FAMU-FSU College of Engineering
Department of Electrical and Computer Engineering

PRELIMINARY DESIGN REVIEW

EEL4911C – ECE Senior Design Project I

Project title: **Autonomous Water Quality Sampler**

Team #: 8

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Submitted in partial fulfillment of the requirements for

EEL4911C – ECE Senior Design Project I

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Project Executive Summary

This proposal is submitted in response to:

Invitation for Bid:
Project #8

AWQuSam Engineering will be providing a turn-key autonomous water quality sampler that will be utilized for acquiring hydrographic and water quality data by the Florida State University Department of Oceanography. As requested in the solicitation, the system will be designed and implemented to support the gathering of water quality and hydrographic data along Florida's coastal environment. The AWQuSam will drive itself across a bay, at least 5km, navigating with GPS, recording key oceanographic parameters, and relaying samples of data to a base station.

To accomplish these tasks, the AWQuSam will employ means that facilitate acquisition of useful scientific data, such as temperature and salinity, in the shallow environments of the Florida shelf. Signal processing will be performed via a PIC microcontroller aboard the AWQuSam. All acquired data will be logged onto an SD memory card for analysis by researchers.

A GPS system will be incorporated into the AWQuSam for use by the navigation, guidance and recovery systems. In addition to the AWQuSam, a base station will be developed in order to receive streamed data from the AWQuSam.

The primary objective of the AWQuSam is to remain autonomous, navigating and performing the aforementioned tasks, for the duration of the trip.

Presently, there is no such autonomous system for effectively collecting hydrographic data in shallow environments. The team believes their creative, potentially transformative, concepts can revolutionize oceanographic research by advancing discovery in this area.

The team of engineers is confident the data reflected in this document represents innovative test and evaluation techniques. Attention has been paid to detail, and the team holds a firm commitment to completing this task in an efficient and accurate manner.

1 Introduction

1.1 Acknowledgements

AWQuSam Engineering would like to thank the FAMU / FSU College of Engineering and the Florida State University Department of Oceanography for monetary contributions toward the development of the Autonomous Water Quality Sampler, hereafter referred to as the AWQuSam. Thanks, also, to researchers within the Florida State University Department of Oceanography for contributing oceanographic expertise and equipment necessary for developing the AWQuSam.

1.2 Problem Statement

There is a need for water quality and hydrographic data from the coastal environment in order to understand the processes that mix and transport nutrients, carbon, pollutants, and other material entering the ocean from sources on land.

Ship-based measurements are expensive because of the operating cost for a sea-going vessel and crew. New platforms for sampling the ocean at high resolution are being used now in many coastal regions around the United States. These platforms, called gliders, are roughly torpedo shaped and, like gliders in the atmosphere, have a relatively large glide ratio in order to translate vertical motion into horizontal distance.

In the shallow environment of the Florida shelf, there is no room for large vertical excursions to provide for the buoyant force to drive the horizontal motion and gliders are not practical.

A new kind of platform is needed that moves across shallow bays and estuaries and measures key water quality parameters like temperature and salinity.

The AWQuSam is a fully autonomous surface vehicle designed to navigate the shallow waters along the Florida coast. Routes can be programmed into the AWQuSam prior to excursion, and the AWQuSam will navigate the route, collecting key oceanographic data along the way. A GPS system will be incorporated into the AWQuSam for use by the navigation, guidance and recovery systems.

The AWQuSam will process scientific information, such as temperature and salinity, from sensors located in the water. Signal processing will be performed via a PIC microntroller aboard the AWQuSam. All acquired data will be logged onto a SD memory card for analysis by researchers. Samples of data will be streamed via license-free channel to a receiver for real-time analysis. A base station will be developed in order to receive streamed data from the AWQuSam.

1.3 Operating Environment

The AWQuSam will be operated in the shallow environment of the Florida coastal shelf. It will be operated and/or stored in a salt-air atmosphere with humidity levels potentially reaching 100%. While operating, the AWQuSam may experience extended exposure to sunlight. During the summer months, the AWQuSam may be stored in temperatures of up to +70°C and while operating, may be exposed to temperatures of up to +55°C. In addition, the AWQuSam may experience winter storage temperatures as low as -20°C and operating temperatures of -5°C. The AWQuSam may experience crashing waves of up to 1m in height, winds of 40knots, and driving rainfall.

1.4 Intended Use(s) and Intended User(s)

The AWQuSam is intended to be used by oceanographic researchers. It will primarily be deployed by users with at least a Bachelor's degree and knowledge of the system. However, the AWQuSam may be deployed by individuals with no knowledge of the system, and it shall be designed to allow such a user to deploy the system with the aid of user documentation which will be provided among project deliverables (See Section 1.6). Untrained personnel will be able to program a new mission path into the AWQuSam with only the aide of instructional documentation which will be provided by the project team. Once deployed, the AWQuSam will be fully autonomous. Collected data will be analyzed by oceanographic researchers.

The AWQuSam will be used to collect precise hydrographic and water quality parameters near the surface of the Apalachicola bay area and other shallow water environments. It will record water temperature and conductivity information. The AWQuSam will be used to collect this oceanographic data in an environment where there is presently no effective method for collecting such data. It is not intended to collect data on land or in deep ocean environments.

1.5 Assumptions and Limitations

The AwQuSam shall measure and record water temperature to a precision of 0.01ºC at a rate of 8 samples per second. It shall measure and record water conductivity to 0.01 S/m at a rate of 8 samples per second. Temperature, conductivity, and position will be transmitted to a base station receiver at a rate of one time every 5 minutes. The AWQuSam will not be deployed for missions longer than 12 hours. The system is to be used only for surface water applications, and is not to be deployed in areas with ocean currents in excess of 5 knots or with waves greater than 2m in height. The end user will program paths into the AWQuSam using GPS coordinates.

The end product shall be no larger than 2m in length, 0.8m in width, and 0.5m in height (excluding antennas) to facilitate easy transport in the back of a van to and from a launch site. It shall weigh no more than 40kg to allow for deployment by one to two persons. An AWQuSam prototype shall be designed and delivered by April 13, 2011 with expenditures not to exceed $2000.

1.6 Expected End Product and Other Deliverables

One (1) Autonomous Water Quality Sampler prototype will be delivered to facilitate the gathering of oceanographic data in shallow coastal waters. Its path will be programmable by the end-user. Once programmed, the AWQuSam shall propel itself across the surface of bays and estuaries recording water temperature and conductivity.

The AWQuSam will be delivered with documentation detailing instructions for programming new paths. Data formats found in the data log and transmissions will be documented to facilitate analysis by researchers. Documentation will also be provided with instructions for performing maintenance and for servicing the system or components. Prototype and documentation shall be delivered by April 13, 2012.

2 System Design

2.1 Overview of the System

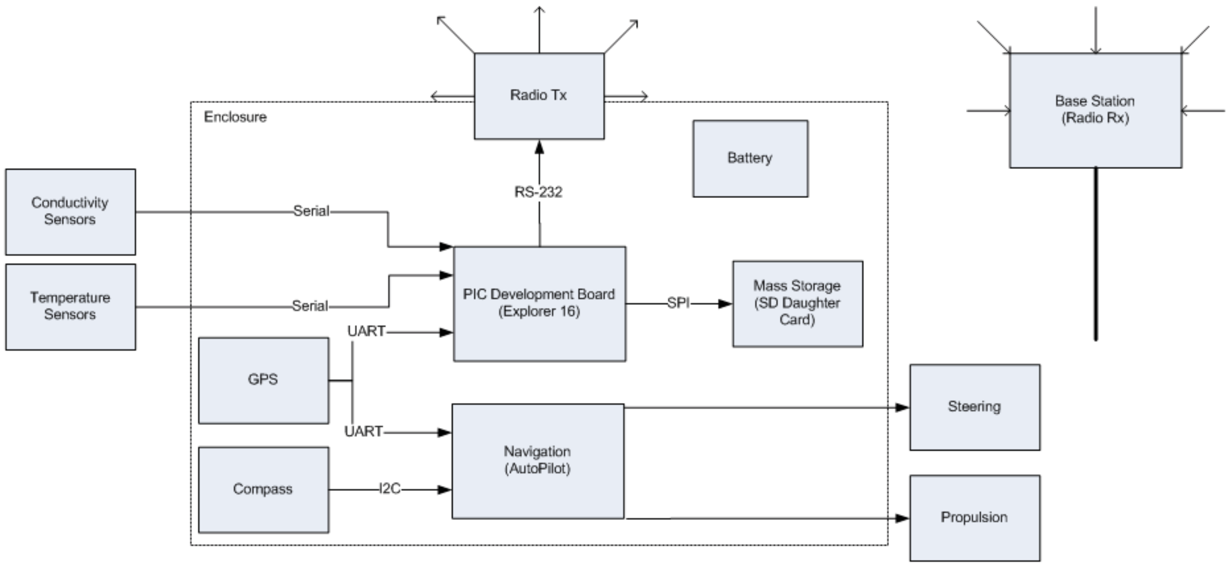

Figure 2.1.1: Top-level architecture of AWQuSam

The AWQuSam's design revolves around the Explorer16 PIC development board. This is a microcontroller based board. It will receive inputs from conductivity and temperature sensors. This information will be logged to an SD card. A separate navigation subsystem will receive inputs from a compass and GPS module that will be used to drive the steering and propulsion systems.

2.2 Major Components of the System

2.2.1 Explorer16 Development Board

The design revolves around the Explorer16 PIC development board. This is a low cost, efficient microcontroller based development board. It includes the dsPIC33FJ256GP710 microcontroller, which features up to 85 I/O pins. It, also, has a 12-bit A/D converter, two UART interfaces, two SPI interfaces, and two I2C peripheral interfaces. In addition, this microcontroller offers capture, compare, and pulse width modulation peripheral functionality that will be utilized in the design..

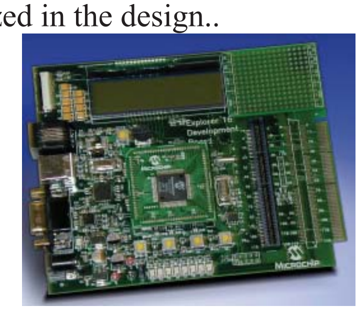

Figure2.2.1.1: Explorer16 Development Board

The Explorer16 offers expansion capabilities in the form of daughter cards and plug-in-modules. This easy integration feature will be utilized in the design of the AWQuSam. The development board also features pushbuttons, a 16x2 LCD display, and LED indicators that will be useful for debugging and programming.

2.2.2 Conductivity Sensors

A number of vendors were consulted in order to determine the conductivity sensor best suited for this design. The most practical option from YSI is their 600R model conductivity/temperature sensor. This series can sample at 10Hz. However, the sensor costs $2062 per unit, plus $85 for each pigtail connector for integration with the development board

Forston Labs offered a conductivity sensor for $125 per unit, but they only resolve to 0.02ppt. In addition, the response time of this conductivity sensor is too slow for this application.

PME offered a rapid-response conductivity sensors, as well. However, this option is not very stable. Engineers at PME advised the team that their sensors are not well suited for twelve hours of unattended operation. These sensors do not resist fouling and are quite fragile.

Figure 2.2.2.1: SBE-4 Conductivity Sensor

The SBE-4, by Seabird Electronics, will be used to gather water conductivity data. This sensor provides a precise, rapid response that satisfies the design requirements. Seabird Electronics is a premier manufacturer of marine instruments and sensors. This sensor outputs a variable frequency square wave signal (from 2.5kHz to 7.5kHz) corresponding to the conductivity (from 0S/m to 7S/m).

2.2.3 Temperature Sensors

A variety of temperature sensors are available. Thermocouples offer a fast, almost immediate, response to temperature changes. However, they are best suited for extremely high temperature. RTDs are stable temperature sensing devices. However, because they are best suited for a wide temperature range, detailed precision is not guaranteed.

