1st April 2023

Dr. Mike Hegedus and ENSC 405W Instructional Team
School of Engineering Science
Simon Fraser University
8888 University Dr.
Burnaby, BC, V5A 1S6

Re: ENSC 405W Final Project Proposal

Dear Dr. Hegedus and instructional team,

Gamma Insights is a team committed to providing an alternate method of groundwater detection that allows for unmanned, long-term monitoring in remote locations. This is application that currently lacks options in the low-to-mid price range, yet groundwater level is an key indicator for by resource-limited users, such as research teams. As a solution, Gamma Insights proposes the Hy-dar system.

Enclosed, you will find Gamma Insights's Project Proposal, which makes a business case for Hy-dar. The proposal describes the scope, risks, and benefits of the project, as well as examining the target market, competition, and cost analysis for Hy-dar as a product. We also include an introduction to our team members and the expertise they bring to this endeavor.

Hy-dar uses Ground-Penetrating Radar to detect how far the level of the water table is below the Earth's surface, recording its measurements over time. The system is self-powered by mounted solar panels, robust to outdoor conditions, can be installed and left unattended for multiple seasons at a time, and is able to be uninstalled and relocated. Further, our solution does not require the extensive drilling, licensing, or specialized equipment other methods of water table measurement rely on, reducing cost and logistical concerns. These factors make the Hy-dar system ideal for teams with limited resources and studies in remote wilderness locations or environmentally sensitive areas.

For any questions or concerns, please contact our Chief Communications Officer, Michael Ungureanu, at mungureanu@sfu.ca.

Sincerely,

M. U.

Michael Ungureanu
Chief Communications Officer

Gamma Insights (Company #06)

Final Project Proposal: Hy-dar

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Submitted to:

Dr. Mike Hegedus and ENSC 405W Teaching Team
School of Engineering Science
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Executive Summary

The water table is an important feature of the environment, both ecologically and geologically. Monitoring its level can result in important insights, with short term changes reflecting weather events and potentially predicting floods or droughts, and long-term variations helping researchers map the changing climate. Current methods of water table monitoring either involve drilling wells (a non-portable and invasive method), or are not autonomous, making long-term monitoring challenging. Further, these methods are highly expensive. Gamma Insights proposes a rugged, portable device, Hy-dar, that fills this gap in functionality for long-term remote use and caters to a lower price bracket. In this way, the Hy-dar system provides an ideal alternative to researchers and resource management groups interested in unmanned groundwater monitoring, especially in remote environments.

The Hy-dar system utilises ground-penetrating-radar (GPR) technology for collecting measurements of the water table. Commonly used in construction and various other sub-surface material mapping applications, GPR operates by sending electromagnetic waves directly into the ground while simultaneously receiving the attenuated reflected signals created by sub-surface interfaces and objects. From the shape, time delay, and strength of these reflections, it is possible to infer information about these underground objects without excavating the site.

Unfortunately, high-resolution GPR imaging presents serious technical challenges, such as high-speed sampling and large bandwidth requirements. The cost and difficulty of developing faster circuits and components is high even for well-established companies today, and so is out of the scope of this project. Instead, the Hy-dar system prototype will aim to satisfy a reduced set of requirements.

While the global market for this product is large, we will focus on British Columbia (BC) as an addressable market for the scope of this project. The direct demand from the academic market comes from three major research labs in BC studying groundwater-related topics, and several more labs investigating ecosystem health, climate change, wildfires, etc. Further, as the Hy-dar system lowers the cost of groundwater level measurement, research groups that found it unaffordable before may begin using this product. Though the academic market is not large, this product also opens up opportunities in the commercial market for provincial or municipal governments for environmental monitoring and assessment, the "smart agriculture" industry for irrigation needs, and in schools as an educational tool. Both academic and commercial markets are expected to grow as climate change and water use becomes a larger focus of innovation.

Hy-dar is quicker, easier, and more autonomous way to obtain measurements than its competitors, and provides the flexibility to perform a wide range of studies with one tool. Gamma Insights is working hard to make this project a reality so groundwater measurement is accessible to every researcher. Our Proof of Concept design ($574) was finalized on March 20th, 2023 and implementation is expected to be finished by April 12th, 2023. We expect to refine this design into a full prototype (expected to cost $1344) by August 2023. As a company, our hope is that with better water data, humanity will be better equipped to face modern water problems.

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Glossary

Acronym	Definition
BMS	Battery Management System
EFN	Environmental Flow Need
FMCW	Frequency Modulated, Continuous Wave (radar)
GPR	Ground Penetrating Radar
GWT	Ground Water Table
PCB	Printed Circuit Board
PoC	Proof of Concept
RF	Radio Frequency
RX	Receive
TX	Transmit
USD	United States Dollar

Table 1 - Glossary

1. Introduction

With the climate noticeably changing over time, the predictions and mapping of subsequent changes to the environment have become increasingly beneficial and are of interest to research groups nationwide. Gamma Insights aims to develop the Hy-dar – a Ground Water Table (GWT) measurement device capable of measuring water table depths over long periods of time in remote areas.

