January 20, 2014

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

Re: ENSC 440 Proposal - Solar Powered Battery Unit for an Offshore Hydrophone

Dear Dr. Rawicz,

The following document contains the ENSC 440 project proposal of AquaSol Solutions: a solar powered battery unit for a marine hydrophone. Department of Fisheries and Oceans Canada (DFO Canada) currently uses land based hydrophones to monitor the migration patterns of endangered resident killer whales on BC's coast. We at AquaSol Solutions have been called upon to design a solar powered battery unit to enable the use of offshore hydrophones.

We provide background information on why monitoring whale migration patterns is crucial to restoring the species to healthy population levels. We discuss the feasibility of completing the project in one semester, and outline the steps our team will take to ensure delivery of a quality product design. We also examine the sources of funding to be used for the purchase of required system components.

We are a team of highly motivated individuals with diverse backgrounds and skillsets. Our organizational responsibilities are presented, as well as our anticipated contributions to the design of our ENSC 440 project. In this document, more information can be found regarding our various backgrounds and their importance in delivering a successful project.

Sincerely,
AquaSol Solutions

Aiste Guden
Bharat Advani
David Stevens
Michael Lew
Martin Gradowski

Solar Powered Battery Charger for Offshore Applications

Project Proposal

Project Members:	Bharat Advani Martin Gradowski Aiste Guden Michael Lew David Stevens
Contact Person:	David Stevens aquasol-solutions@sfu.ca
Submitted to:	Dr. Andrew Rawicz – ENSC 440W Steve Whitmore – ENSC 305W School of Engineering Science Simon Fraser University

Issued Date: January 20, 2014

EXECUTIVE SUMMARY

Several communities of killer whales (Orcas) reside along the coast of British Columbia between the months of April and November. The population of these killer whales has declined due to pollution, overfishing, and from vessel traffic and their generated acoustic disturbances. For our capstone project, we wish to focus on the lattermost of these concerns by collaborating with the Marine Mammals Coordinator from the Department of Fisheries and Oceans Canada (DFO).

DFO would like to install hydrophones on navigational buoys to listen for killer whale calls and noise from vessel traffic. This will allow them to obtain a more complete view of killer whale migration patterns. AquaSol Solutions has been called upon to design a means of powering these hydrophones in remote, offshore locations. We propose to design a rechargeable battery pack powered by a corresponding solar power unit, along with control and monitoring units to ensure reliable operation of the system. Our system will interface with the hydrophones and a wireless unit that streams the real-time acoustic information to a receiver.

AquaSol Solutions consists of five fifth-year students in a variety of engineering disciplines. We bring with us many different perspectives, as well as skills in PCB design, digital signal processing, software engineering, biomedical instrumentation, and a background in renewable energy. Our team of engineers at Solar Aquatic Solutions has the diverse skillset necessary to bring this project to completion.

The estimated budget for the project is $1500. Our primary source of funding will be DFO, and we also plan on applying for the Wighton Fund and the Engineering Student Society Endowment Fund (ESSEF). The project will take approximately three months to complete; our expected completion date is April 20, 2014.

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1. INTRODUCTION

Killer whale communities that are common along the coast of British Columbia include the Southern Resident Killer Whales (SRKW) and Northern Resident Killer Whales (NRKW). The populations of these whales have been rapidly declining; current population estimates are eighty one for the SRKW, and two hundred fifty for the NRKW [4].

These rapidly declining population levels represent a threat to the delicate ecological balance of marine environments. Furthermore, there is also evidence that the decline of whale populations adversely affects commercial and industrial fisheries; this is because whales prey on predatory fish that in turn prey on commercially significant fish [3].

Along with pollution, a major contributor to the declining population of killer whales is disturbance from vessels. The presence of vessels distracts the whales from their normal behavior. In particular, vessel noise and sonar signals from the vessels hinder the whales' abilities to use echolocation to search for prey. This is especially dangerous for the whales in regions where salmon, a commercially significant fish and a major killer whale food source, is already sparse [2] [1].