This application requires measuring a relatively limited temperature range. However, accuracy and sensitivity to small changes is important over this range. A fast-response thermistor is the best solution.

Figure 2.2.3.1: OL-710 Thermistor

The design will utilize such a thermistor for acquiring temperature data. In particular, the design will use the OL-710 device by Omega Engineering. This instrument offers a level of precision in the range of temperatures experienced in the Apalachicola river and bay system.

2.2.4 GPS

Figure 2.2.4.1: D2523T GPS Module

The D2523T complete GPS module will be used in the design of the AWQuSam. This module revolves around the UBX-G501chipset. It features a 26dB helical Sarantel active antenna and supports 50 channels.

2.3 Performance Assessment

The system shall be designed to satisfy the requirements of the specification as discussed with the customer. It will measure and record eight samples each second of water conductivity, water temperature, and position for the duration of the mission. During each conductivity and temperature sample, a measurement will be recorded at the surface of the water and at a level six inches below the surface of the water.

The AWQuSam will allow for programmable mission paths in the form of GPS waypoints. It will autonomously propel itself across the surface of the water to each waypoint before reaching its final destination.

The AWQuSam will also wirelessly transmit a sample of recorded data to a base station receiver every five minutes. This will provide researchers a real-time glimpse of what is being recorded and where the AWQuSam is presently located.

3 Design of Major Components

To improve the flow of the engineering design process, the design of the AWQuSam will have a modularized approach. The top-level design is divided into several critical subsystems. The boundaries of the subsystems are well-defined, such that they can be independently designed and then integrated.

3.1 Mechanical Housing

3.1.1 Hull

The AWQuSam hull will enclose all the electronic and mechanical components but shall allow for easy access. It shall displace more volume of water than the entire weight of the craft in order to achieve maximum buoyancy in order to cruise effectively in shallow waters. The craft shall be streamlined, hydrodynamic, and engineered to be as stable and as energy efficient as possible. It needs to be water tight to avoid damaging electronic and propulsion components if it capsizes or rains. It also needs to be light enough so that the craft is able to be carried by two using handles at each end of the hull.

The dimensions of the hull shall be modest in order to meet the requirements. After further analysis and preliminary testing the maximum target dimensions are 2m x 0.8m x 0.5m. The hull needs to be relatively light; no more than 50% of the total weight of the AWQuSam.

The operating environment also poses some design challenges, mainly material. AWQuSam shall not suffer any degradation of performance when operated in and when stored in a salt fog atmosphere. It shall not suffer damage from exposure to sunlight. The AWQuSam shall be operable in a hot, humid environment with a diurnal cycle peak of 100% humidity. The AWQuSam shall be fully operable at a continuous, ambient temperature of +55°C, and shall suffer neither damage nor degradation due to storage at a temperature of +70°C. The AWQuSAm shall be fully operable at a continuous ambient temperature of -5°C, and shall suffer neither damage nor degradation due to storage at a temperature of -20°C. The AWQuSam shall operate and remain functional during driving rain. The vehicle instrumentation shall not suffer any damage from waves up to 1m in height.

Different options for the hull were considered.

(1) Custom design for an aluminum hull.

This preliminary design was explored first. The benefits of a custom design is that the team is able to optimize the design to the project's specific necessities. This design involved using a flat bottom v-hull hybrid in order to achieve great buoyancy and displace through waves easily.

This option poses crucial disadvantages like cost, time to manufacture, and reliability for it would be difficult to manufacture on current facilities.

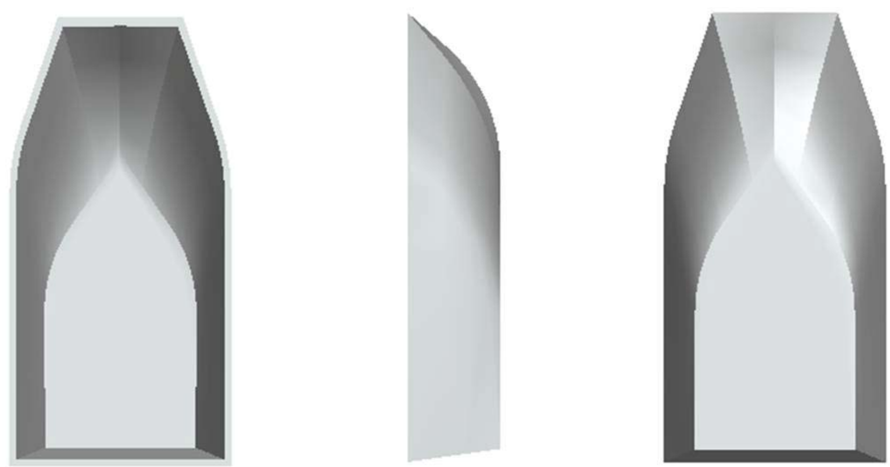

Figure 3.1.1.1: CAD model for aluminum hull

(2) Using a 8 ft jon boat.

This option would require an additional purchase. The advantages of this option is the time, labor, and money saved. After conducting research on the cost and availability for an 8ft jon boat, the team realized that (a) they are not very common and (b) it would be necessary to buy a used jon boat for it to be economical.

The advantages of a jon boat is their high buoyancy and strength. Although they might not be as stable or able to cruise through waves as easily as the project demands.

The jon boat would need to be refitted to accommodate the needs of the AWQuSam.

(3) Purchasing a used kayak

Finding a used kayak would be easier than an 8ft jon boat. Using a kayak has many advantages and has proven, in the past, to be useful for this type of operation. Some of the benefits of a kayak is that they are very durable, light weight, easily transportable, cheap, and fairly streamlined.

Buying a kayak also makes sense economically. It would save time, money, and labor cost in comparison with building a custom hull. As was the case with the jon boat, the kayak would also need to be refitted to accommodate the needs of the AWQuSam. These accomodations include: internal support for propulsion and electronic components; structural support for sensors, and a stabilizing structure below the hull.

Decision Matrix

Option	Cost [20%]	Hydrodynamics [10%]	Bouyancy [10%]	Stability [10%]	Durability [15%]	Time to build [20%]	Weight [7%]	Ease of Transportation [8%]	Total
Aluminum Hull	0.4	0.3	0.2	0.4	0.15	0.4	0.175	0.24	2.27
Used jon boat	0.6	0.2	0.5	0.4	0.6	1	0.07	0.32	3.69
Used kayak	0.8	0.5	0.05	0.4	0.6	0.8	0.28	0.32	3.75
*Ranked from 1-5									

The kayak clearly comes out as the winner of the three options due to its few disadvantages. It will prove to be the fastest, lightest, and cheapest of all the three options. It will only need to be slightly retrofitted to satisfy design requirements, as oppose to designing the whole structure from scratch as was the case with the aluminum hull.

It is important to mention that in order for reproduction many different types of kayak could be used therefore the different components that will be refitted into the kayak should also be refitted into different types of kayaks.

The prototype design for the AWQuSam shall use a Riot Kayak Trickster. This model is normally used in salt water and its great for tricks. This means it slides easily therefore a stabilizer keel shall be implemented and used both as a structural element as well as a hydrodynamic element. This keel shall ensure the AWQuSam moves in a straight line while also protecting the sensors from impact with any external object.

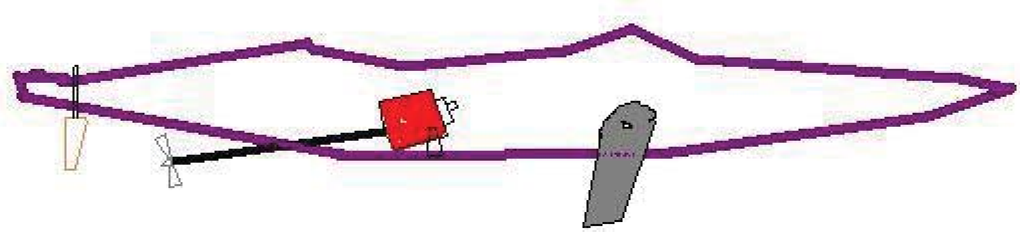

Figure 3.1.1.2: Kayak hull retrofit concept drawing

An internal structure will be put in place in the main compartment of the hull. The purpose of this structure is to hold the engine and the shaft in place. The engine and the shaft shall be placed in an angle coming out of the bottom of the back of the kayak as seen in this concept picture.

On the external sides of the kayak two stabilizing keels need to be fixed. The main purpose of these keels is to prevent the kayak from sliding. The keels will also house the sensors of the AWQuSam. The keels will be hold in place by a rotating about-an-axis-joint so that if it impacts on shallow ground it has some freedom to rotate and come back into position after impact. In order to hold the keels two structures will be bolted to the side of the kayak. Most likely these structures will be designed as an aluminum bar fixed to the hull.

Figure 3.1.1.3: Riot Kayak Trickster

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Figure 3.1.1.4: Sensor Placement

3.1.2 Electronics Housing

The electronics housing shall be placed inside the hull and shall enclose all electronic components. It shall be easily accessible when out of the water; however, when in operation all seals shall be water tight indefinitely. The main challenge is to seal tight all electronic components during operation but prevent components from overheating.

The dimensions of the electronics housing is constraint by the dimensions of the hull. Currently these dimensions shall not surpass 0.6m x 0.9m x 0.3m. An important consideration is the use of multiple or only one enclosure for all the electronic components in the subsystem: battery, FPGA board, all wires, etc...

To meet these requirements multiple water tight boxes shall be fixed to the interior of the AWQuSam. Each box shall hold in place one or more of the electronic components. The location of every component shall depend on weight distribution and most importantly necessity; for example some components might need to be closer to the antenna.

The boxes will be fixed to the AWQuSam using 3M Velcro to reduce the amount of protrusions done on the hull.

Using seal tight tupperware boxes could prove to be as a reliable option. For many reasons including its low price, light weight, and simple mechanism. They shall be refitted to meet the requirements of an electronic housing like methods for holding in place the different components of the electronic subsystems, a method for displacing heat from the box, and sealing all protrusions for wires and leads.

3.2 Propulsion System

The propulsion system for the AWQuSam should be designed to allow for effective movement around shallow and turbulent waters. It shall be powerful enough to move the craft at speeds up to 5 knots. This is required because the area on Appalachicola Bay have currents that the reach these speeds. The propulsion system will provide enough power for at least 12 hours of continuous use. It shall also be submersible and its housing, water tight. Its main mechanism shall be reliable and simple.

The propulsion system needs to take into account its own weight so that it is not to heavy to be counterproductive in buoyancy. It shall also be able to fit inside the hull of the AWQuSam so its dimensions are constrained by the dimensions of the hull. Target dimensions shall not exceed 0.6m x 0.5m x 0.5m. A very important aspect of the propulsion system is the fuel used. For this reason all aspects being evaluated shall include fuel specifications.

A variety of options were explored to meet the requirements.

(1) Electric trolling motor.

A used trolling motor with a thrust somewhere in between 27 to 40 lbs would be bought. The trolling motor shall be hold in place in the back of the kayak so that it provides a straight thrust forward. It shall not be more than a feet deep in the water.

The motor shall be powered by several batteries in order to allow for the required speed and run time. This poses an enormous disadvantage for batteries, as it adversely affects the project budget constraint and weight requirements. For a 30lbs of thrust the trolling motor would require approximately 125lbs of weight in batteries. The main advantage is the reliability of electric motors and that it produces no emissions.

(2) A water pump jet drive.

The propulsion system modeled as a water jet drive uses a gas-powered water pump typically used in applications where high volumes of water need to be removed such as draining a pool. This allows for it to be almost completely above water providing effective propulsion in shallow waters. The system works similarly to a jet ski in that it will take water from an inlet and accelerate through a nozzle under pressure and shoot it out producing thrust.

