SYSTEM-LEVEL DESIGN REVIEW

TEAM 4 – ROBOSUB

November 21, 2014

COMPETITION OVERVIEW

- Hosted by The Association for Unmanned Vehicle Systems International (AUVSI)
- Located in San Diego, CA at the TRANSDEC pool
- Last year's competition had 7 tasks that require the sub to have various abilities

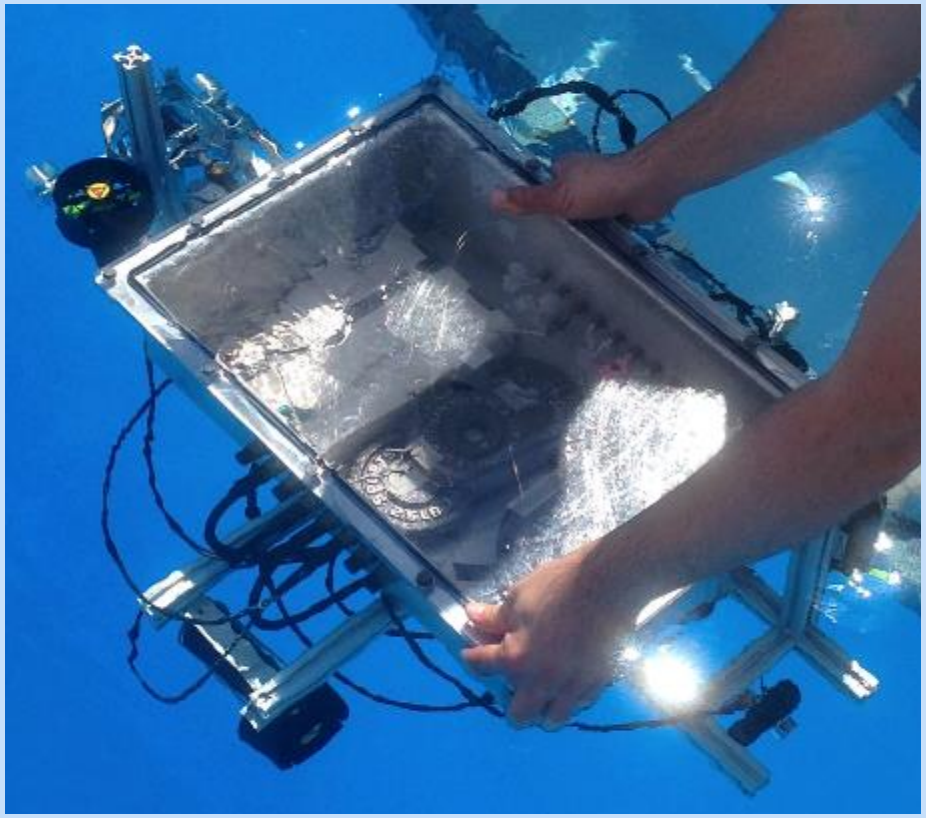
INTRODUCTION

Key Requirements

- Run autonomously without any attachments
- Change depth, direction, and speed
- Pass through and around PVC structures
- Recognize colors

Key Limitations

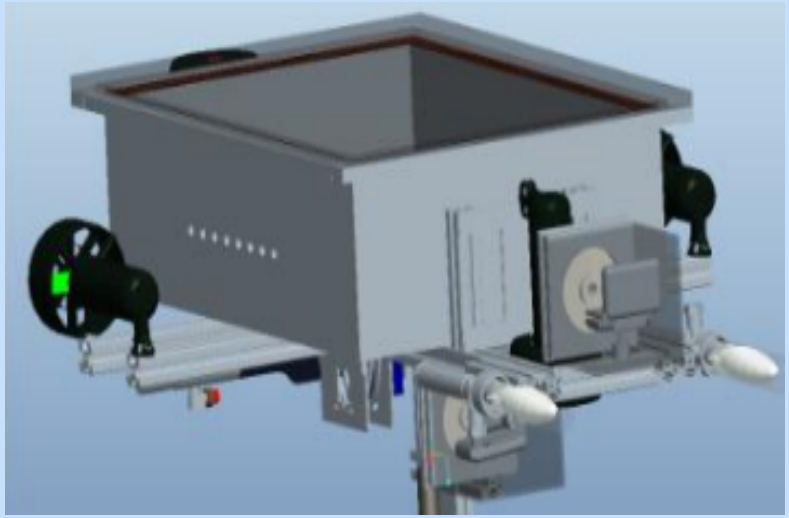
- Must use last year's sub
- Sub must weigh under 125 lbs