DFO studies the migration patterns of the killer whales off the coast of British Columbia to help plan vessel routes that would minimize the risk to killer whales. They also stream real-time underwater sounds to detect killer whale calls and vessel sounds, in order to provide immediate feedback to the vessels in case they are in the proximity of killer whales. Currently, their recording and streaming system involves a navigational buoy outfitted with hydrophones and a wireless unit. The buoy is wired to and powered by land stations. However, the wiring is cumbersome and limits the range and mobility of the buoy.

To overcome these problems, DFO has asked AquaSol Solutions to design a solar-powered battery pack to wirelessly power the hydrophones and wireless unit. The battery pack would last for two weeks without recharging during the months of April to November – the period of peak killer whale activity in the region. Our proposed system would interface with the existing hydrophones and wireless unit, and will contain a battery pack monitoring system to ensure reliability and send a warning signal in case of imminent failure.

Figure 1: Solar-Powered Navigational Buoy [5]

2. System Overview

DFO already has pre-existing GSM (wireless transmission) units, hydrophones, and receivers. Our project involves designing a solar-powered battery charger system and power supply to charge the GSM unit and hydrophone. The solar panel will send electrical power to the charge controller, which will regulate the charging of the battery pack. The bulk of our efforts will reside in designing the battery protection/monitoring unit which will monitor individual batteries for their status. The battery protection/monitoring unit will communicate with the GSM unit to provide battery information that will be sent to the receiver so that maintenance crews can monitor the status of the batteries. The battery protection/monitoring unit will contain a fail-safe mechanism in the event of battery overheating or other issues, while sending an alert to the GSM unit.