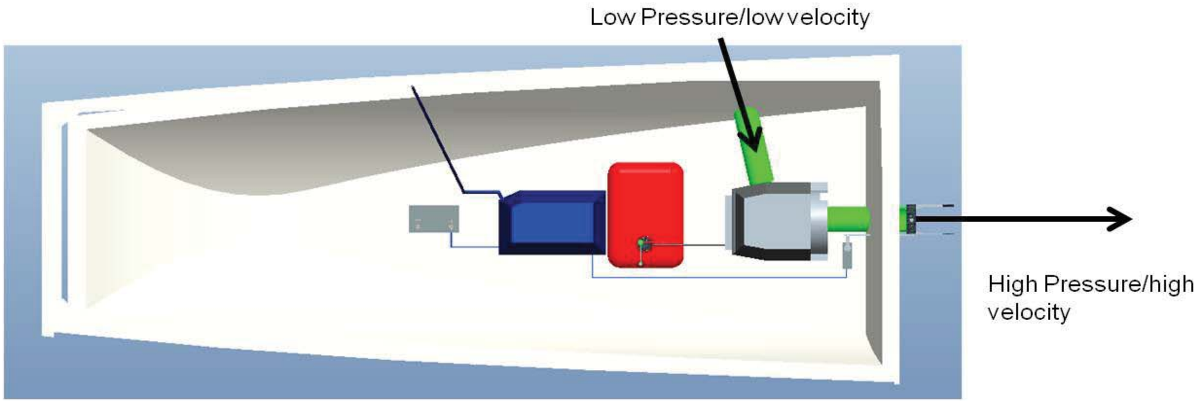


Figure 3.2.1: Water pump jet drive concept drawing

Based on the research the team performed, the design will require a 5 gallon gas tank connected to the water pump to fulfill the required run time. The water pump gas engine has an internal fuel tank but is gravity fed. To ensure that it remains full a small fuel pump will turn on intermittently to transfer fuel from the external fuel tank to the internal fuel tank of the water pump. This rate will be based on the averaged fuel consumption. Another option is to have it connected to the micro-controller and have it to work on a rate based on speed to fuel rate consumption.

In order to control the propulsion a servo motor needs to be connected to the throttle. This is required to increase and decrease speed as well as completely shutting down the motor. Depending on the water pump purchased, and its specifications, it maybe necessary to add a second servo motor to manage the "kill switch".

(3) Prop driven gas engine.

A small 35 or 99cc gas engine would be purchased new. The engine thrust and rpm shall be able to impulse the AWQuSam at a max of 5 knots. To achieve this, the team selected two options (a) a Predator 99cc engine and (b) the Honda GX 35 shown below:

GX 35

Engine Type	Air cooled 4 stroke OHC petrol engine
Cylinder Sleeve Type	Aluminium Cylinder
Bore x Stroke	39 x 30mm
Displacement	35.8 cm3
Compression	8.0 : 1
Net Power	1.0 Kw (1.3 HP) / 7000 rpm)
Max net torque	1.6 Nm / 0.16 Kgm / 5500 rpm
Ignition System	Transistorised
Starting System	Recoil
Fuel tank Capacity	0.63 l
Fuel cons. at rated power	0.71 L/hr - 7000 rpm
Lubrication	Crankcase Pressure Driven
Engine Oil Capacity	0.1 l
Dimensions (L x W x H)	198 x 234 x 240 mm
Dry Weight	3.33 kg (w/o clutch)

Figure 3.2.2: Honda GX35 gas engine and specs.

Performing thrust and speed calculations for engine and propeller, the team found that the Honda GX 35 will reach a maximum speed of 7.8 knots. More than the required 5 knots. The 99cc Predator engine could propel the AWQuSam to approximately 11.3 knots.

The propeller diameter, pitch, and number of blades for this application was estimated using a very complex algorithm found online at surfbaud.co.uk/wave/.

For the Honda GX 35, the team concluded that the best kind of propeller would be a 3-bladed propeller with a diameter of 4 in and a pitch of about 4 in as well. The material for the propeller is yet to be determined.

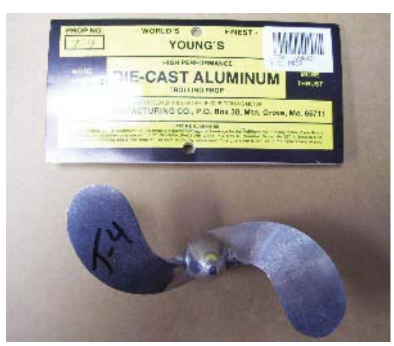


Figure 3.2.3: Propeller similar to one ideal for this project

Speed Tests conducted 11-03-2011 using the Riot Kayak Trickster

For 78lbs of mass	
Thrust (lbs)	Speed (mph)
5	3.8/3.4
10	4.8/4.7
18	6.4

For 33lbs of mass (hull only)	
Thrust (lbs)	Speed (mph)
5	4.6
10	6.4
15	7

A comparison chart for all the different options:

Options	Weight [lb]	Cost [U$S]	Thrust [lb]	Speed [knots]	Run time [hr]	Type/amount of fuel
Pacer Self-priming transfer pump	80	449.99	45	6.5	12	unleaded gasoline, 4 gallons
Trolling Motor Minn Kota	167	168.99	30	6.5	12	12V 100Ah battery, 3
Prop driven Honda engine 35cc	22	290	29	7.8	12	unleaded gasoline, 2 gallons
Prop driven Predator engine 99cc	58	180	76	11.3	12	unleaded gasoline, 4 gallons

**weight and cost include propulsion and fuel only.
**for thrust calculations, assume +53lbs for hull and other components except propulsion components.
**speed calculations are approximate based on tests and online thrust calculators.

From the table above, it is apparent that the most powerful propulsion system is also the cheapest. The prop driven Predator 99cc engine and Honda 35 cc engine come out on top. The Honda GX 35 has the advantage of being the lightest and its power is enough for the operating requirement. It is also a Honda which makes it very reliable. A disadvantage is that it would require a clutch housing for a centrifugal clutch system.

Both the 99cc and the 35cc engines would require an external gas tank to store enough fuel for 12 hours of operation. The benefits of the 35cc engine is that its gas tank is located at the bottom of the engine so external tanks would be easier to place next to it using only gravity to feed the fuel.

The Honda GX35 comes on top slightly over the 99cc Predator due to its reliability, size, weight, and fuel tank. A clutch mechanism will also allow for the engine to be placed in neutral therefore it would be easier to recuperate the craft if it is not moving.

3.3 Steering System

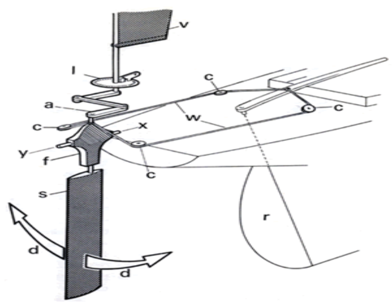


Figure 3.3.1: Sevomotor, possible rudder placement, and a rudder.

The steering subsystem for the AWQuSam will be essential for its navigation. It shall keep the AWQuSam on its track despite operating conditions like currents or side winds. Its mechanism shall be strong so that it will be able to shift easily while moving. The design shall allow for a turning radius of no more than 3m. In essence the steering system shall be reliable, clutter free, and simple.

The steering will be achieved by having a waterproof high torque digital servo linked to a rudder. The servo is connected to the microcontroller board and will correct itself as a function of how far it deviates from the path. Pulse width modulated signals will control the servo. The rudder will be turned by a mechanical arm linkage which runs through the transom wall on the back of the boat. Since the linkage arm runs through the transom wall and will be close to or below the water level, the team’s engineers must ensure this enclosure is water tight while still allowing the arm to move accordingly.

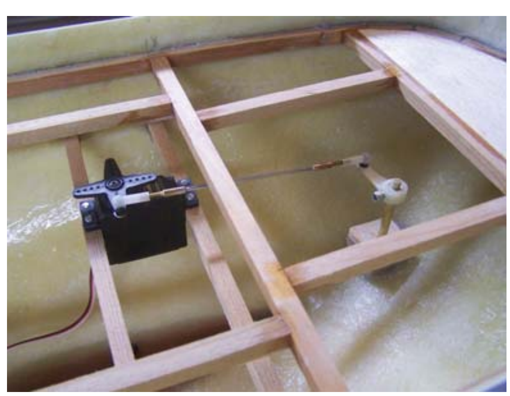


Figure 3.3.2: Servo steering system proof of concept

3.4 Navigation System

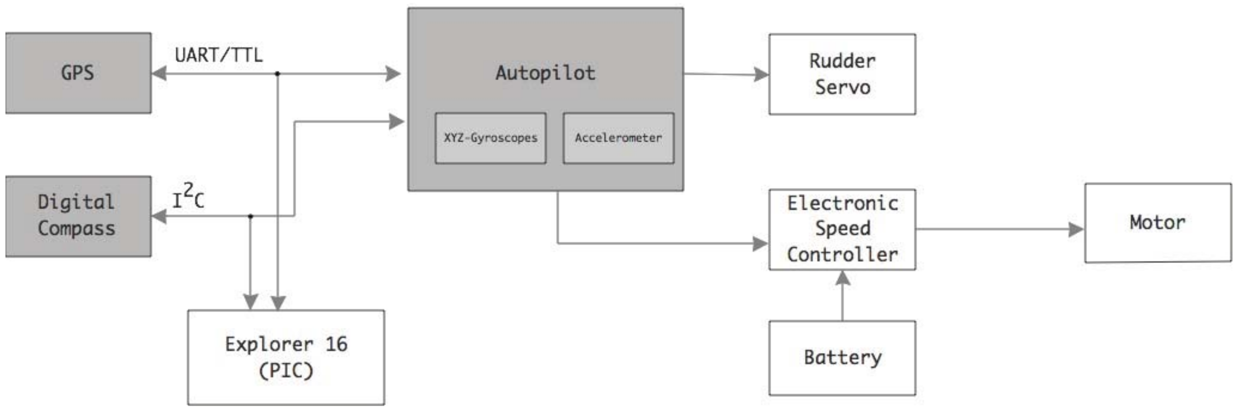


Figure 3.4.1 Top-level Architecture of Navigation System

As an autonomous vehicle, the AWQuSam must be able to maintain its path-planning strategies on-board during its mission. To satisfy this requirement, on on-board navigation system is being designed to undertake this task. This navigation system will use an Autopilot module equip with a dsPIC33FJ256 microcontroller, a set of gyroscopes that monitor the vehicles x, y, and z orientation, and an accelerometer. The Autopilot module is an off-the-shelf component with opensource software programming potential. The Autopilot will be provided with input data from the GPS module, and digital compass (magnetometer). It will process this data during the mission to determine its bearing, and distance from the current waypoint it is progressing towards. Once it calculates its bearing and distance to a waypoint, it will calculate the appropriate information to output to the rudder-servo and the electronic speed controller in the propulsion system.

For datalogging purposes, the Tx ports for the GPS and digital compass will be connected to an input pin on the Autopilot and Explorer 16 board.