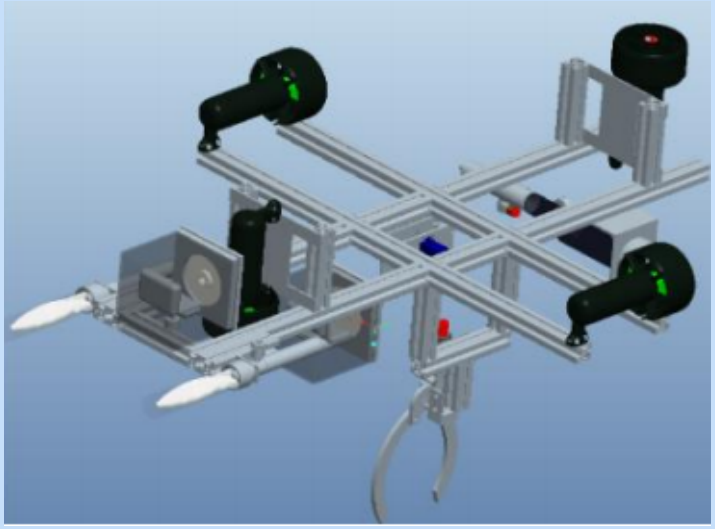
CONCEPT GENERATION & SELECTION

MECHANICAL DESIGN

- Inherit previous year hull and frame structure
- Note: The torpedoes and Claw system are not in current framework



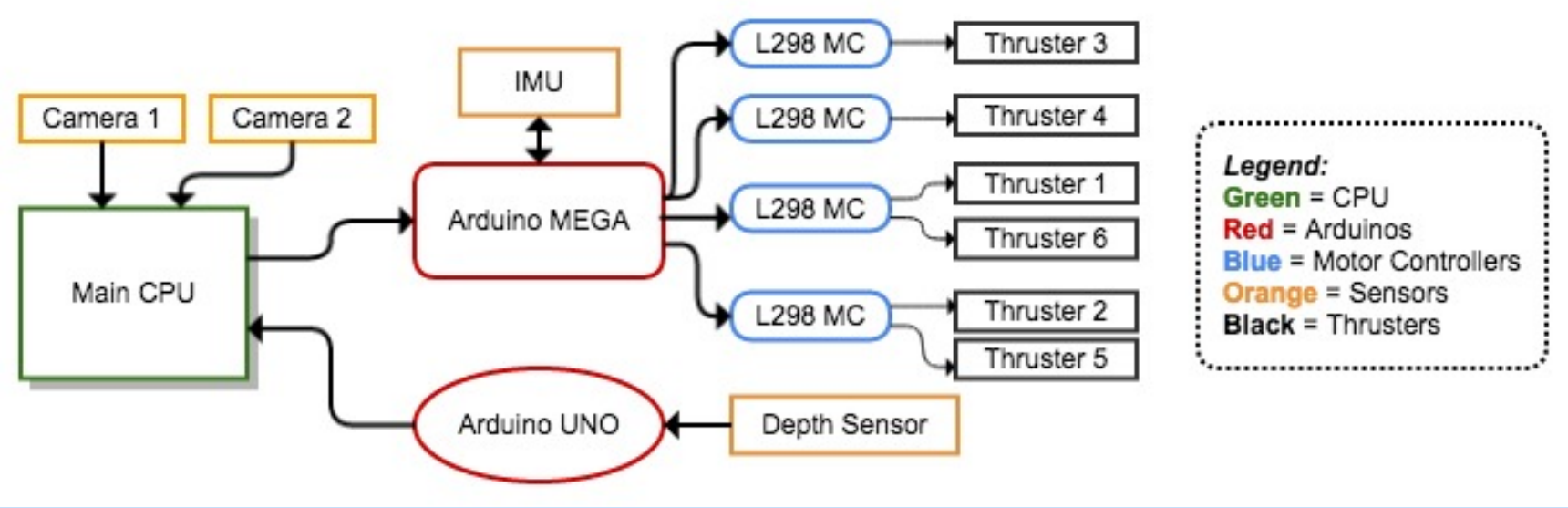
CAD model of hull RoboSub Project Proposal 2012