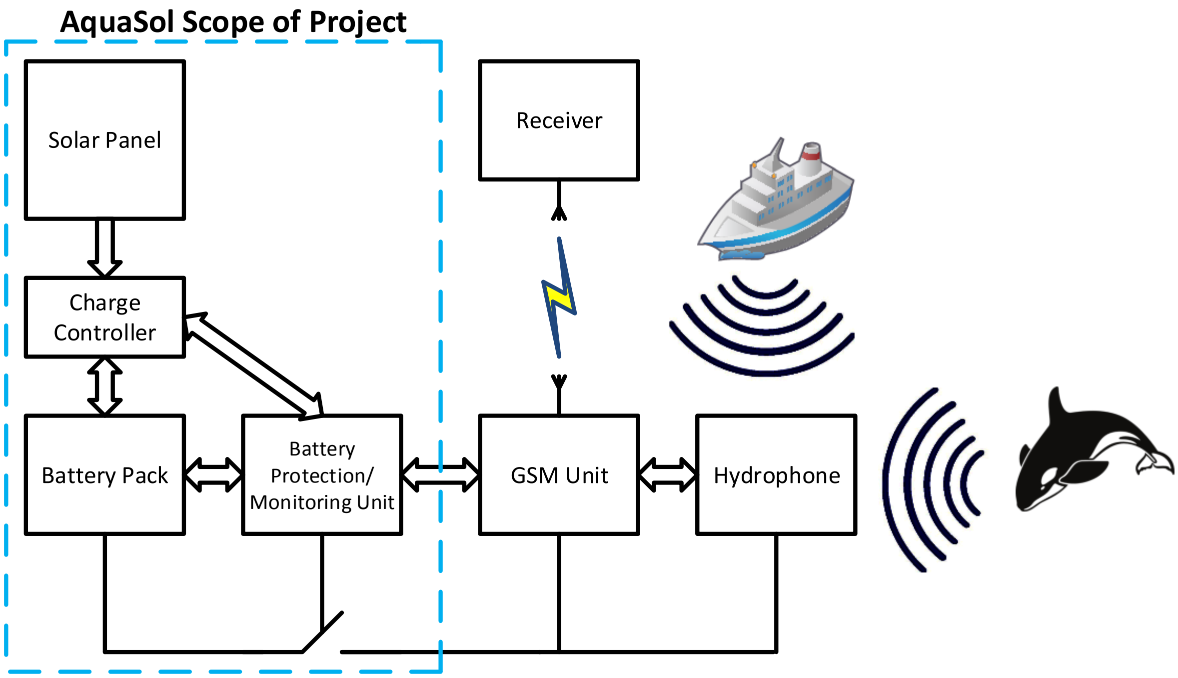

Figure 2: Block Diagram of Solar Battery Charger System

3. Product Design

The proposed solution involves creating two primary modules: a solar panel attached to a buoy and several lithium ion battery packs that are housed inside a waterproof container. The solar panel provides charge to the battery package during daylight hours and connects to it via heavy-duty waterproof cables. The battery packs must power a 24V, maximum 12W hydrophone with GSM transmission device, which is housed in a separate container. The battery packs must be capable of providing around 2 weeks charge under sunless conditions, although their expected operational times will be in June to September. Ideally, the hydrophone will be able to be powered on site all year round.

A single battery pack will consist of several smaller battery modules, each connected to the solar panel through a single charge controller. Because thermal runaway is a known risk with lithium ion batteries, the battery modules will be separated from each other with thermal isolation material in order to prevent a single overheating battery from crippling the functionality of the entire system. The individual battery modules will be grouped together in packs of 6, with each pack connecting to a small module monitoring controller. The monitors will be connected to a battery management software system, which will track the charge and temperature on each battery pack and cut off power to any pack that exceeds a critical temperature threshold. The battery management system will connect to the hydrophone and transmit data about its charge and the status of each battery pack to the GSM chip, so information about the system can be monitored remotely.

Current solar-powered battery charging systems do provide some of the functionality we require, namely that of providing a solar panel and a basic charge controller. Our proposed design offers a significant improvement over the existing systems for the given application. We have chosen to use lithium ion batteries in place of lead acid because of they contain 2x – 3x higher energy density than lead acid [6], which would lead to being able to store more power within a limited space. Additionally, lithium ion batteries tolerate deep cycling (discharge greater than 50% capacity) better than lead acid batteries, losing capacity at a much lower rate. The primary disadvantage of lithium ion is that the cost is almost 4x higher than lead acid. We have determined that the additional cost is justified, as the application may require long periods of providing power to the device without recharging.

Our main constraint for this project is the limited availability of time. Although we have been promised funding for the materials from the DFO in support of this project, we still only have a little over 3 months to fully complete and test the device. Thus, our goal is to produce a smaller, lower capacity proof of concept within the timeframe in order to minimize the investment risk from our sponsors and to be able to properly test the full design before committing further resources to make a large-scale version.

Our proposed design takes into account future scalability. As the individual lithium ion batteries would be relatively independent units connected to a charge controller and battery management system, scaling the design would require a larger solar panel, more battery units with a larger waterproof housing, and additional ports to the charge controller and battery management system.

This product would provide renewable energy to allow the existing hydrophone device to monitor killer whales in more remote areas, as it would no longer depend on being plugged in or within constant reach of DFO site employees. Once the system has been developed, it would allow researchers to gain more detailed information about the locations and numbers of endangered killer whales.

4. Risks

Lithium ion batteries are susceptible to thermal runaway. Therefore, it is important to limit charging current, as well as regulate the temperature to remain between 0 – 45 ˚C while charging. Lithium ion batteries should not be charged in sub-zero temperatures as this can lead to permanent damage that can compromise the safety of the battery.

During discharge, it is important to ensure that the temperature does not exceed the range of -20 to -60^{0} C. To resolve this problem, we plan to utilise temperature sensors to detect any violations, and thus allow us to cut off battery connection to the load and charger in order to save the batteries from damage [7].

Another risk is to avoid any accidental shorts during testing, development, and maintenance as this can lead to thermal runaway or damage to the batteries. Therefore, our design will have emergency shutdowns and power disables to avoid danger to the engineers/technicians and the electronics. For maintenance of the unit, we plan to include manual hardware switches to disconnect the battery and solar panel from the system to ensure engineers/technicians work in a safe environment [8].

5. Resources

We have several resources available to us to allow for the successful completion of this project. Firstly, one of our main resources is the collaboration with Paul Cottrell (DFO) who not only is able to provide direction on the overall project, but is also a contact point and facilitator for connecting experts in the operation and use of the Hydrophone and wireless communication systems with our company.