The GWT is the boundary separating the unsaturated soil visible on the Earth's surface from the sub-surface saturated soil, demonstrated in Figure 1. The depth of the water table is related to various ecological and geological features within the environment such as vegetation growth [1] and groundwater availability [2]. As a result, short-term changes in GWT depth can be used to characterize ecosystem health along with weather events such as droughts and floods as exemplified by British Columbia's Environmental Flow Need (EFN) policies. Additionally, long-term variations in the water table level allow researchers to map climate change and variability over time.

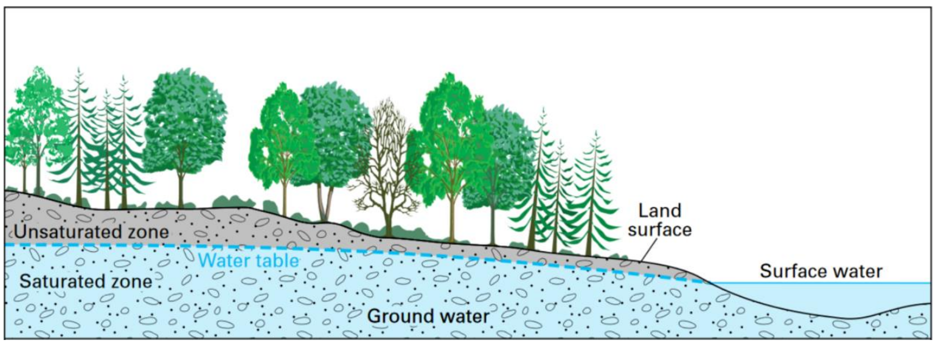

Figure 1 - Diagram of the ground water table [3]

Measuring the water table over time is commonly achieved using observation wells, which is the method employed by British Columbia's (BC) Ministry of Environment and Climate change to monitor the GWT using a network consisting of over 200 wells [4]. In recent cases, hydrology research groups have started to utilize Ground Penetrating Radar (GPR) technology for collecting short-term measurements of the water table. Commonly used in construction and various other sub-surface material mapping applications, GPRs operate by sending electromagnetic waves directly into the ground while simultaneously receiving the attenuated reflected signals [5]. This attenuation and time delay allow for a mapping of interfaces below the soil's surface. Studies have shown that this technology is capable of receiving up to 40% of the transmitted signal energy from GWT reflections [6]. The general concept the Hy-dar will be developed around is detailed in Figure 2 below.

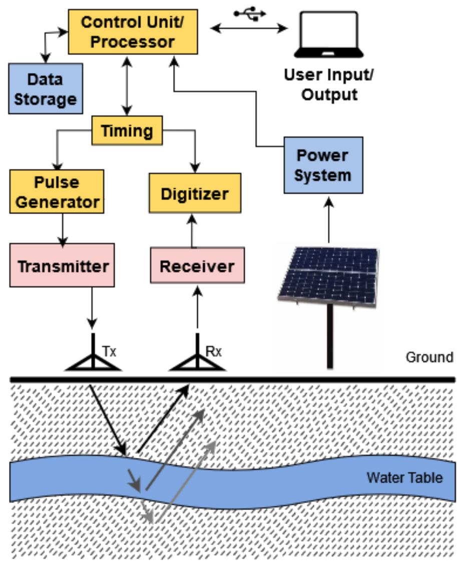

Figure 2 - Block diagram detailing the function of the Hy-dar's GPR implementation.

The current methods available for GWT measurement present an opportunity to enable measurement of ground water levels in remote areas without the need for drilling. By leveraging GPR technology, Gamma Insights intends to enable researchers to further understand the effects of climate change on the environment in British Columbia while facilitating the predictions of weather events across the province.

2. Project Scope

Gamma Insight's goal is to enable groups who want to autonomously monitor GWT levels in a less expensive and less invasive method than the existing solutions. To do this, the Hy-dar system utilizes GPR and relies on the reflections of the emitted signals to map the GWT. Effective GWT measurements would require a resolution of less than 10cm [7], and a range of depths up to and exceeding 10m [4]. To be a competitive option, Hy-dar needs to be able to take measurements over the course of a year or more with an adjustable interval between measurements. If Hy-dar is to perform these duties in remote environments, potentially in flood-prone areas, it must be rugged and weatherproof.

For the Hy-dar system to meet the GWT requirements without any permanent fixtures, it employs GPR. This method of imaging is complex and presents serious challenges such as advanced timing and bandwidth requirements, and high-speed sampling. Gamma Insights has determined that the cost and difficulty of overcoming these challenges for the competitive specifications puts them out of the scope of this project. As such, the Hy-dar system prototype will aim to satisfy a reduced set of GPR requirements so that other subsystems can be developed.

If Hy-dar is used for deployments longer than a year, it must be able to power itself continuously for over a year. Because the Hy-dar system is being designed with South-Western British Columbia in mind, it must contend with the constant overcast of the coastal winters. To allow for remote deployment of the Hy-dar system, Gamma Insights is designing a solar power system which will require allowances for inconsistent power supply in winter months. This problem is difficult to test within the timeframe of this project, however Gamma Insights does aim to develop a solution for the prototype.