CAD model of framework and components RoboSub Project Proposal 2012

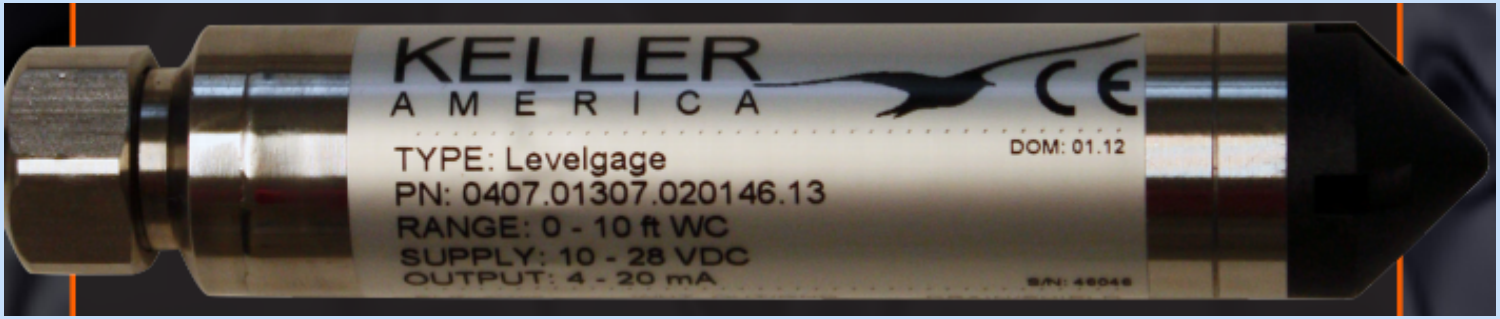
ELECTRICAL DESIGN

- Use same connections/wiring as last year
- Cameras interface directly with the main CPU
- Arduino UNO interfaces with the depth sensor
- Arduino MEGA interfaces with the smaller controllers for the thrusters and the IMU (Inertial Measurement Unit)



NEW DEPTH SENSOR

- Thank you to Dr. Nico Wiender for consulting on the selection of the depth sensor