GPS Smart Antenna Engine Board

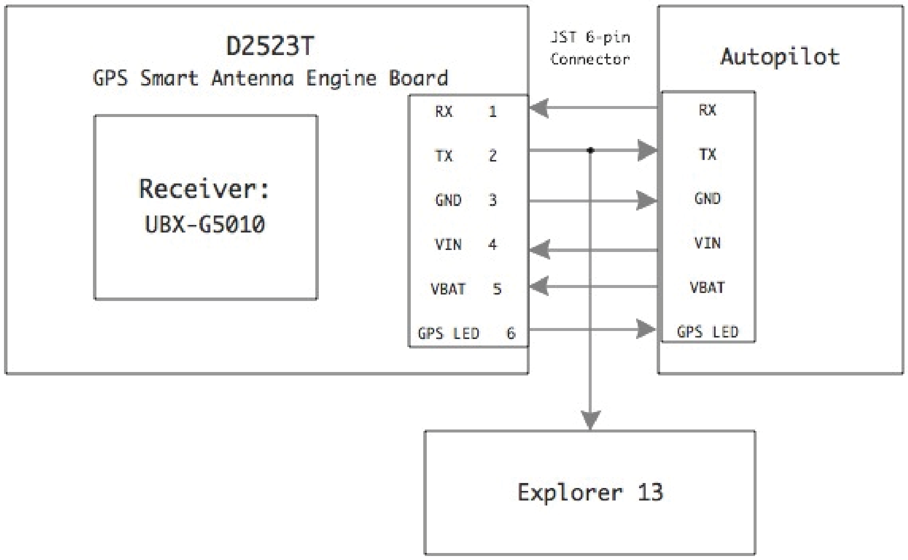


Figure 3.4.2 Interface between GPS Engine Board and Autopilot module

The GPS Smart Antenna Engine Board (GSAEB) has an factory integrated receiver chip, the UBX-G5010. It uses the GPS protocol format, NMEA, to output messages. There are 7 NMEA message strings which the GPS outputs contyinously. The only message strings of importance for the navigation system are the Global Positioning Recommended Minimum Specific [GPS/Transit data] (GPRMC) and the Global Positioning System Fix Data (GPGGA). The GSAEB will communiate with the Autopilot module thru a Universal Asynchronous Receiver / Transmitter and Transistor-Transistor Logic (UART/TTL) interface via a 6-pin JST connector.

Table 3.4.1 Pin Layout for D2523T GPS Smart Antenna Engine Board

Pin No.	Pin Name	I/O	Description	
1	RX	I	Data Input (TTL level)	
2	TX	O	Data Output (TTL)	
3	GND	GND	Ground	
4	VIN	I	Supply Voltage	3.3V +/- 10%
5	VBAT	I	Backup Battery Supply Voltage	
6	GPS LED	O	LED Indicator	

Once the GSAEB is connected to the Autopilot, its initialization procedure will determine the baud speed, the GPS NMEA headers to monitor from the output stream, and setup variables to compare its generated checksum against checksum received in the data stream. The Autopilot module will be designed to retrieve and store pertinent information from these two data streams.

GPS NMEA: $GPGGA

$GPGGA,hhmmss.ss,llll.ll,a,yyyyy.yy,a,x,xx,x.x,x.x,M,x.x,M,x.x,xxxx*hh

Table 3.4.2 GPS NMEA: $GPGGA Message Description

Name	Example Data	Description
Sentence Header	$GPGGA	Global Positioning System Fix Data
UTC of Position	hhmmss	Time Stamp
Latitude position	llll.ll	Degrees, decimal minutes
N or S	a	
Longitude	yyyyy.yy	Degrees, decimal minutes
E or W	a	
GPS Quality Indicator: - 0 = Invalid - 1 = GPS fix - 2 = DGPS fix	x	- 0 = Invalid - 1 = GPS fix - 2 = DGPS fix
Number of Satellites in Use	xx	
Horizontal Dilution of Precision (HDOP)	x.x	Relative accuracy of horizontal position
Altitude	x.x	Antenna altitude above mean-sea-level
Units of antenna altitude, meters	M	
Geoidal separation	x.x	
units of geoidal separation, meters	M	
Age of Differential GPS data (seconds)	x.x	Age in seconds since last update from diff. reference station
Diff. reference station ID#	xxxx	
Checksum	*hh	

GPS NMEA: $GPRMC
$GPRMC,hhmmss.ss,A,llll.ll,a,yyyyy.yy,a,x.x,x.x,ddmmyy,x.x,a*hh

Table 3.4.3 GPS NMEA: $GPGGA Message Description

Name	Example Data	Description
Sentence Header	$GPGGA	Global Positioning System Fix Data
UTC of Position	hhmmss	Time Stamp
Data Status	A	

Latitude position	llll.ll	Degrees, decimal minutes
N or S	a	
Longitude	yyyyy.yy	Degrees, decimal minutes
E or W	a	
Speed of Ground in Knots	x.x	
True Course	x.x	
UTC Date	ddmmyy	Date Stamp
Magnetic Variation Degrees	x.x	Easterly variation subtracts from true course
E or W	**a**	
Checksum	*hh	

The latitude and longitude coordinates extracted from the data stream will be used to calculate the true course between the current GPS coordinate and the current waypoint. It will also be used to calculate the distance between the current GPS coordinate and the current waypoint. The calculated information will be used to determine rudder control and navigation path during the mission.

Honeywell Digital Compass

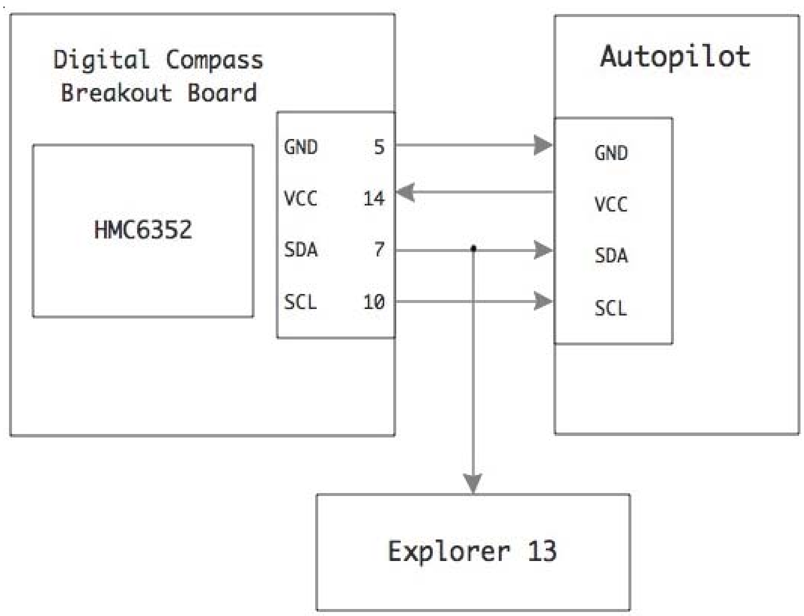


Figure 3.4.3 Interface between Digital Compass and Autopilot module

The Honeywell HMC6352 Digital Compass Breakout Board is equip with a 2-axis magnet-resistive sensors which supports algorithms for heading computation. Of the 24 pins provided by the HMC6352 chip, only 4 are needed to acquire heading computation from the device: GND (pin 5), SDI (pin 7), SCL (pin 10) and VCC (pin 14).

Table 3.4.4 Pin Layout for HMC6352 Digital Compass

Pin	Name	Description
1	OF-	No User Connection (Offset Strap Negative)
2	SR+	No User Connection (Set/Reset Strap Positive)
3	NC	No User Connection
4	NC	No User Connection
5	GND	Supply/System Ground
6	NC	No User Connection
7	SDI	I2C Data Output (SPI Data In)
8	SDO	No User Connection (SPI Data Out)
9	PGM	No User Connection (Program Enable)
10	SCL	I2C Clock (SPI Clock)
11	SS	No User Connection (Slave Select)
12	NC	No User Connection
13	NC	No User Connection
14	VDD	Supply Voltage Positive Input (+2.7VDC to +5.0VDC)
15	NC	No User Connection
16	NC	No User Connection
17	NC	No User Connection
18	NC	No User Connection
19	CB2	Amplifier B Filter Capacitor Connection
20	CB1	Amplifier B Filter Capacitor Connection
21	NC	No User Connection
22	CA2	Amplifier A Filter Capacitor Connection
23	CA1	Amplifier A Filter Capacitor Connection
24	OF+	No User Connection (Offset Strap Positive)

The breakout board will connect to the Autopilot and the Explorer 13 microcontroller I2C ports. Below is the method which will be used to initialize the digital compass upon startup.

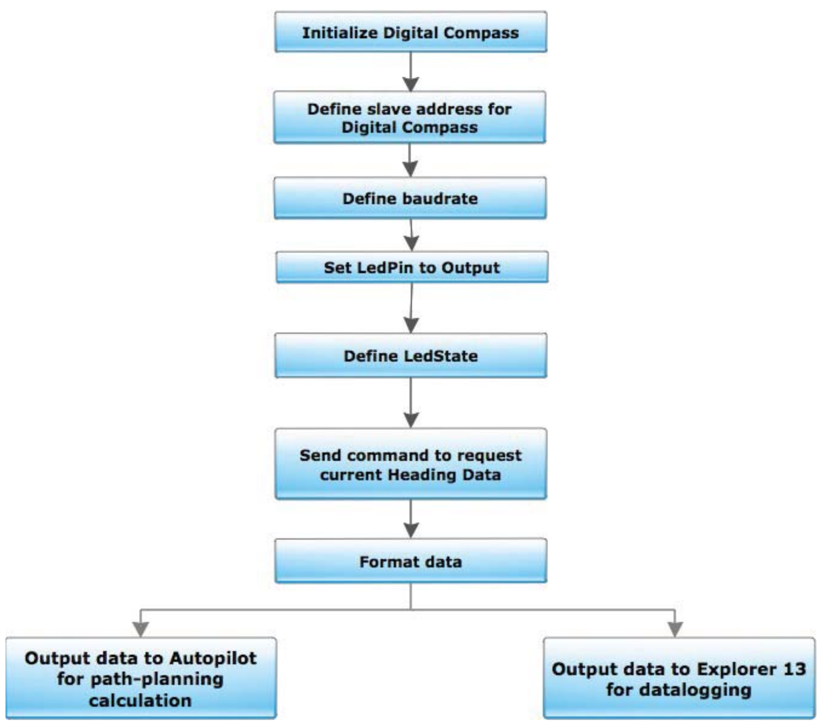


Figure 3.4.4 Digital Compass Operation Flowchart

Once the GPS and Digital Compass are initialized, the Autopilot will begin processing and performing calculations on the incoming data in order to set the rudder-servo and speed controller parameters periodically throughout the mission.