Finally, the Hy-dar system must be able to survive the harsh environments it is designed for. This entails being resistant to destructive forces from wind, falling branches, and even wildlife, as well as being weatherproof to survive the wet environments of South-Western British Columbia. When designing the prototype, Gamma Insights aims to ensure it meets these requirements.

3. Risks/Benefits

3.1 Societal Risks

The primary risks to society from the Hy-dar system are electrical fire and subsequent damage to the environment. Aside from these concerns, the system has little risk to society at large, as it can only affect things in its immediate vicinity, is very resource-constrained, and has a low level of human interaction. Thus, the majority of risks posed occur on the individual level, typically during installation or data retrieval.

Electrical fire poses the largest risk to the Hy-dar system. Due to the autonomous nature of this groundwater measurement system, unexpected events like fire due to system overload, wiring faults or battery damage may not be detected right away, and the user may be unaware of the event until it is too late to prevent further damage. In the most extreme case, an electrical fire in a remote forest under dry and windy conditions could spark a forest fire and cause widespread destruction. However, Gamma Insights has taken several measures to prevent such a catastrophic event. On top of weatherproof electrical insulation from the environment, proper circuit protection and testing for wiring faults, the system is low-power and infrequently active (with the exception of the battery and charging system). To address safety concerns associated with lithium-based batteries, Gamma Insights uses a $LiFePO_4$ battery with a dedicated, integrated Battery Management System (BMS) that prevents operation when the battery can't safely function. $LiFePO_4$ batteries are less likely to combust or explode than other common lithium-based batteries [8], and the integrated BMS ensures a professional quality of battery safety.

After the considerations taken by Gamma insights, environmental risk is low for the Hy-dar system. Leaching, corrosion, and leakage of material or by-products have been addressed for Hy-dar though weatherproof enclosures or insulation on all electronics, non-corrosive exterior materials, and a lack of gaseous, liquid or powder materials or by-products which may leak or spill into the environment. One unaddressed concern is forest fire occurring around the device; in this case, the device may give off toxic gases as plastic and electrical components burn, posing a localized hazard. Unfortunately, it is very difficult to design any GPR system that can withstand the extreme conditions of a forest fire.

There is some low level individual risk while people are in close contact with the Hy-dar system. Manual installation introduces the possibility of human error and improper installation, and the stabilizing guy wires are easy to trip over in dark conditions. To address this, Hy-dar uses status LEDs confirming successful installation and guy-wire reflectors. Similarly, shock and electrocution risks are mitigated with electrostatic discharge (ESD) shielding around exposed components – such as Printed Circuit Boards (PCBs) – and insulated electrical components. A painted decal informs unaware pedestrians not to move the system.

3.2 Business Risks

Due to the relatively niche nature of the Hy-dar's intended deployments and usage, some risks related to business operations are important to acknowledge. Initially, the Hy-dar's intended market is southwestern B.C., which poses some risks. Although there are several hydrology centered research groups including the B.C.'s own Ministry of the Environment, the niche of this type of application is evident. However, this risk may be mitigated naturally by an increased interest in climate change in the future.

As mentioned previously, the standard GWT monitoring method of observation wells are relatively expensive, however this hasn't stopped governmental and environmental organizations from implementing numerous instances of them [4]. As a result, these existing groundwater level monitor deployments are highly unlikely to switch to using an alternative method since the initial costs have already been sunk and the systems function as expected. This was considered during the early development stages of the Hy-dar system since deployments are tailored for remote destination where wells are not possible, however it is worth noting the difficulties of expanding the already small initial market.

Furthermore, since the Hy-dar system is primarily of interest to hydrology and earth science research groups, if funding were to decrease for such organizations the implementation of such a system may not be justified. With the general increase of interest in climate change research and environmental monitoring, such a risk of little concern; it is however worth noting the reliance on the importance of such data and funding to applicable research groups.

In order for the Hy-dar to expand to different environments and measure the water table and lower depths than those present in B.C., different GPR specifications would be required and subsequently more power, and as a result a higher initial cost. In some cases an upgraded Hy-dar could potentially cost more than renting a mobile GPR system periodically or digging a well if the location permits. Although this risk is not detrimental to the Hy-dar's potential to enhance hydrology research, it is worth noting that the market for such a device is physically limited by the cost of high-resolution, low depth penetrating radar systems.

3.3 Benefits

The Hy-dar has the potential to provide the benefit of enhanced climate change data over time to the scientific community and general public. Although the intended use-case of the system is those particularly of interest to hydrology researchers and geoscientists, the benefits of monitoring the GWT can be widespread. The collection of such data over time could allow communities which regularly experience floods or drought to predict the occurrence of such weather events in advance. Additionally, the Hy-dar can be used to monitor groundwater supplies which many remote communities rely on as a water source.