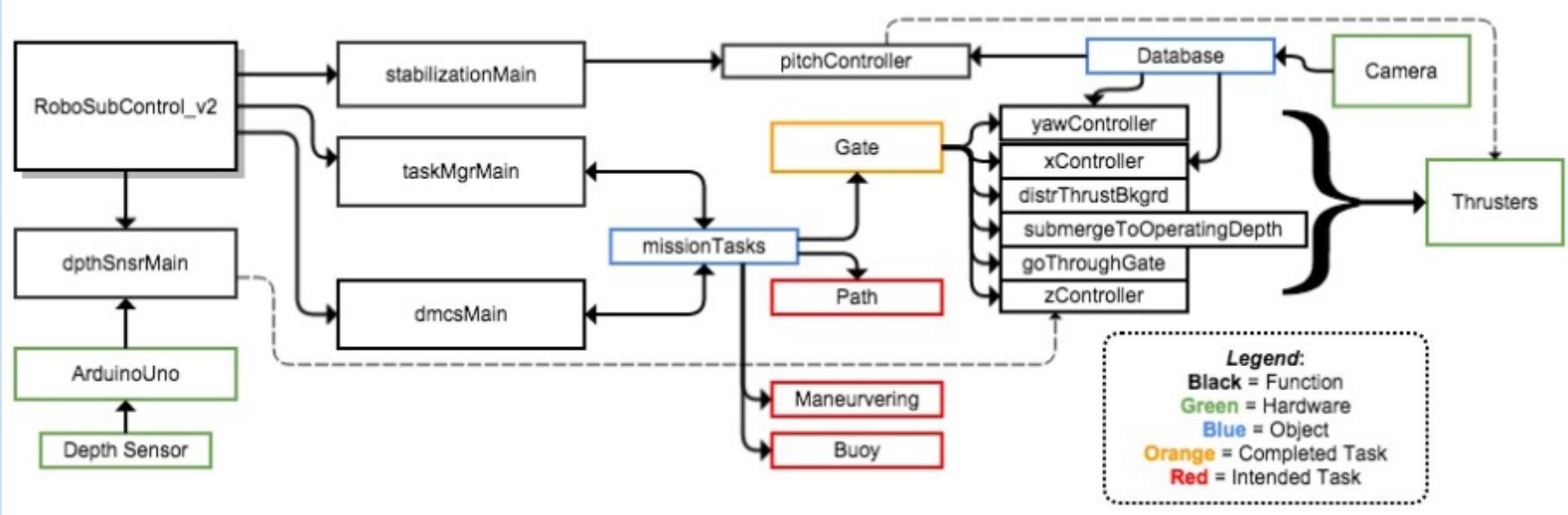


Specification

- Pressure Range : Relative 0 to 900ftWC
- 1% full scale total error band
- 20mA,0-5V DC analog Output