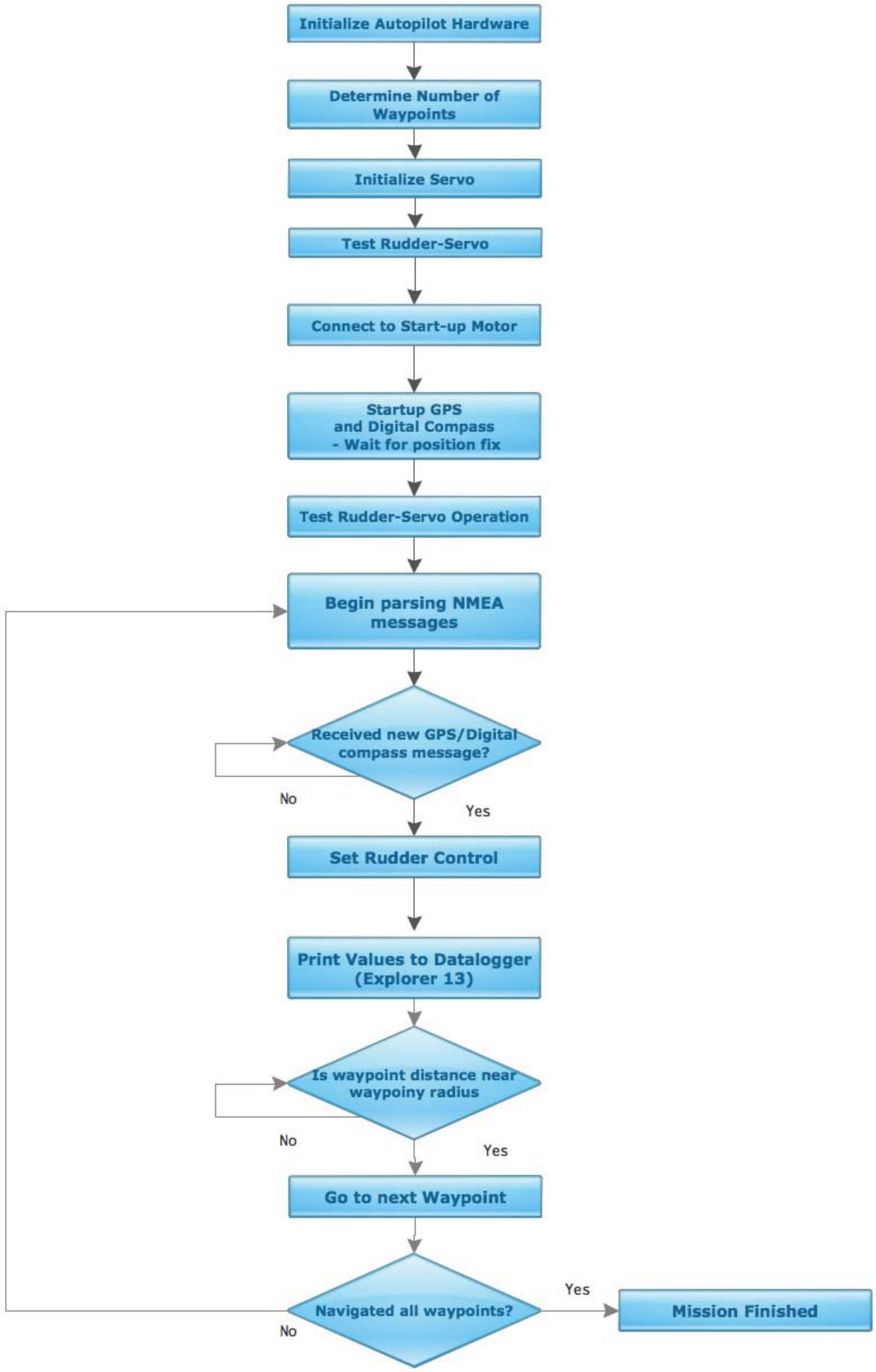


Figure 3.4.5 Navigation System Operation Flowchart

3.5 Data Acquisition System

3.5.1 Conductivity Acquisition

The SBE-4 conductivity sensor has a 3-pin connector, as shown in Figure3.5.1.1. The team will utilize a RMG-3FS to pigtail cable (SBE PN: 17029) to facilitate placement of the sensor some distance away from the development board.

Figure3.5.1.1: RMG-3FS Connector on SBE-4

The sensors outputs a variable frequency square wave signal (from 2.5kHz to 7.5kHz) corresponding to the conductivity (from 0S/m to 7S/m). The square wave is a ± 0.5V waveform. The design will implement a microcontroller based frequency counter. Consequently, the waveform must be conditioned to have 0-3.3V TTL logic levels so the microcontroller can effectively count the rising edges of the waveform, as shown in Figure3.5.1.2.

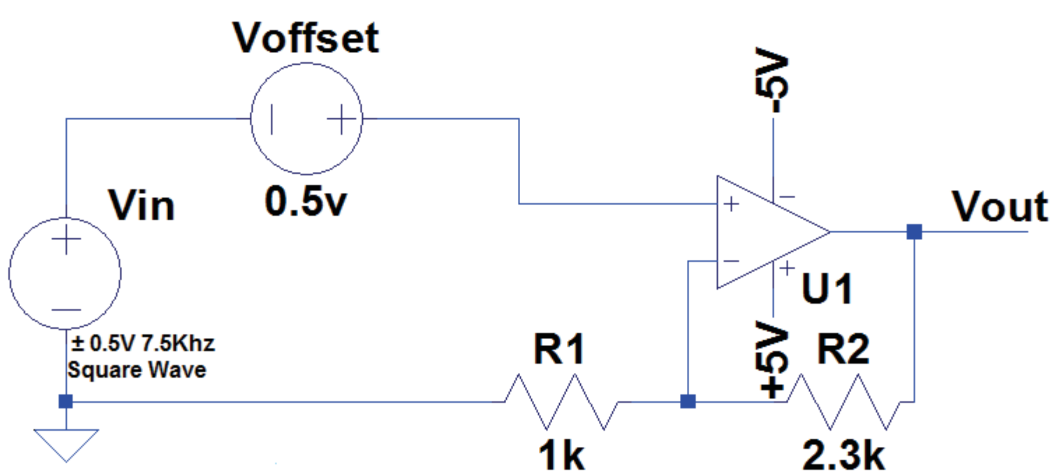


Figure3.5.1.2: Signal conditioning circuitry

A DC offset is introduced to the square wave before amplifying the signal. The gain of operational amplifier is given as:

$$V_{out} = V_{in}(1 + \frac{R_2}{R_1})$$

Figure3.5.1.3 shows the output waveform as well as the intermediary steps. Observe that the output waveform has the same frequency as the input, but now has TTL levels that can be processed by the microcontroller.

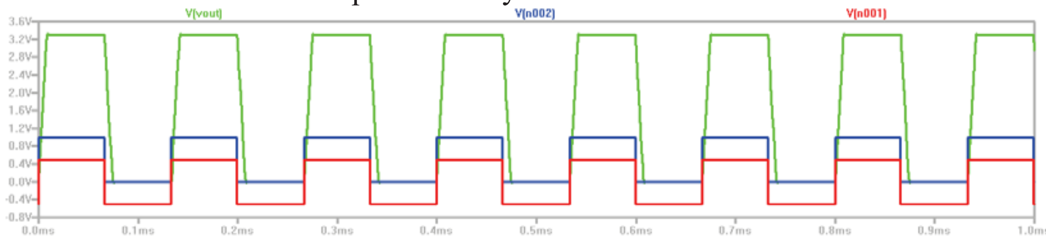


Figure3.5.1.3: Conditioned output of conductivity sensors

The design will utilize the input capture capability of the PIC microcontroller on the Explorer16 development board to determine the number of clock cycles between consecutive rising edges of the signal. From this information, the signal period can be determine, and subsequently the signal's frequency. A detailed timing analysis has not yet been performed (see Section 6.1, Technical Risk 1).

The conductivity can, then, be calculated from this frequency using the thermal coefficient of expansion, bulk compressibility, water temperature, and calibration data provided by the manufacturer.

3.5.2 Temperature Acquisition

Figure3.5.2.1 provides an overview of the design for measuring temperature.

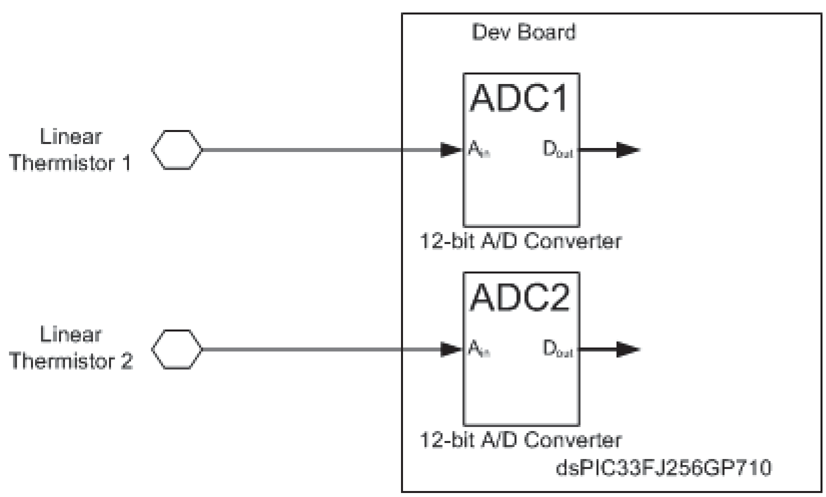


Figure3.5.2.1: Overview of Temperature Sensing Module

Because the relationship between a thermistor's voltage and the temperature is not innately linear, some design work must be performed. The OL-710 thermistor actually consists of two thermistors. When used with a particular resistor set, the output is linearized over a range of temperatures.

Each linear thermistor, as shown in Figure3.5.2.1, is actually represented by the circuit schematic shown in Figure3.5.2.2, below.

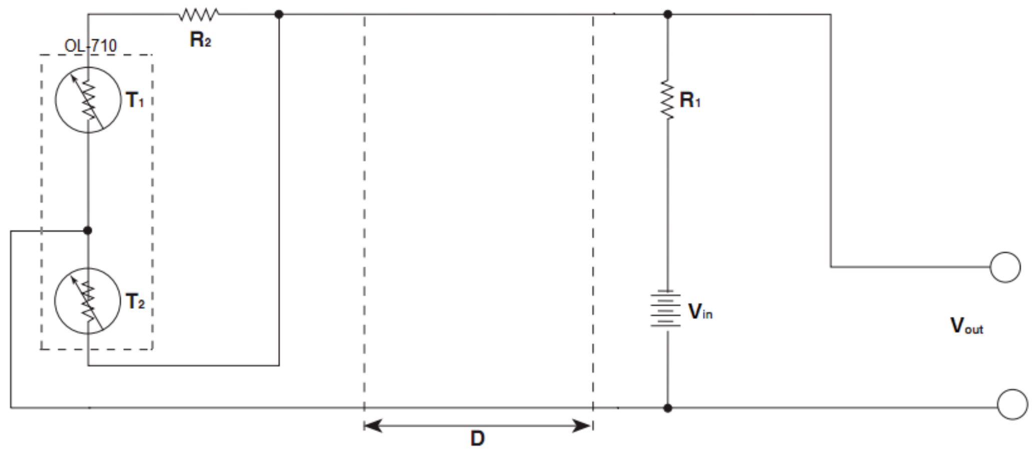


Figure3.5.2.2: Linear Thermistor Circuit Schematic

Resistor values of R_1=5700Ω and R_2=12kΩ can be selected to provide linear voltages across the range corresponding to -5ºC to 45ºC. With this resistor set, relationship between voltage and temperature is described as follows:

$$V_{out} = (-0.0056846 \cdot V_{in})T + 0.805858 \cdot V_{in}$$

The surface water temperature of the Apalachicola Bay is not known to fluctuate outside the range of 5ºC to 35ºC. The team will provide a system capable of accurately recording temperatures in the range of 0ºC to 40ºC. With a properly configured 12-bit analog to digital converter, this will allow for precision of 0.01ºC

Utilizing the equation above, the A/D converter can expect voltages in the range of 1.9089642V to 2.6593314V corresponding to 40ºC and 0ºC, respectively. The A/D converter control register will be configured to use external reference voltages V_{ref+} and V_{ref-}. These voltages will be set to match this range of voltages. This allows the team to fully utilize the resolution of the analog to digital converter.

After passing through the analog to digital converter, a digital representation of the analog voltage will be obtained. With this, the voltage can be determined. Based on the voltage, the temperature can be computed and stored in a variable of 16-bits for the Data Handling and Data Logging routines. This process will be performed for both temperature sensors.