4. Market / Competition

4.1 Market

As mentioned earlier, the GWT represents useful information for different areas of research, particularly hydrogeology. It can also be of use to researchers and government entities looking at ecosystem health, climate change, wildfires, and other related topics. While the global market for this is much larger, we will focus on the addressable British Columbia market.

In BC, one of the larger research groups in hydrology is the Coastal Hydrology Research Lab based out of Vancouver Island University (VIU), with 8 members and 4 affiliate members [9]. Another is the Simon Fraser University Groundwater Resources Research Group with 14 members [10]. Additionally, the

University of Victoria's Water & Climate Impacts Research Centre is a team of 11 researchers [11]. Finally, at the University of British Columbia Department of Earth, Ocean and Atmospheric Sciences there are currently 5 researchers focused on Hydrogeology [12]. In total, this represents 3 formal research groups, 28 researchers and students directly involved in hydrology research relevant to ground water. While this represents a small number of potential users, a network of monitoring stations could include hundreds of stations, as there are currently over 200 observation wells in British Columbia. This would also be of interest to the provincial government's environmental agencies, who have working relationships with the research groups previously mentioned, and currently rely on observation wells [4].

Another potential market for the Hy-dar system includes agriculture in British Columbia (BC). Irrigation affects the GWT, and to preserve the health of ecosystems near agriculture, BC's government has outlined requirements for minimum water table depth before manure spreading [13]. This depth is within 60cm, and the government recommends measuring this through an excavation of up to 120cm [13]. For best results, and on large farms, this would result in many excavations. Using the Hy-dar system, this could be reduced to a series of measurements at key points on the land [14]. Additionally, understanding the water table and its movements over a year could allow for optimal agricultural utilization of land and minimize excessive irrigation. "Smart" agriculture is a growing industry, comprising 1.19 billion USD in 2021 [15]. This market is shown in Figure 3 as well as projected growth.

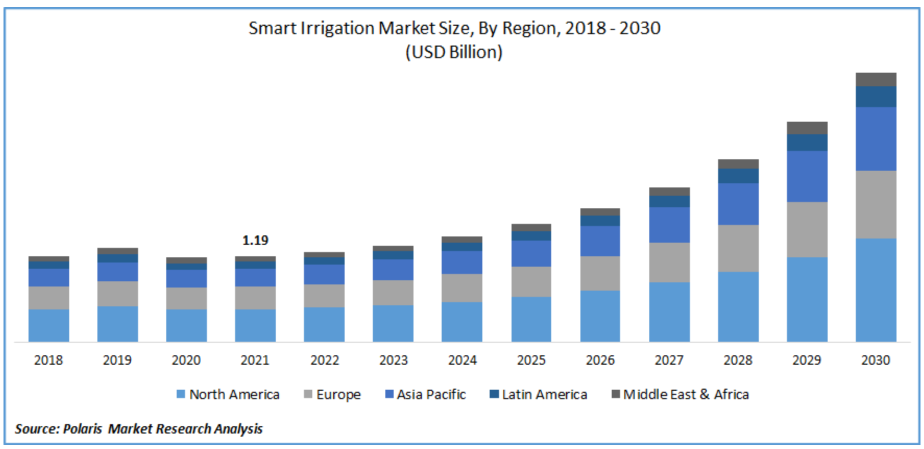

Figure 3 - Smart Irrigation Market Projection

4.2 Competition

Various methods for measuring the ground water table are utilized with the most proven being observation wells and more recently GPRs. Wells are optimal for long-term monitoring, whereas GPRs are valuable for short-term measurements potentially being taken in multiple areas due to their remote nature. Unfortunately, both of these solutions are quite expensive to implement and show the polar opposites in terms of mobility and measurement interval as shown in Figure 4 below.

Currently the B.C. Ministry of Environment and Climate Change monitors GWT levels using 226 observation wells that utilize pressure transducers for measurement, where most of the wells transmit data in real time through satellite communication [4]. These wells involve drilling to depths usually greater than 50 feet and can cost over $10,000 to construct [16]. In addition, installing or decommissioning a well can only be performed by qualified well drillers, well pump installers, or professional engineers and geoscientists [4].

Alternatives available commercially that do not require well drilling instead utilize GPR. Current products using GPR involve mobile systems with wheels (resembling a lawn mower) that are pushed around by a technician or researcher. This usually involves proprietary equipment and software, and requires manual user operation [17]. These mobile GPR systems are also costly, with prices starting well above $10,000 USD but often exceeding $20,000 USD [18], with rental costs that are also relatively high – usually in the thousands of dollars per month [19].

As stated, current methods of GWT monitoring either involve drilling wells (a non-portable and invasive method), or are not autonomous, making long-term monitoring challenging. The Hy-dar system fills this gap in functionality for long-term remote use, as shown in Figure 4.