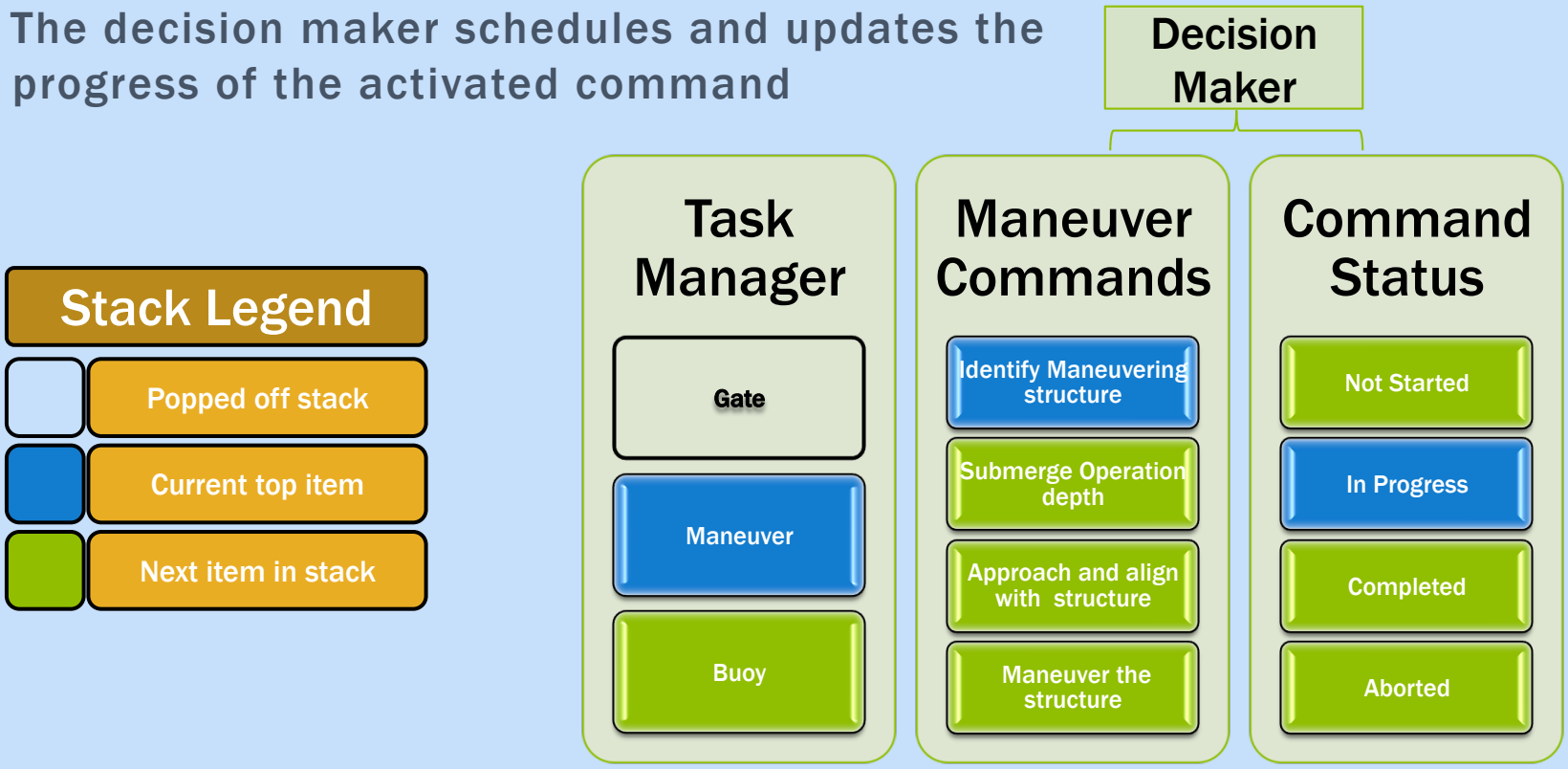
CODE STRUCTURE

- Build upon last year's code
  - Change path implementation
  - Implement Maneuvering and Buoy tasks



ADDING NEW TASKS AND DECISIONS

- The Task Manager is implemented using a stack
  - Each task has a set of commands
  - The decision maker schedules and updates the progress of the activated command