3.6 Data Logging System

This system consists of an SD Card. The data will be recorded using a 2-Dimensional array. This array will be 6 by 345600 . Each slot consist of a double with no more than 2 decimal places. The first parameter of the array is the number of data recorded in each sample. This number will be divided in two for the conductivity sensors, two for the temperature sensors, and two for the location (one for latitude and one for longitude). The second number of the array is the maximum number of samples needed to be recorded per mission. The time will be recorded in second 2-dimensional array. This array will be 3(hours, minutes and seconds) by 345600

$$\frac{Samples}{Mission} = \frac{8\,Samples}{Second} \times \frac{60\,Seconds}{Minute} \times \frac{60\,Minutes}{Hour} \times \frac{12\,Hours}{Mission}$$

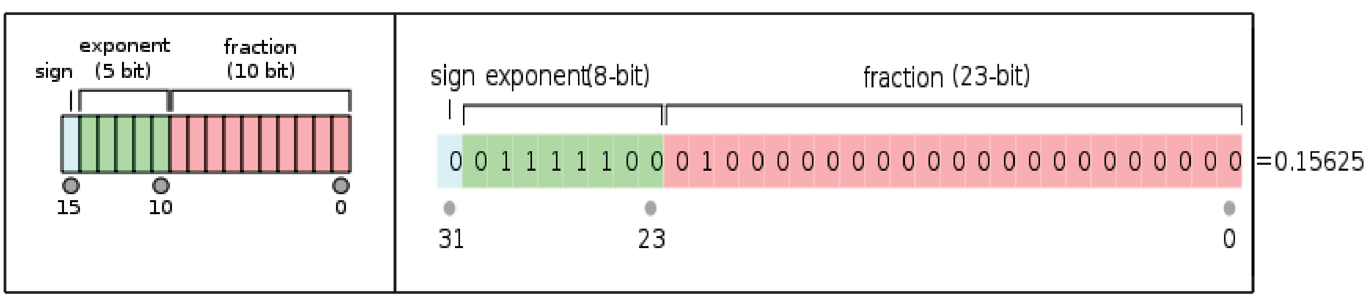
3.7 Data Handling System

The purpose of this module is to convert the last line of the array into a bit stream and send it to the transmitter. The total length of one transmission is going to be 145 bits. . The first 64 bits consist of the first part of the first array mentioned in the data logging system. This part consist of the data collected by the two conductivity sensors and the 2 temperatures sensors. Each number in this section will be converted into a half-precision IEEE-754 floating point standard and sent to the data transmission system. The next part of the first array will represent location. Latitude and longitude will be represented in single precision IEEE-754 floating point standard consisting of 32 bits each. The remaining 17 bits are coming from the time array. This data will be transmitted as the binary equivalent (5-bits for hours and 6-bits for each minutes and seconds) . Each number will be converted into six bits and sent to the data transmission system.

The IEEE-754 floating point standard is a method used to represent fractions in a bit stream. Do to the length of our data points half-precision (16-bits) ans single-precision (32 bits) are needed. This bits are divided into 3 sections. These sections are:

- Sign: 1 bit
- Exponent: 5-bits (half-precision), 8-bits (single-precision)
- Fraction: 10 bits (half-precision), 23-bits (single-precision)

The actual exponent is calculated by subtracting the bias from the value represented in the binary section. 15 is the bias of a half-precision number while 127 for single-precision.



<u>Pseudo Code</u>

typedef struct

```
            {
                        unsigned int bit : 1;   } Bit;

        void main (double c1, double c2, double t2, double t2, double lat, double long, int
                h,
                        int m, int s)
        {

            //BitArray structure.
            Bit bitstream[145], con1[16], con2[16], tem1[16], tem2[16], latitude[32],
                            longitude[32], hour[5], minute[6], second[6];

            con1 = half(c1);
            con2 = half(c2);
            tem1 = half(t1);
            tem2 = half(t2);
            latitude = single(lat);
            longitude = single(long);
            hour = integer(h);
            minute = integer(m);
            second = integer(s);

            for (int i =0; i<145: i++)
            {
                        if (i < 16)
                                    bitstream[i] = con1[i];
                        else if (i <32)
                                    bitstream[i] = con2[i-16];
                        else if (i <48)
                                    bitstream[i] = tem1[i-32];
                        else if (i <64)
                                    bitstream[i] = tem1[i-48];
                        else if (i<96)
                                    bitstream[i] = latitude[i-64];
                        else if (i <128)
                                    bitstream[i] = longitude[i-96];
                        else if (i <133)
                                    bitstream[i] = hour[i-128];
                        else if (i <139)
                                    bitstream[i] = minute[i-133];
                        else
                                    bitstream[i] = second[i - 139];
            }

}
```

3.8 Data Transmission System

Figure3.8.1 shows a block diagram of the data transmission system of the AWQuSam.

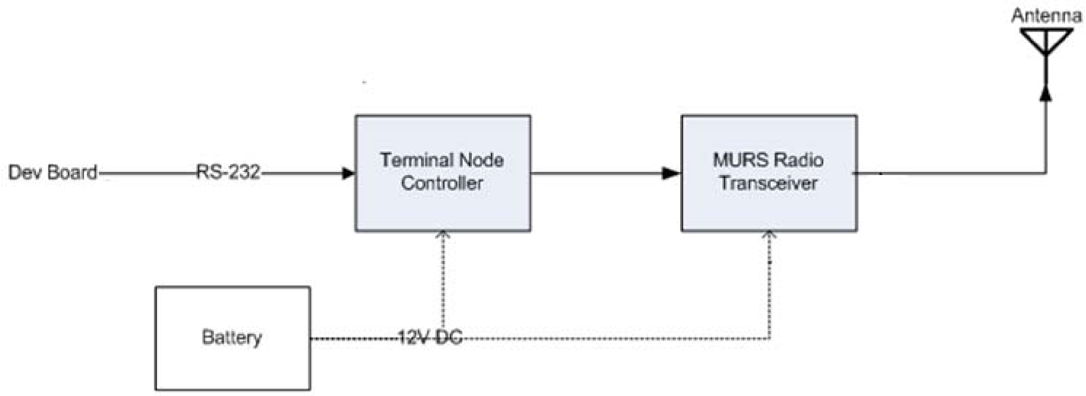
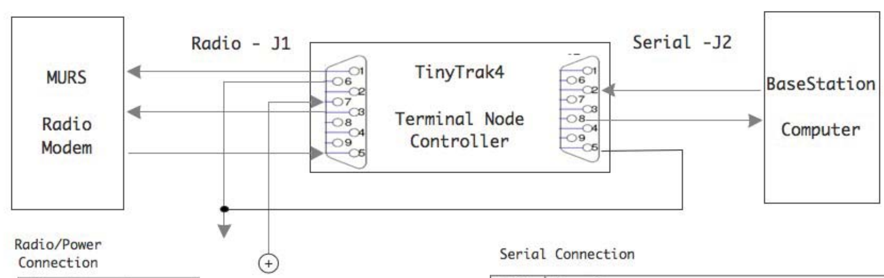


Figure3.8.1: Top-level block diagram of Data Transmission System



Radio/Power Connection

Pin	Function
1	Audio out
2	Carrier Detect
3	PTT Out
4	JP1
5	Audio in
6	Ground
7	Power In
8	PTT In
9	No connection

Serial Connection

PIN	Function
1	No Connection
2	Primary Serial data in from a GPS or computer
3	Primary Serial data out to a GPS or computer
4	Power out for GPS (Vin or 5V), or alternate power input
5	Ground
6	No Connection
7	Secondary Serial data out to a GPS or computer
8	Secondary Serial data in from a GPS or computer
9	No Connection

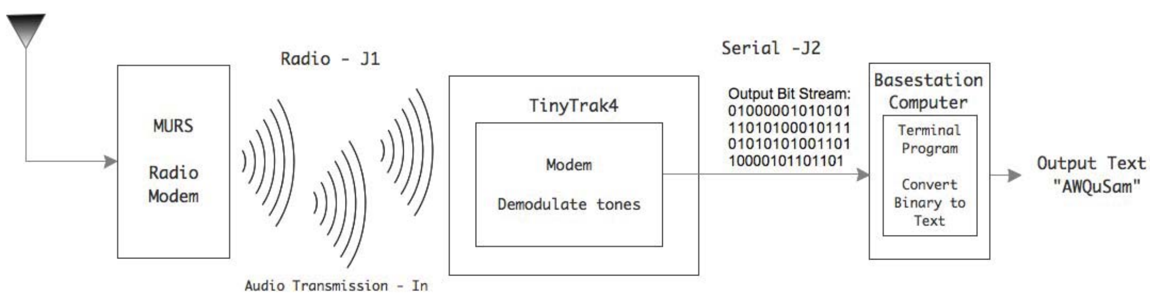


Figure3.8.2. TNC will receive serial bit stream from data handling routine

The MURS radio to be used in the design is the Dakota Alert MURS Base Station, model M538-BS. This model was selected because it is a low-cost, effective transmission system. It is only capable of transmitting and receiving on the MURS frequencies, hence it is FCC approved for unlicensed user.

Figure3.8.3: M538-BS Dakota Alert MURS Radio

The antenna to be used on the AWQuSam is MURS45 by Firestik. This is a 5/8 wave antenna with gain of 6dB over isotropic. A 5/8 wave antenna was selected over a 1/4 wave antenna because they tend to propagate better in the horizontal plane.

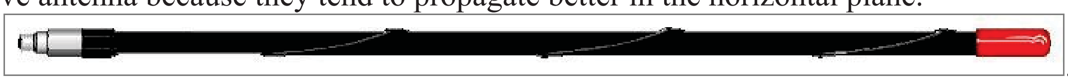


Figure3.8.4: Firestik MURS45 Antenna

The terminal node controller will output an audio signal that represents the serial bitstream sent by the AWQuSam. This audio signal will be passed to the M538-BS radio's microphone in port. Figure3.8.4 illustrates the scenario. The speaker audio line will be used at the base station receiver, and the mic audio line will be used at the AWQuSam transmitter.

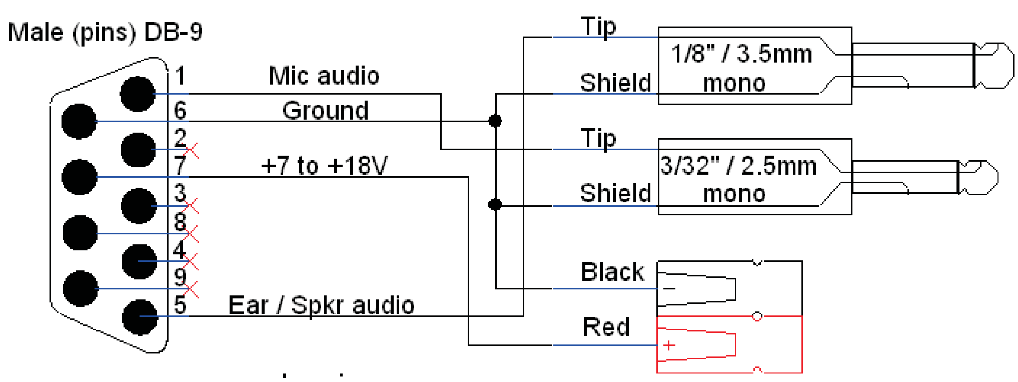


Figure3.8.5: Terminal Node Controller to M538-BS Interface

To interface with the terminal node controller, some modifications must be made to the radio. The push-to-talk button must be pressed while a transmission is active. Grounding the radios PTT line activates this function. While transmitting data, the microcontroller will pull the PTT line of the radio down. Figure3.8.5 below shows the internals of the M538-BS MURS radio.

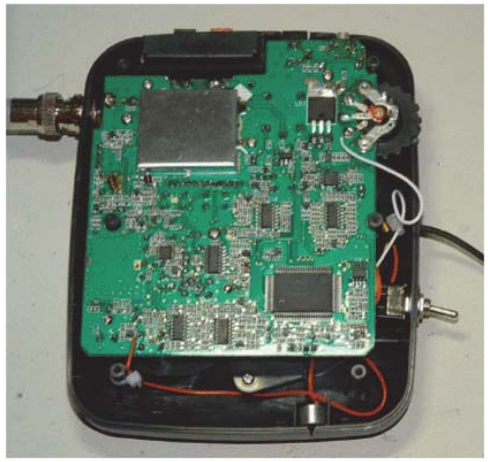


Figure3.8.6: M538-BS MUR Radio Open Box

3.9 Base Station Receiver

The Base Station Receiver functions in much the same way as the Data Transmission System (See Section 3.8) with data travelling in the opposite direction, as shown in Figure3.9.1.