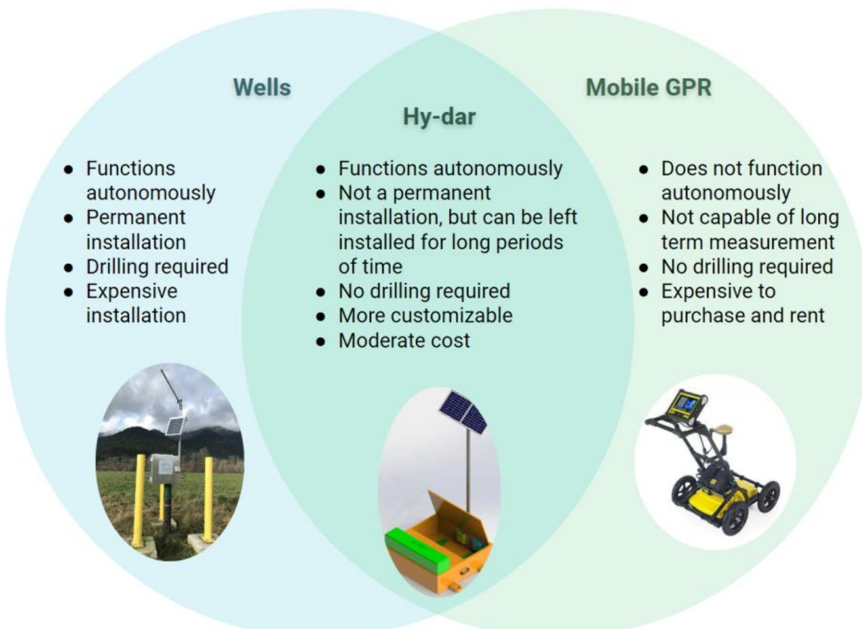

Figure 4 - Comparison of GWT measurement solutions

5. Company Details

Founded in January 2023, Gamma Insights aims to simplify GWT monitoring through the development of the Hy-dar system, an autonomous, non-invasive, and flexible GWT monitoring solution. Gamma Insights is comprised of 6 SFU engineering students, whose roles, interests, and past experiences are outlined below.

Michael Ungureanu – CEO, CCO

Michael is in his 6th year of electronics engineering, completing a computing science minor. Their coop experiences include testing high voltage motors, and testing radio devices, which sparked their interests in high voltage electronics as well as radar and radar applications. As Chief Communications Officer (CCO) they hope to apply their organized testing methodology to maintaining communications between their team and the team's correspondences. Their interests in radar led them to proposing the Hy-dar system, and as such they were appointed CEO.

Joanna Giannopoulos – co-CTO

Joanna is a 6th year electronics engineering student minoring in computer science whose interests include HAM radio, Software Defined Radio (SDR), image & signal processing, and machine learning. Previous co-ops at Orbital Research Ltd. and Rostrum Medical Innovations have provided experience with high frequency satellite communication devices and embedded firmware and software for biomedical applications, respectively. In her spare time Joanna also leads the Radio Communications sub-team of SFU Satellite Design Team. As co-Chief Technical Officer (co-CTO), Joanna intends to use her experience with radio systems to support the development of the Hy-dar system.

Nicholas Polyzogopoulos – CFO

Nicholas is a 5th year computer engineering student with interests in digital electronics design and verification, multimedia signal processing and compression, and deep learning. His previous co-op experience includes working in the ASIC industry in a verification role, and in the laser profiling industry doing electronics development. As the Chief Financial Officer (CFO), Nicholas plans to use his experience with parts sourcing and management to maintain an accurate budget.

Tyler Bailey – CIO

Tyler is a 4th year computer engineering student interested in real-time embedded systems and digital electronics design. Through previous co-ops he has gained experience with automation testing of networked radio devices along with firmware design and validation for battery management systems. Tyler hopes to leverage this experience in the development process of the Hy-dar and as Chief Information Officer (CIO) is responsible for managing development repositories and project management software.

Basil Giannopoulos – COO

Basil is a 6th year of electronics engineering student with a physics minor. Their interests lie in sensors, instrumentation, sustainability, novel materials, and microfluidics. Past co-op experiences in the biotech industry and the smart lighting industry have helped them develop a methodological approach to experiment setup and testing/verification, practical skills in electronics and biochemistry labs, and experience with laser cutting, 3D printing, and PDMS molding (microfluidic chips). As the Chief Operations Officer, Basil aims to help the team pursue their most ambitious goals while keeping safety, feasibility, resource constraints and scheduling in mind.

Joanna (Yuyu) Li – co-CTO

Yuyu is a 6th year computer engineering student interested in computer architecture and hardware design. She is passionate about pushing the boundaries of what's possible in this field and always looking for new and innovative ways to apply her skills and expertise. Her previous co-op experience includes designing circuits, testing prototypes, and troubleshooting issues. As co-Chief Technological Officer (co-CTO), Yuyu aims to provide technical leadership and strategic direction to the team while ensuring the project stays on track from a technological standpoint.

6. Cost Analysis

6.1 Cost Estimate

Our Hy-dar system consists of three main components: the signal transmission module, signal reception module, and the signal processing unit. Below is the cost breakdown for every module. Parts manufactured by the team are highlighted in green. All other parts are purchased or will be purchased.