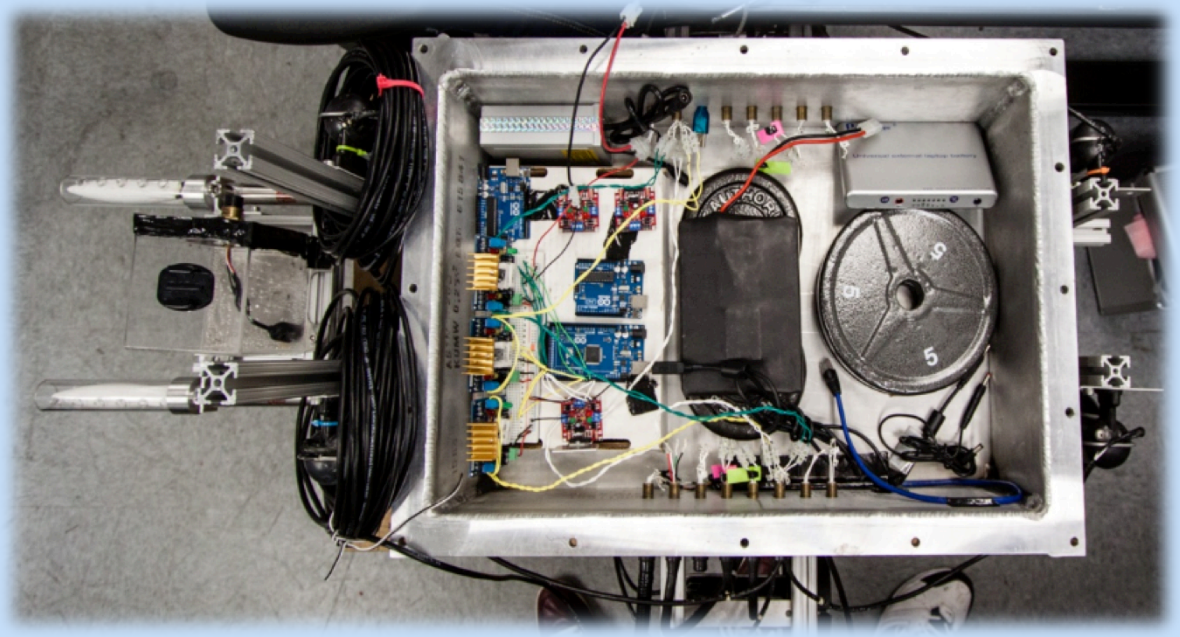


DETAILED SYSTEM DESIGN

COMPONENT INTERFACE

HULL

- Last Year's Design
- Components changes:
  - Depth Sensor and additional Lithium Ion Battery Pack



POWER SYSTEMS

- Power Supplies
  - Universal Laptop Battery
    - Powers the Zotac
  - 2 Lithium Ion Battery Packs
    - 1 Powers the Thrusters
    - 1 Powers the Depth sensor

Power Supply	Voltage (V)	Max Voltage (V)	Cut Off (V)	Max Discharge Current (A)	Capacity
Lithium Ion Battery Pack	14.8	16.8	11.0	30.0	20 Ah or 296 Wh
Universal Laptop Battery	16 or 19	19.0	13.0	3.0	4000 mAh

Components	Max Current (A)	Ave. Current (A)	Voltage Required (V)
Zotac PC Board	3.5	1.5	19.0
Arduino UNO	0.75	0.5	7.0 - 12.0
Arduino Mega	0.75	0.5	7.0 - 12.0
Motor Controllers	2.0	1.5	5.0
IMU	0.075	0.060	3.5 - 16.0
Thrusters	12.0	3.0	19.1
Depth Sensor	0.020	0.012	8.0 - 11.0

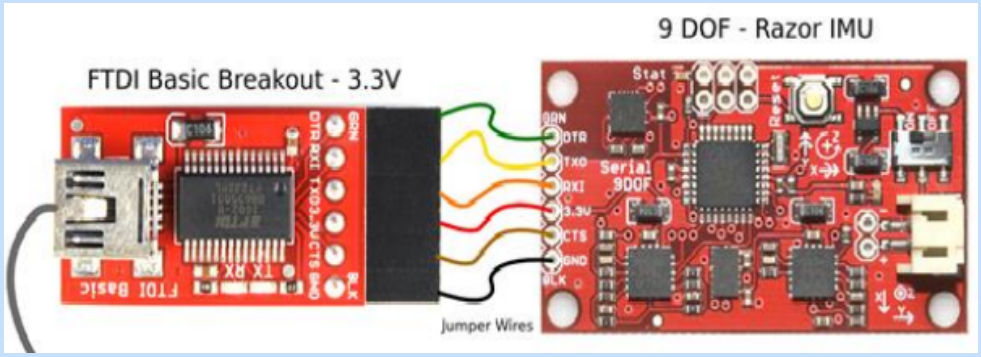
MAIN PROCESSING UNIT

- Zotac
  - CPU Intel Core i3-2330M Processor (2.2 GHz, Dual-Core)
  - Has 4 X USB 2.0 Ports, and 2 X USB 3.0 Ports
  - Max Capacity of 16GB

- Provides power for the Arduino MEGA, Arduino UNO and the Inertial Measurement Unit (IMU)