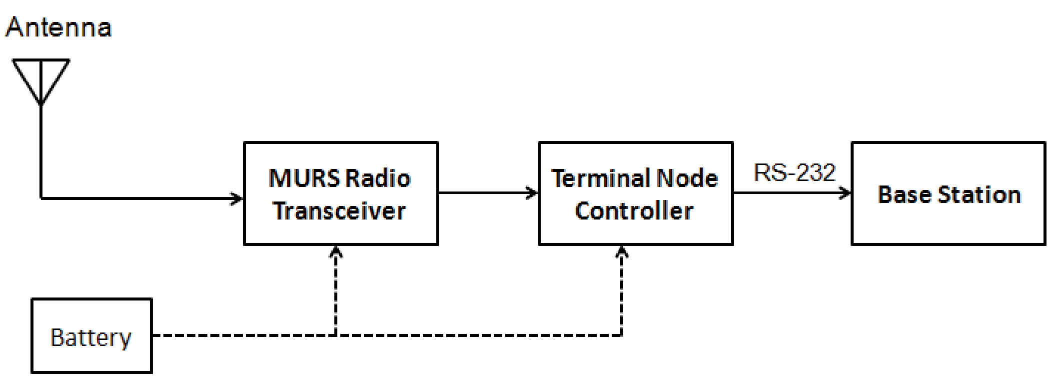


Figure3.9.1: Top-level Block Diagram of Base Station Receiver

To select a suitable radio transceiver, the team performed some quick calculations to determine the receive sensitivity required to achieve the desired transmission range (5km). From the Friis Transmission Equation:

$$Pr = Pt + Gt + Gr + 20log(\frac{\lambda}{4\pi R})$$

$$Pr = 33dBm + 6dBi + 6dBi + 20log(\frac{1.96m}{4\pi 5000m}) = -45.12dBm$$

In the above equation, a transmission power of 2W was assumed over a maximum distance of 5km, with receive and transmit antenna gains of 6dB over isotropic. The wavelength, λ, based on a frequency in the 151-154MHz MURS band. It is apparent that the receiver must have a sensitivity of -45.12dBm to transmit over this range with these antennas.

The antenna used on the receiver is another model by Firestik, the MURS-BASE. It is also a 5/8 wave antenna with gain of 6dBi.

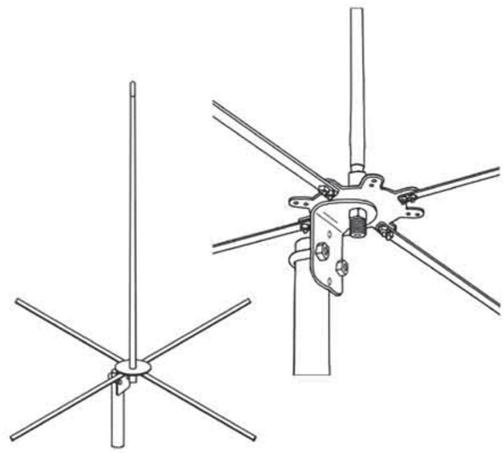


Figure3.9.2: MURS-BASE Antenna by Firestik

Refer to Figure3.8.5 for information regarding the interface between the terminal node controller and the MURS radio where the speaker audio line will be used at the base station receiver, and the mic audio line will be used at the AWQuSam transmitter.

The terminal node controller will demodulate the received audio signal into the serial bitstream that was transmitted by the AWQuSam. It performs error detection and correction before relaying the data to the TNC's output. This bit stream will be printed to a terminal on a PC furnished by the Florida State University Department of Oceanography.

3.10 User Interface

3.10.1 Keypad Interface

The keypad interface will allow the end-user to program paths into the AWQuSam using GPS coordinates of waypoints and final destination. The keypad will be located on board of the AWQuSam.

Figure 3.9.1.1 shows the process for developing the user interface which can be broken into four phases; Program Mode, Keypad Initialization, User Input, and GPS Coordinates.

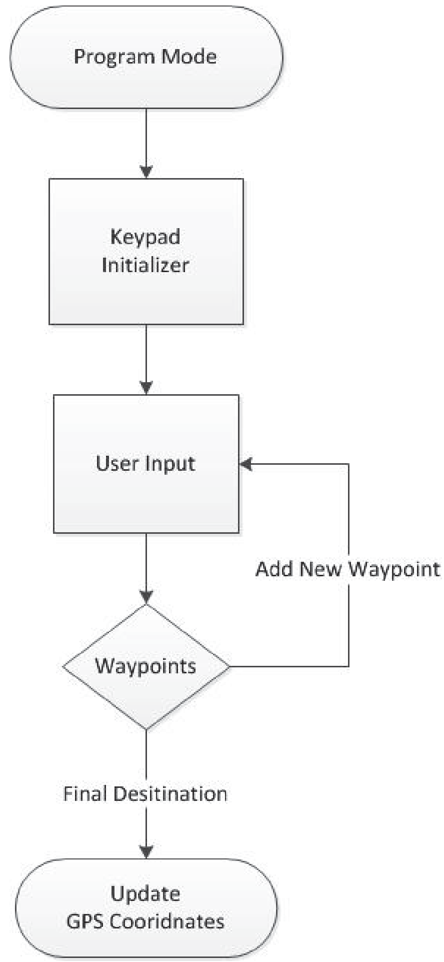


Figure 3.10.1.1: User Interface Flowchart

1. Program Mode

After the board has been powered on by the user, in order to access the "Program Mode", the user would have to press one of the four push-buttons listed.

S3: Active-low switch connected to RD6 (user-defined)
S4: Active-low switch connected to RD13 (user-defined)
S5: Active-low switch connected to RA7 (user-defined)
S6: Active-low switch connected to RD7 (user-defined)

The push-button would throw an interrupt and cause the processor to save its state of execution and begin executing in "Program Mode". This occurs when the program polls the switches and discover that one is active-low.

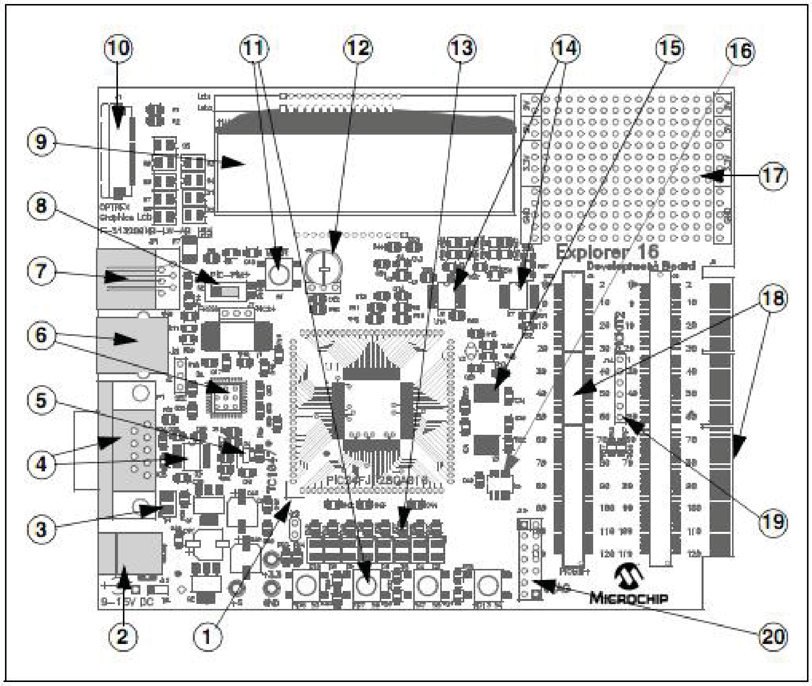


Figure 3.10.1.2: Push-Button Locations (#11)

2. Keypad Initialization

To initialize a standard 4x4 keypad, the team would first develop a matrix to understand what characters should be associated with each given row and column. The matrix format should mimic the exact character layout displayed on the keypad.

Col 1	Col 2	Col 3	Col 4	
1	2	3	A	Row 1
4	5	6	B	Row 2
7	8	9	C	Row 3
*	0	#	D	Row 4

```
rom char* KeyPadMatrix = {
        '1', '2', '3', 'A',
        '4', '5', '6', 'B',
        '7', '8', '9', 'C',
        '*', '0', '#', 'D',
        0xFF
};
```

Then the keypad connections would be defined as follows:

```
volatile bit row1port  @PORTA.1
volatile bit row1tris   @TRISA.1
volatile bit row2port  @PORTA.2
volatile bit row2tris   @TRISA.2
```

```
                    .
                    .
                    .
volatile bit col1port  @PORTA.5
volatile bit col1tris   @TRISA.5
volatile bit col2port  @PORTA.6
volatile bit col2tris   @TRISA.6
                    .
                    .
                    .
```

The two main functions that would be designed to take input from the keypad would be a "ScanKeypadInit()" and "ScanKeypad()". "ScanKeypadInit()" would be designed to to begin by turning on the row outputs and reading column inputs. "ScanKeypad()" is designed to return the key being pressed. This will later be used by storing and printing to the LCD screen

Pseudocode:

```
void ScanKeypadInit(){
    //Set rows to output
    row1tris = 0;
    row2tris = 0;
    ...

    //Set columns to input
    col1tris = 1;
    col2tris = 1;
    ...
};
void ScanKeypad(){
    char key = 0, row;
    for(row = LSB; row < binary 0001000; row shift left 1)
    {
        //Turns the rows output
        row1port = row (bit 1)
        row2port = row (bit 2)
        row3port = row (bit 3)
        row4port = row (bit 4)

        //Read columns and break if key is pressed
        if(col1port is pressed)
            break;
        increment key;
        if(col2port is pressed)
            break;
        increment key;
```

...

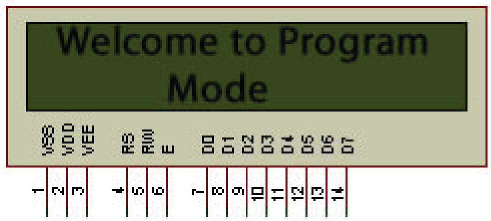
return KeyPadMatrix[key];

}

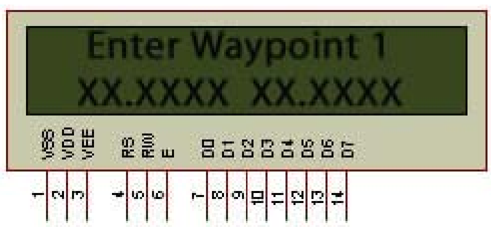
3. User Input

The user input will be entered through the keypad via prompts from the LCD display

screen. Once the micro-controller has been sent to "Program Mode" the LCD Display will alert the user to enter in the first waypoint.



The LCD by default limitations can only output 16 characters for each of the two lines on the screen. The first 6 numbers without a decimal point will be evaluated as "XX.XXXX" (where X is each digit) and stored as the longitude value for the GPS. The final 6 numbers without a decimal place will be evaluated the same and stored as the latitude values for the GPS.



The user will be given three options during their waypoint entries; if the user selects pushbutton 4 (RD13), this will indicate that the user has entered something inaccurately and the program will throw that data away and refresh the waypoint. If the user selects pushbutton 5 (RA7) this will indicate that the user is ready to enter in their next waypoint and a new prompt will be displayed. The final pushbutton 6 (RD7) will indicate that there are no more waypoints and the final destination has been determined. The program will then store that information and exit from "Program Mode".

Pseudocode:

/ Explorer 16 Dev board provides lcd libraries and functions that can be called*

```
to output to the lcd therefor there will be no need to develop code for initializing
and writing to the lcd display*/

#include<lcd.h>

Init_LCD(); //will initialize lcd display
lcd_cmd(LCD_CURSOR_OFF); //turns the cursor off
lcd_cmd(CLEAR_LCD); //clears lcd of any previous display

char* text = "Enter Waypoint 1";
puts_lcd(text, 16); //prints text to the first line of lcd

char userinput[16];    //character array to store user input
int i = 0;
while(i < 15) {        //for 16 keystroks
        char keyentry =keypadScan();  //scan
        lcd_data(keyentry);    //prints keystroke to LCD
        userinput[i] = keyentry;
}
puts_lcd(userinput, 16);
```

4. GPS Coordinates Update

The user input will be stored as floating point numbers that will be sent to the GPS module to indicate the direction and coordinates for the AWQuSam to begin traveling. This information will be stored in multiple variables for each waypoint. Once the AWQuSam has reached the waypoint indicated by the GPS, it will then be updated with the next waypoint and destination. This routine will be the format for how the AWQuSam will continue on its course.