Our other two main collaborators that will help to ensure the successful completion of this project are Dr. John Bird, who may be able to provide an appropriate environment for testing our product; and Dr. Ash Parameswaran, who has extensive experience in electronic systems and who has offered lab areas and equipment for the assembly and storage of aspects of the project.

6. Budget and Funding

Table 1: Cost breakdown of all materials that will be required

Item	Cost
Solar Panels	$300
Batteries (Proof of concept)	$300
Microcontrollers	$60
Test Equipment	$300
Charge controller	$150
PCB	$250
PCB Components	$140
Total	**$1500**

7. Schedule

We have structured our project schedule based on several critical aspects and deadlines for the project. We have taken into account the due dates of the required project documents, but also included research, design, and the time required for component orders and shipping. A full breakdown of our schedule with estimated start dates can be found at the end of this document.

8. Team Organization

Table 2: Organizational Responsibilities of Team Members

Responsible Team Member	Task
Bharat Advani	Design of company name and logo
Aiste Guden	Recording meeting minutes
Michael Lew	Meeting agenda
Marty Gradowski	Booking meeting rooms in library
David Stevens	Team contact with CIO (Steve Whitmore)

AquaSol is made up of five senior engineering students, each offering a unique and diverse skillset to the company. As a highly motivated team, AquaSol strives to design reliable green energy systems to meet the needs of the future.

AquaSol follows a bottom up corporate structure in which all members are of equal status. We decided not to assign hierarchical roles (such as CEO, CTO, CFO, etc.) since all members of the team exhibit equal and adequate leadership skills. Rather, we assign tasks according to strengths and abilities. Based on the experience of the team members, Martin and Michael will be tasked with the hardware design, Aiste and Bharat will be responsible for the software development, and David will serve as an integrator of both the hardware and software. Martin has the responsibility of reserving a study room in the library for all team meetings. Who does the minutes?

The team will meet twice a week, on Tuesday and Thursday, in the Bennett library study rooms to discuss progress and difficulties. Based on these discussions, team members may have their roles adjusted or reassigned in order to complete important tasks or milestones. No individual will be assigned as a moderator or leader for the meetings; rather, everyone will act professional and respectful, allowing each member to voice their opinions. The meetings are projected to last

1 hour, but are scheduled for 2 hours; however, the full 2 hours will only be used based on necessity.

To ensure consistency of documentation, AquaSol has created a Dropbox folder for all group members to diligently update any of their current work so that other group members can remain updated on the progress of the project.

AquaSol group members are highly professional and function well as a team. Coupling the teamwork with each member's strong work ethics and complementary skills, we believe that AquaSol will be capable of designing a reliable solar powered battery charger.

9. Company Profile

Marty Gradowski

Marty is a fifth year Engineering Physics student at SFU. He is passionate about renewable energy, and holds a Residential and Commercial Photovoltaic Systems certificate from Solar Energy International (Colorado, USA). His dedication to renewable energy has led to an NSERC USRA position (Summer 2012) with Dr. Martin Ordonez, where he spent the semester developing a photovoltaic array simulator for varying irradiance and temperature profiles. This experience, coupled with training received from Solar Energy International, has inspired him to build a functioning solar powered DC lighting system for his home. Marty's passion for clean technologies that protect our environment will be an asset to our team of engineers responsible for developing a solar powered hydrophone for monitoring of whale migration patterns.

Bharat Advani

Bharat is a fifth-year Electronics Engineering student at SFU. He has done two co-op terms for a back-end CAD team at PMC-Sierra, where he designed and developed an email-based framework for handling DRAM instance generation requests. He has also worked as an undergraduate research assistant for Dr. Daniel Lee, working on the theory of power allocation in multi-way relay networks. Bharat has some background in analog and digital systems, and will be able to provide auxiliary support for every aspect of the project.

David Stevens

David is a fifth year Biomedical Engineering student at Simon Fraser University (SFU). He is passionate in areas of medicine and biotechnology and also has a strong interest in renewable energy. He has done three co-op terms working for Nippon Telegraph and Telephone Corporation (NTT) for the Microsystems Integration laboratories working on non-invasive blood glucose sensing. He has also spent a semester working as a research assistant in Dr. Bonnie Gray's lab, where he worked to develop a novel micro fluidic PCR chamber. David has a strong background in electronic and computer engineering concepts and applications, along with first hand knowledge and experience in the development of software and hardware applications for lab and production use. This would be useful for general support on the overall testing and implementation of the various components and aspects of the project.

