500    28    0  -16u |  27   70   1.1    11M    0%    0.0 |  28   6.7k ␣
↪ 12M    0%
 nr  500    30    0  -14u |  28   70   1.1   9.2M    0%    0.0 |  28    48k ␣
↪9.6M    0%
 nr  500    26    0  -13u |  27   71   1.1    12M    0%    0.0 |  28    30k ␣
↪ 12M    0%
 nr  500    31    0  -17u |  27  n/a   1.1   8.8M    0%    0.0 |  28    43k ␣
↪8.8M    0%
 nr  500    29    0  -14u |  27   70   1.1   9.9M    0%    0.0 |  28    52k ␣
↪ 10M    0%
```

```
nr  500   27   0 -7.0u |  27   70   1.1   11M   0%   0.0 |  28   47k  ␣
↪ 11M   0%
nr  500   26   0  -14u |  27   71   1.1   11M   0%   0.0 |  28   57k  ␣
↪ 12M   0%
nr  500   27   0  -16u |  27   70   1.1   11M   0%   0.0 |  28   49k  ␣
↪ 12M   0%
nr  500   28   0  -10u |  27   71   1.1   11M   0%   0.0 |  28   41k  ␣
↪ 11M   0%
```

6 Implementation

Note: Refer to 3.4 for overall design and implementation

For the implementation, it will mainly consist of the testing process referred to in the Gantt chart where the college undergraduates will be able to utilize our project.

However, preliminary implementation will require all team members to actively search for a sample pool of students who are applicable based on their major, who will be willing to engage in the rather long testing process. This process will most likely be the most time consuming and thus, an appropriate sample size must be acquired prior to the start date mentioned in the Gantt chart.

7 Professional Responsibility

This discussion is with respect to the paper titled “Contextualizing Professionalism in Capstone Projects Using the IDEALS Professional Responsibility Assessment”, *International Journal of Engineering Education* Vol. 28, No. 2, pp. 416–424, 2012

7.1 Areas of Responsibility

Area of Responsibility	NSPE Definition	IEEE Code Of Ethics	Importance

Work Competence	Only taking on work that engineers are capable of completing.	to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations	Medium. This project doesn't require the smartest of EE or SE's but it is still a meaningful project where we will impact the lives of the users.
Financial Responsibility	Working to uphold the value of currency and its meaning in our society	Not Stated	None, Cell companies will charge what they want from customers. As long as the cell service works it brings in the money.
Communication Honesty	Being honest in our ideas with the understanding that communal good is better than individual gain.	to protect the privacy of others	High, There is a lot to be confused about in 5G and web development.
Health, Safety, and Wellbeing	Prioritize public and personal health over financial or other incentives.	to hold paramount the safety, health, and welfare of the public	Low, 5th Generation Cellular service is really more of a privilege than a right.
Property Ownership	Respect others contributions and do not take credit for others' achievements	to credit properly the contributions of others	Medium, The goal of ARA is to provide Cellular service to rural communities, and our project goal is to improve and understand this service
Sustainability	Work for long term success.	to strive to comply with ethical design and sustainable development practices	High, Understanding Power Consumption/Requirements for the 5G Tech, both Radio Towers and User

			Equipment, is incredibly significant
Social Responsibility	Work only on projects which create outcomes of advance for all members and communities in society.	to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging	Medium, people in this modern world should be cognizant of the technology they utilize.

7.2 Project Specific Professional Responsibility Areas

Note: Refer to the table above.

In terms of team performance based on the professional responsibilities listed in the table above, we have noted this on a scale from “High, Medium, Low, None”.

Work Competence: Medium

Our team is performing moderately well based on the experience of our team and the introduction to a rather complex and unfamiliar topic of 5G network and beyond. We are able to comprehend 5G concepts and applications as well as utilize some technical jargon specific to 5G networks. We, as a team, can still look to improve in this area over time.

Financial Responsibility: None

The project application will not be responsible for any financial decision on the behalf of clients as our project will be open sourced and free to users. Thus, the team has not performed in this area of professional responsibility in the context of our project.

Communication and Honesty: High

The team has kept a close tab on the integrity of the topics presented and will continue to do so as this professional responsibility is the foundation of our project. Any miscommunication or lack of honesty in terms of our information presented to users will be detrimental to the project and thus, the team has worked closely with the advisor to avoid this.

Health, Safety, and Wellbeing: Low

The team has not put too much emphasis on this professional responsibility as mentioned in the above table. Safety will be more of a concern once the web development is near completion and there will be strides taken to ensure the safety of users data when visiting the website. As of right now. This is currently ranked low.

Property Ownership: Medium

As our project will be referencing information online and in textbook and documentation of the ARA network and 5G network, there will be a huge importance in providing proper credit to resources utilized in the project. The team currently has a list of resources that will be utilized during our project development and will spend more time near the end of the development process to properly give credit where applicable to align with this professional responsibility.

Social Responsibility: Medium

As our project is mainly advancing the user's experience with the ever growing 5G network and application capabilities, our project ties in nicely with this aspect of professional responsibility. Thus, the team has currently performed moderately well as the process of this project development has already begun to influence the advancement of the project members.

7.3 Most Applicable Professional Responsibility Area

Communication and Honesty is a crucial area to focus on. There will be a lot of jargon on our website and from as part of the process for making our website. We as a group will strive to give correct definitions without misleading via oversimplification. We will need to back up our claims and be willing to change in order to agree with 3GPP’s growing definitions.