Proof of Concept (PoC)

Parts	**Description**	**Cost ($CAD)**
Transmission module		
Pulse generator	Generate pulses of 2ns for TX.	$40
Voltage controlled oscillator	Oscillate the input signal to a desired center frequency. Oscillation frequency is controlled by a voltage input.	$100
Band pass filter	Allows only the desired frequencies to pass through while attenuating or blocking all other frequencies. On the transmitter end.	$6
Splitter	Split the oscialltor signal into two signals.	$33
Mixer	Up converts the baseband pulse to 500 MHz.	$56
Transmit Antenna	Transmits the signal.	$10
Signal reception module		
Band pass filter	Allows only the desired frequencies to pass through while attenuating or blocking all other frequencies. On the receiver end.	$6
Mixer	Down converts the received signal back to baseband.	$56
Variable Gain Amplifier	Amplifies the received signal.	$82
Receive Antenna	Receives the reflected signal.	$10
Signal processing unit		
Raspberry Pi 3	Collecting data and storing them on an SD card	$40
ESP 32	Converting analog data coming from the signal reception module into digital signals.	$15

SD card	Data storage	$15
Miscellaneous		
SMA connectors	Commonly used for connecting antennas and other RF components	$30
Protoboards	For implementing the prototyped design	$10
SMA cables	Used to connect devices that require a high frequency signal, such as radio transmitters and receivers, antennas, and other RF devices.	$35
SMA Adapters	For connecting components.	$30
Total		$574

Table 2 - PoC Cost Analysis

Engineering Prototype

Costs for the Engineering Prototype are estimates. Some manufactured components that were implemented on proto boards for the PoC will be manufactured as PCBs, and the antenna prototype will be remade for higher performance.

Parts	**Description**	**Cost ($ CAD)**
Transmission module		
Pulse Generator PCB	Generate pulses of 2ns for TX.	$80
Voltage controlled oscillator	Oscillate the input signal to a desired center frequency. Oscillation frequency is controlled by a voltage input.	$100
Splitter	Split the oscillator signal into two signals.	$33
Mixer	Up converts the baseband pulse to 500 MHz.	$56
Bandpass Filter PCB	Allows only the desired frequencies to pass through.	$30
Transmit Antenna	Transmits the signal. Will be made from sheet aluminium with improved matching + isolation features compared to PoC.	$60
Signal reception module		
Band pass filter PCB	Allows only the desired frequencies to pass through while attenuating or blocking all other frequencies. On the receiver end.	$40
Variable Gain Amplifier	Amplifies the received signal.	$82
Mixer	Down converts the received signal back to baseband.	$56
Receive Antenna	Receives the reflected signal. Will be made from sheet aluminium with improved matching + isolation features compared to PoC.	$60
Signal processing unit		
Digitizer PCB	The main module that converts the analog signal from the reception module to digital signal.	$150
Computing processor	Main computing module that processes the digital signal and output results.	$150
Power		
Battery pack w/ BMS	Main power supply for the system.	$150
Solar panel	Energy source.	$100
Solar charge controller	Controller which charges the battery pack and powers the system using the photovoltaic source.	$20

Current Sensor	Shunt-based current sensor used for inferring the battery pack's state of charge.	$10
Miscellaneous		
SMA connectors	Commonly used for connecting antennas and other RF components	$30
Protoboards	For implementing the prototyped design	$10
SMA cables	Used to connect devices that require a high frequency signal, such as radio transmitters and receivers, antennas, and other RF devices.	$35
SMA Adapters	SMA female to male adapters	$12
Enclosure	The physical housing for the system.	$80
Total		$1344

Table 3 - Engineering Protorype Cost Analysis

6.2 Funding

There are three main funding sources for the Hy-dar project: The Engineering Science Student Endowment Fund (ESSEF) fund administered by the Engineering Science Student Society (ESSS), the Wighton Development Fund administered by Dr. Mike Hegedus, and the Gamma Insight team member's own personal funding contributions as a last resort. Parts libraries from the ESSS and Wighton Fund are also available; however, the only parts that we may use from this are the microcontrollers (Raspberry pi 3, ESP32).

Gamma Insights is planning to apply for funding from both the ESSEF and Wighton Fund at the beginning of next term (Summer 2023), when applications will be taken. The ESSEF fund proposal will be submitted before the third week of class. Applying to both these funds will involve creating a proposal (similar to this one) in order to compete for funding. The Wighton fund will treat projects that benefit society preferentially, and we think the Hy-dar will demonstrate a positive benefit to society. The ESSEF Fund accepts class projects (Category C), which the Hy-dar project will fall into.

6. Project Planning

Gantt charts for Hy-dar project for the duration of ENSC 405W (January to April) are shown below. The first Figure 5 shows the first half of the semester and Figure 6 shows the second half for better viewing.

Planned milestones are shown in green. If these milestones were not achieved by the planned date, the actual milestone date is shown in red.