Michael Lew

Michael is a fifth-year Electronics Engineering student at SFU with a high interest in hardware design. He has completed a co-op placement at Verathon Medical, where he designed a PCB for a D/A video converter prototype. He has also worked as a systems/hardware engineer co-op at Broadcom, where he often performed PCB rework, hardware debugging, and verification. Michael has as also worked as a research assistant for Dr. Ash Parameswaran, designing a PCB for a potentiostat circuit. Michael will be an asset in the hardware design aspects of the project.

Aiste K. Guden

Aiste is in her fifth year of Computer Engineering at SFU. Her primary interests lie in embedded firmware programming and operating system functionality. She has co-op experience at Tesla, where she programmed microcontrollers the body-control system, which included developing APIs for drivers and interfacing with an RTOS, RF communication, and creating firmware for testing the battery management system. She also worked for a semester in Dr. Lesley Shannon's lab, where she modified an embedded Linux operating system to function with asymmetric hardware. Although Aiste's strengths are primarily in programming and digital communication, she has some experience with circuit analysis, which would be useful as support on the hardware aspects of the project.

10. Conclusion

AquaSol Solutions is dedicated to providing robust and reliable self-contained renewable energy solutions for challenging and sensitive marine environments. In partnering with DFO Canada, our proposed renewable energy charging, power management and monitoring system will improve the versatility and capabilities of existing monitoring systems.

Our approach to providing near continuous renewable power takes the latest in battery and solar technology and couples it with a custom designed charging and monitoring unit to provide a cost efficient, easily upgradable and expandable end product that is safe and reliable. This approach will allow us to complete this project within our projected time frame of 3 months and within the estimated budget.

Contingent on the successful completion of this project by April 20, we envision that DFO will be on track to have their hydrophones able to be deployed in remote areas in the very near future to help in their goal of being able to better monitor both vessel traffic and whale migration patterns off the coast of British Columbia.

11. Sources

- Digikey
- Linear Technologies
- Texas Instruments

- Polar Batteries
- Latitude 51 Solar
- MRO Electronics

12. REFERENCES

Sources: where we're planning on purchasing parts

[1] Wild Whales. *Boat Disturbance*. Available: http://wildwhales.org/conservation/threats/boat-disturbance/

[2] Canadian Geographic. *Sound Polution*. Graham Slaughter. Available: http://www.canadiangeographic.ca/magazine/dec11/orcas_sound_pollution.asp