4 Schedule

(See Appendix A)

Long lead items have been purchased. Many shorter lead items have been purchased and are already in house. Preliminary design work has been conducted, and the team is undergoing a more detailed design stage. This period must be complete before the designs can be effectively implemented. Consequently, some tasks are behind schedule as the schedule presently stands. Observe that there is some flexibility in the schedule, particularly after December 17. This period was established to mitigate any scheduling risks, and will be used to ensure the project is completed in a timely manner.

5 Budget Estimate

Item	P/N	Manufacturer	Distributor	Qty	Projected Cost	Actual Cost
PIC Development Board w/ Programmer	DV164037	Microchip	Microchip	1	$225	$225.00
SD Daughter Card	AC164122	Microchip	Microchip	1	$28.50	$28.50
Conductivity Sensor	SBE-4	Seabird	In House (FSU Oceanography)	2	-	-
Temperature Sensor	OL-710	Omega	Omega	2	$200	$173.00
Compass Module	SEN-07915	Honeywell	Sparkfun	1	$34.95	$34.95
GPS	GPS-09566	ADH Technology Co. Ltd	Sparkfun	1	$79.95	$99.95
microSD 1GB Memory Card	COM-08163	A-Data	Sparkfun	1	$9.95	$9.95
USB to Serial Converter	USB-232-1	CommFront	CommFront	1	$30	
MURS Radio Modem	RV-M3-M	Raveon	Raveon	2	$260	$113.00
Mobile Antenna	MURS45	Firestik	TBD	1	$24.99	
Base Station Antenna	MURS-BASE	Firestik	TBD	1	$39.99	

4x4 Keypad	TBD	Grayhill	TBD	1	$20	
Wiring and Accessories					$200	
Battery	Lead Acid Battery for UPS and Alarm Systems	Power Sonic	Amazon	2	26.78	
Servo Motor	High Torque Water Proof Servo	Traxxas	TBD	3	83.76	
Propulsion Motor	Semitrash Water Pump	Powerhouse	Northern Tool + Equipment	1	399.99	
Enclosure	Aluminum Roll	Roll Valley	Home Depot	3	38.97	-
Frame	N258509 Square Tube	National Mfg.	Amazon	8	98.00	$140.00
Hoses	Discharge and Suction Hoses with couplings	TBD	TBD	1	40.00	
Mounting Hardware	Sealants and Bolts	TBD	TBD	N/A	40.00	
SubTotal:					1880.83	
Shipping & Handling						
Total Proposed Expenditures:					**$2000.83**	**$779.45**

Table5.1: Product Prototyping Budget

6 Overall Risk Assessment

Technical Risks

ID	Risk Item	Probability	Impact	Mitigation Plan
1	Microcontroller Timing - Detailed timing analysis has not yet been performed. This introduces a risk that not all tasks can be performed on same µC while still recording 8 samples/second	Medium	Medium	If this is an issue, the most efficient coding methods will be implemented
2	Conductivity Sensor Organic Matter - The SBE-4 is a pump-driven conductivity sensor that could be congested with organic matter	Medium	Medium	Engineered netting will be used around the intake pump to disperse organic material
3	Conductivity Sensor Pump Depth - The sensor pump has not yet been thoroughly tested to determine if it can pump water at the surface.	Medium	High	Sensor will be used at the highest level it can effectively operate to discourage air intrusion.

Schedule Risks

ID	Risk Item	Probability	Impact	Mitigation Plan
1	Personnel Leave - Illness or absence of any engineer would require over-allocating other resources	Medium	High	Some flexibility has been built into schedule. Many subsystems have multiple engineers assigned. One engineer can divide time to cover responsibilities of absent engineer.
2	Centralized Design - Majority of design is on the same microcontroller development board, but this board is not available to all engineers simultaneously	High	Low	Programmer will be installed on multiple computers to allow for independent programming and parallel design work. Module testing time will be coordinated.

Budget Risks

ID	Risk Item	Probability	Impact	Mitigation Plan
1	Increase Product Expenses - Price estimates in the original proposal could possibly be lower than what the team actually pays	Low	Moderate	To make sure that this never occurs, the team makes budget talks a priority at every meeting.
2	Unforeseen Expenses -As the team continues moving forward in the design and development of the AWQuSam, there may be devices or products that the team was initially unaware of, that are a necessity to the completion of this product.	Moderate	High	If an engineer can identify a component that may be needed in the future early in the process, it becomes much less expensive to solve compared to the final stages of the design.
3	Safety Risk - AWQuSam impacting a diver in the head is a grave safety concern. Addressing this issue requires budget modification	Moderate	Moderate	A strobe / revolving beacon can be added to address the safety concern. Reserve budget allotment must be used for this.

6.1 Technical Risks

Technical Risk 1: Microcontroller Timing

Description

A detailed timing analysis has not yet been performed. This introduces a risk that not all required tasks can be performed on same microcontroller while still satisfying requirements that the AWQuSam measure and record eight samples per second of all required oceanographic data.

Probability: Moderate

Because this assessment has not yet been performed, there is a relatively significant chance that the team finds this to be an issue.

Consequences: Moderate

If this risk comes to fruition, it would require utilizing more advanced coding techniques with emphasis on timing.

Strategy

If timing is an issue, more advanced coding techniques, with an emphasis on timing, will be performed. Routines written in C will be converted to Assembly to minimize the number of clock cycles per task. Some tasks can be relegated to a separate microcontroller to free up timing for the main development board. The team has ordered a PIC programmer that allows for programming of different microcontrollers besides that found on the Explorer16. Rather than polling methods, sensor information will be passed to the main development board, triggered by an interrupt, when data is ready. This allows the main development board to perform other tasks and process more critical information.

Technical Risk 2: Conductivity Sensor Organic Matter

Description
The SBE-4 conductivity sensor being used for data acquisition relies on a pump-driven system for more precise samples. There exists a risk that this pump could become congested with organic matter (seaweed, algae, etc) or other debris and cease to function.

Probability: Moderate
The amount of organic matter present fluctuates with the seasons and with research location.

Consequences: Moderate
If one sensor becomes congested, useful data can still be gathered from the other sensor. If both sensors are clogged, useful temperature data can still be collected.

Strategy
The team will explore methods for preventing congestion of the pump even when the AWQuSam is operated in an environment that poses a significant risk for rendering the pump useless. One strategy is to engineer a netting system around the intake valve to drive organic matter away from the pump.

Technical Risk 3: Conductivity Sensor Pump Depth

Description
The SBE-4 conductivity sensor being used for data acquisition relies on a pump-driven system for more precise samples. The sensor’s pump has not been thoroughly tested to determine the most shallow level in which it can be effectively operated.

Probability: Moderate
Without conducting tests, there exists a reasonable chance that air intake from surface acquisition could effect measured data.

Consequences: High
If the pump cannot record samples at the surface of the water, it will have to be immersed slightly, which may provide less useful information to researchers.

Strategy
The SBE-4 can be operated either horizontally or vertically. Various orientations will be tested to determine if one is more suitable for surface-level data acquisition. If neither is suitable,

methods for driving water into the pump will be explored. If all other options are exhausted, the sensor will be used at the shallowest level it can effectively operate to minimize air intrusion.

6.2 Schedule Risks

Schedule Risk 1: Personnel Leave

Description
If any of the team's engineers falls ill or otherwise has an extended absence from work, the schedule may be jeopardized as it would require over-allocating other resources

Probability: Moderate
It is entirely probable that over the course of the remaining six months of engineering design work, an individual falls ill and is unable to complete his/her design duties.

Consequences: Severe
In the event of an extended absence, the team's other engineers may be required to work overtime in order to complete the project as scheduled.

Strategy
Some flexibility has been built into schedule. Many subsystems have multiple engineers assigned toward design and implementation. One engineer can divide his/her time to cover the responsibilities of the absent engineer, as required, in order to ensure a timely delivery of the final product.

Schedule Risk 2: Centralized Design

Description
Much of the design revolves around the same microcontroller development board. This is a risk, because this board is not available to all engineers simultaneously.

Probability: High
This risk is very likely to occur, so a mitigation strategy is already being implemented.

Consequences: Low
As this risk pans out, the impact will be minimized because of the strategy highlighted below.

Strategy
Though the development board cannot be used by all engineers simultaneously, the programmer can be installed on multiple computers. This allows for independent programming and parallel design work. Simulations will be performed during these design phases to ensure time with the development board is well-spent. Module testing time will be coordinated among the engineers.

6.3 Budget Risks

Budget Risk 1: Increase of Product expenses

Description
Price estimates in the original proposal could possibly be lower than what the team actually pays. Original estimates, when summed together, just meet the budget constraint of $2,000.00. If any item is slightly larger than anticipated, new funding strategies would need to be implemented.

Probability: Low
The probability is low because of the initial amount of research done on pricing of products. As Table 5.1 states, at this juncture, the team has paid exactly what was estimated.

Consequences: Moderate
If this were to occur it would slow the project down by delaying purchases and moving the team's focus to securing additional funding and budget management.

Strategy
To make sure that this never occurs, the team makes budget talks a priority at every meeting. Also, all purchases go through a designated treasurer and is approved by the team leader before any purchases are made

Budget Risk 2: Unforeseen Expenses

Description
As the team continues moving forward in the design and development of the AWQuSam, there may be devices or products that the team was initially unaware of, that are a necessity to the completion of this product. These new expenses haven't been planned for in the budget and would therefor be in excess of the $2,000.00 limit.

Probability: Moderate
The probability is moderate because the group has done careful planning and designing to make sure that these unexpected expenses won't be revealed in the future. Although the probability stands as moderate because there are no guarantees to what may occur in the future

Consequences: High
If this were to occur, it would slow the project down by delaying purchases and move the focus to budget increases.

Strategy
Team members are constantly doing careful planning and always looking to the future. If an engineer can identify a component that may be needed in the future early in the process, it becomes much less expensive to solve compared to the final stages of the design.

Budget Risk 3: AWQuSam Safety

Description
The AWQuSam injuring a swimmer on impact, damaging a boat or vessel, or destroying any part of the marine environment is a great safety concern for this project. To insure that the AWQuSam meets legal standards and safety, budget modification must be made.

Probability: Moderate
The probability is moderate because the boat should remain autonomous without any supervision for up to twelve hours. Such a long period of time of operation increases the probability of a crash or accident.

Consequences: Moderate
If a crash or accident does happen, the consequences would be greatly severe, especially if an individual is injured. The impact on AWQuSam Engineering's budget, however, is moderate.

Strategy
The teams strategy is to design the AWQuSam to make it as noticeable as possible. By incorporating bright colors, foam cushions, and a strobe siren, would alert neighboring people of the operating AWQuSam and soften the impact if a collision were to occur. Budget adjustments will need to be made for these upgrades.

6.4 Summary of Risk Status

The team has performed a risk analysis and will continue to monitor these and other risks as the project develops. The risks are well understood and managed. The potential impact of each risk has been assessed, as has the probability of the risk's occurence. In the event that one of these risks does occur, a mitigation strategy has been identified and can be implemented.

7 Conclusion

Design and development of the Autonomous Water Quality Sampler is progressing as expected. The preliminary design of the major subsystems are included in this design review. Navigation, data acquisition, data logging, propulsion, and steering are all critical subsystems of the design. These must be integrated with one another and fitted to the mechanical hull, as designed. More detailed design and implementation are the next phases of the project. A vision for the future is established. The project schedule and risk registers are monitored weekly in order to ensure that the project is completed on schedule. AWQuSam Engineering's primary business objective is to meet the customer's requirements by providing quality service and designing with integrity. The quality of the team's service is a direct consequence of the team's commitment to continual excellence.

8 References

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Appendix A - Project Schedule