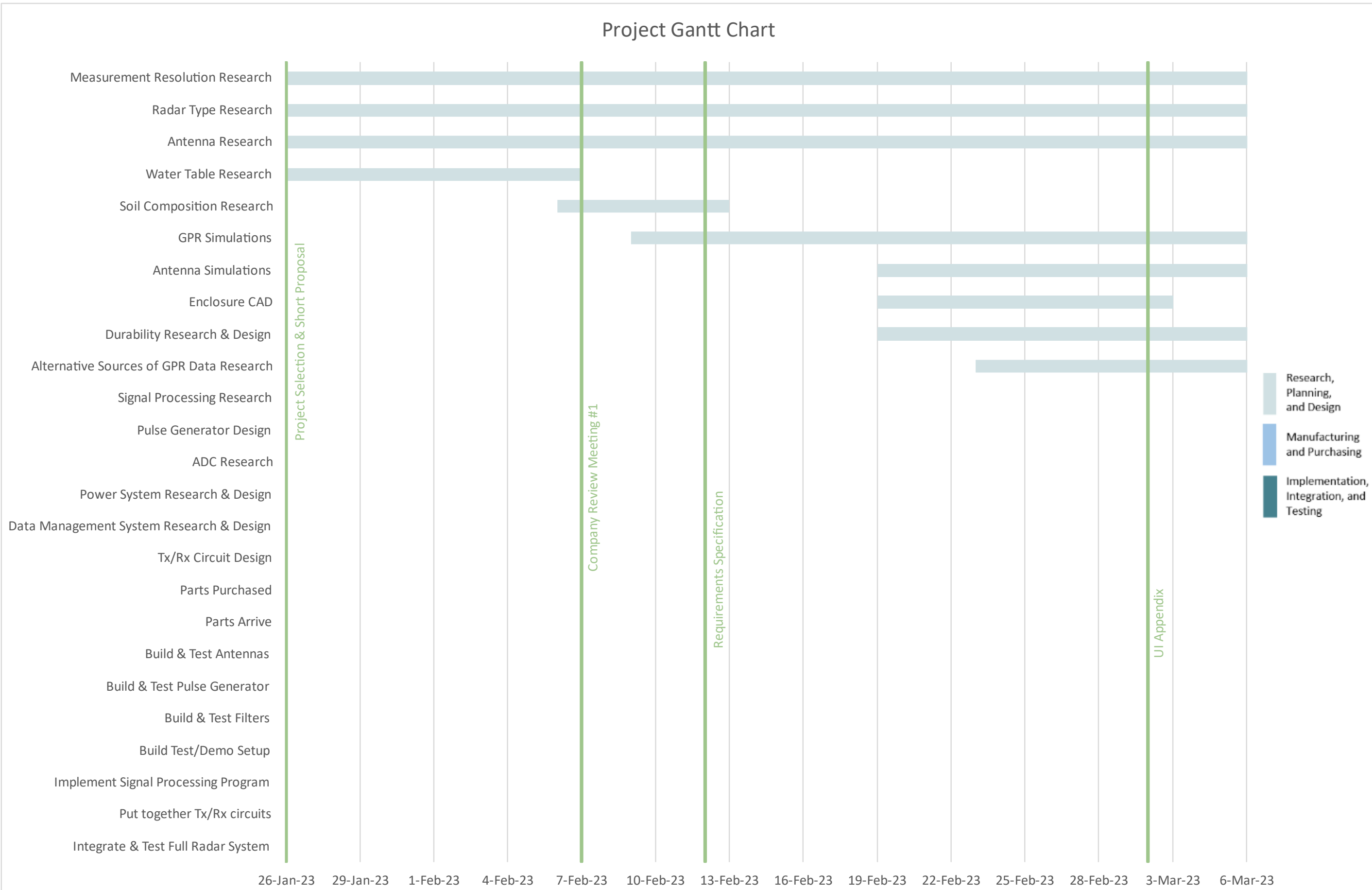

Figure 5 - Gantt Chart for First Half of ENSC 405W

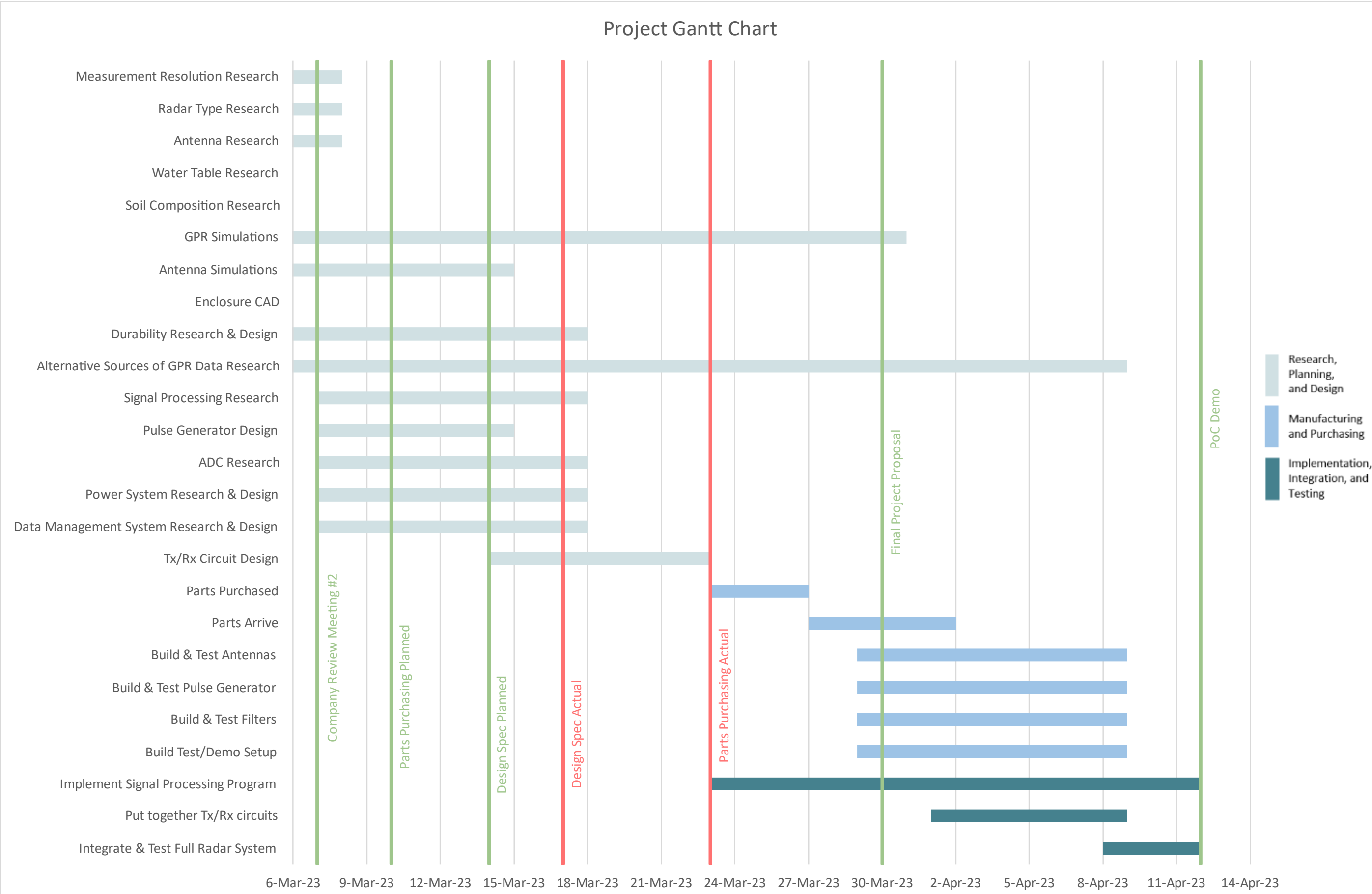

Figure 6 - Gantt Chart for Second Half of ENSC 405W

As seen, two main milestones were delayed throughout the project. The first was the Design Specification, which was delayed by 3 days. The scale of the Design Specification document was underestimated by the team, so significant time resources were reallocated to focus on completing the Design Specification. As a result, the parts purchasing task had to be pushed back until after the Design Specification was due, 2 weeks after the task was originally set to be completed.

7. Conclusion

In conclusion, our proposal for a GWT monitoring system is an exciting and valuable opportunity for exploration and development. Our research has identified numerous potential applications and benefits of such a system, including its use in agriculture, environmental monitoring, and hydrogeological surveys.

Our system currently uses GPR and consists of several components, including an antenna, pulse generator, transmitter, receiver, and signal processing unit. We intend to utilize GPR specialized signal processing techniques to accurately capture and analyze the reflections received by the antenna. High-speed timing performance is necessary for many components of the system, which has proven to be a great challenge to the team in the context of both sourcing and manufacturing components due to limited finances, time, and access to professional equipment and materials. To address these challenges, requirements were reduced for the PoC and prototype. Still, work is ongoing to achieve the necessary performance from components manufactured in-house, and testing has additionally proved a challenge as lowering system speeds means that only far away interfaces (on the scale of meters) provide reflections that can be detected with the systems current timing abilities. Future work to address these issues will be to determine if the use of other radar types (such as Frequency Modulated, Continuous Wave (FMCW)) will ease these high-speed specifications without introducing other challenging specifications, and additionally if other technologies exist that may allow the team to reach the reduced requirements without the use of radar.

Overall, this GWT monitoring system has the potential to be a valuable tool for a wide range of industries, including agriculture, hydrogeology, and environmental monitoring. We believe that our project will make a significant contribution to the field of GWT monitoring technology and will open-up new possibilities for future research and development in the related area. We are proud of what we have accomplished and look forward to seeing how this project progresses and develops.

We would like to thank Dr. Mike Hegedus and teaching assistant Usman Ahmed for organizing, running, and overseeing ENSC 405W. Additional thanks to Professor Chris Hynes for his ongoing assistance with the system’s antenna design. Thank for you for all the support and encouragement in guiding us through this import chapter in our undergraduate careers. We look forward to working with you and learning all we can from your insights and experiences.

8. References

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