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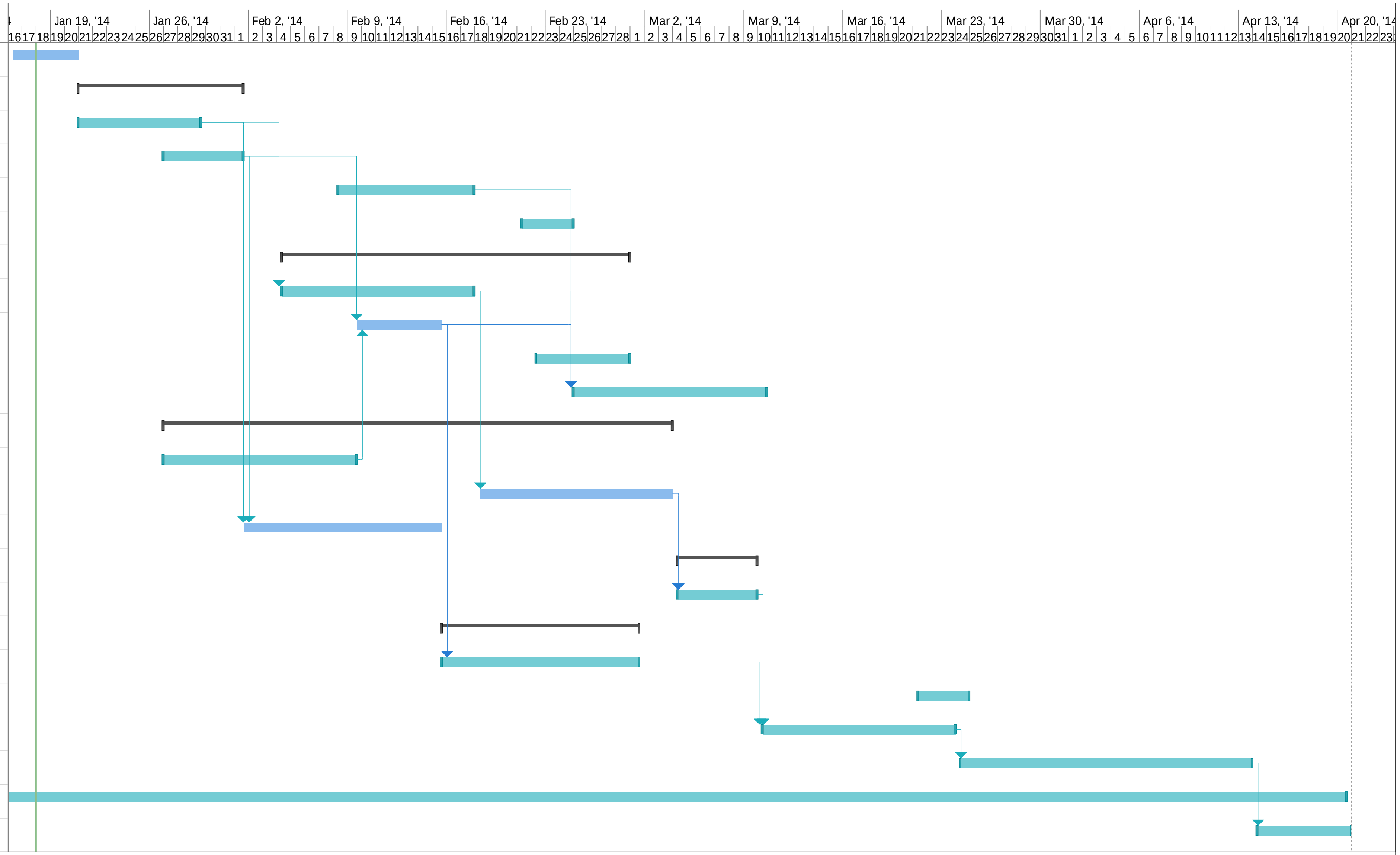
[7] Battery University. *Charging at High and Low Temperatures*. [Online]. Available: http://batteryuniversity.com/learn/article/charging_at_high_and_low_temperatures

[8] Battery University. *Safety Concerns with Li-ion*. [Online]. Available: http://batteryuniversity.com/learn/article/lithium_ion_safety_concerns

ID	Task Name	Start	Predecessors
1	Proposal	Thu 1/16/14	
2	**Project Research**	**Tue 1/21/14**	
3	Design Planning	Tue 1/21/14	
4	Component Research	Mon 1/27/14	
5	Functional Specification	Sat 2/8/14	
6	Oral Progress Report	Fri 2/21/14	
7	**Project Design**	**Tue 2/4/14**	
8	PCB Design	Tue 2/4/14	4,3
9	Software Design	Sun 2/9/14	13,4
10	Testing Plan	Sat 2/22/14	
11	Design Specification	Tue 2/25/14	5,8,9
12	**Component Orders**	**Mon 1/27/14**	
13	Evaluation Board Order	Mon 1/27/14	
14	PCB Order	Tue 2/18/14	8
15	Microcontroller & Component Order	Sat 2/1/14	3,4
16	**Hardware**	**Tue 3/4/14**	
17	Hardware Assembly	Tue 3/4/14	14
18	**Software**	**Sat 2/15/14**	
19	Microcontroller Programming	Sat 2/15/14	9
20	Written Progress Report #2	Fri 3/21/14	
21	HW & SW Integration	Mon 3/10/14	19,17
22	Integrated Testing	Mon 3/24/14	21
23	Documentation	Thu 1/16/14	
24	Post Mortem	Mon 4/14/14	22



Project: Schedule.mpp
Date: Sat 1/18/14

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