8 Closing Material

8.1 Discussion

What we seek to gain from this project is mainly educationally based. We intend to create an educational website that does the following:

- Provide educational content that teaches users the concepts of 5G networking
- Create engaging content and not page long readings
- Provide external resources for further learning
- Provide future insights for learning

We hope that our users will find our website informative and engaging. We will be paying close attention to user feedback through our google form that records responses based on user experience.

8.2 Conclusion

Summarize the work you have done so far. Briefly reiterate your goals. Then, reiterate the best plan of action (or solution) to achieving your goals. What constrained you from achieving these goals (if something did)? What could be done differently in a future design/implementation iteration to achieve these goals?

At the beginning stages of this project, we intended to research advancements in the 5G field around Ames, Iowa. We had connections with Agriculture and Rural Communities (ARA) and were on a path to experiment with their equipment to learn more about the future. Recently, we have taken a new path. We are now focused on education, teaching others about what we have learned along the way. For this educational material, we have been narrowing down ways to acquire server and domain access.

8.3 Appendices

We have recently taken a new direction for this project, evident by the differences between our past submissions and this document. Our new focus is education, and for people to be able to use our website to get efficient information about 5G networking. We have learned a fair bit about 5G networking during this semester, but this new direction is far different from the previous.

Beginning the spring semester, we intend to sink our teeth into website design architecture and start understanding our plan of attack. We hope to produce a website that will help future students and outside users learn basic 5G knowledge in order to push this field to new heights.

8.4 Team Contract

Team Name sdmay23-31

Team Members:

1) Zachary Miller 2) Benjamin Riemersma

3) Ethan Gabriel 4) Adam Kruger

5) Danny Cao

Team Procedures

1. Day, time, and location (face-to-face or virtual) for regular team meetings:

    - Thursday - 5:30 pm (Discord)
    - Friday - 4:30 pm to 5:00 pm (Hongwei Office @ Durham Hall 353)

2. Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):

    - Text - Quick Communication
    - Google Drive - File Storage
    - Discord - Vocal Communication

3. Decision-making policy (e.g., consensus, majority vote):

    - Democracy

4. Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):

    - Personal timekeeping
    - Any important information should be relayed through text

Participation Expectations

1. Expected individual attendance, punctuality, and participation at all team meetings:

- Try to make it to meeting on Discord on Thursday at 5:30 pm
    - Otherwise, inform group via text chat

2. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:

- Make personal deadlines clear and share with group members
- Ask for assistance when help is needed
- Establish group goals

3. Expected level of communication with other team members:

- Anytime during school week, and Sunday night
- Weekends are personal time
    - Unless deadlines or major updates are required

4. Expected level of commitment to team decisions and tasks:

- Life or death.

Leadership

1. Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):

Client Interaction: All team members

Danny - Component Design, Equipment Testing, Electrical Familiarity, Agricultural Applications

Adam - Software design, Debug, Modularity

Zach - Software Design, Testing, Programming, team organization, client interaction

Benjamin - Communication Initiation, Embedded Familiarity, Protocol Familiarity

Ethan - Component Design, Electrical Familiarity, Equipment Testing

2. Strategies for supporting and guiding the work of all team members:

- Keeping updated on Gitlab
- Meeting notes

- Teams updates

3. Strategies for recognizing the contributions of all team members:

    - Recognizing other team members work

Collaboration and Inclusion

1. Describe the skills, expertise, and unique perspectives each team member brings to the team.

Danny - Component Design, Equipment Testing, Electrical Familiarity, Agricultural Applications

Adam - Software design, Debug, Modularity

Zach - Software Design, Testing, Programming, team organization, client interaction

Benjamin - Communication Initiation, Embedded Familiarity, Protocol Familiarity

Ethan -

2. Strategies for encouraging and supporting contributions and ideas from all team members:

    - Be respectful to team members when they have ideas
    - Understand that none of us know what we are doing
    - Don’t Spam other team members

3. Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?)

    - Speaking up if there's a problem
    - Help team members

Goal-Setting, Planning, and Execution

1. Team goals for this semester:

- Complete design document
- Get onboarded with project as quickly as possible
- Give a good lightning talk
- Learn as much as we can

2. Strategies for planning and assigning individual and team work:
    - Coordinating through text/discord
    - Coordinate and plan what to do with differing expertise
    - Be willing to learn
3. Strategies for keeping on task:
    - Stay focused on task
    - Try not to go on tangents
    - Be mindful of deadlines

Consequences for Not Adhering to Team Contract

1. How will you handle infractions of any of the obligations of this team contract?
    - Talk to them and resolve issue quickly
2. What will your team do if the infractions continue?
    - Tell advisor or professor
    - Have team intervention

****

a) *I participated in formulating the standards, roles, and procedures as stated in this contract.*

b) *I understand that I am obligated to abide by these terms and conditions.*

c) *I understand that if I do not abide by these terms and conditions, I will suffer the consequences as stated in this contract.*

1) Zachary Miller DATE 9-15-2022

2) Adam Kruger DATE 9-15-2022

3) Benjamin Riemersma DATE 9-15-2022

4) Danny Cao DATE 9-15-2022