POWERED FROM THE ZOTAC

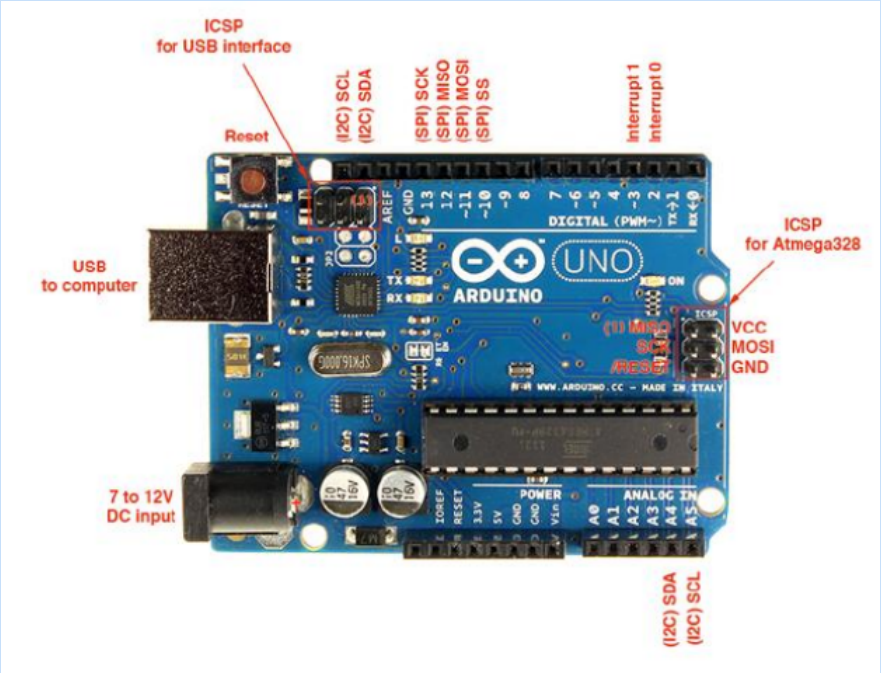
IMU
3.5 – 16V input



Logitech Webcams
5 – 12V input

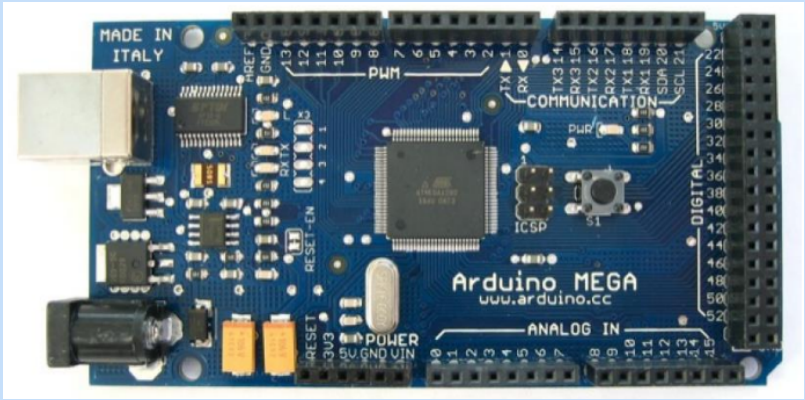
ARDUINO UNO

- Operating Voltage : 5V
- Input Voltage : 7-12V
- Digital I/O Pins : 14 (6 Provide PWM output)
- Analog Input Pins: 6
- DC Current per I/O pin: 40mA
- Flash Memory: 32KB
- Clock Speed: 16MHz



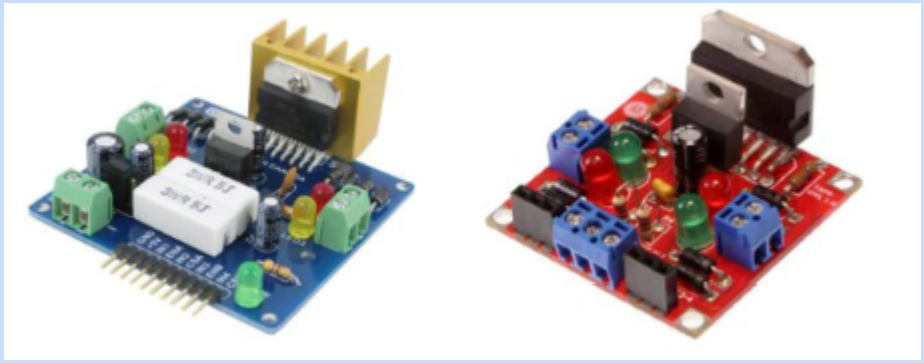
ARDUINO MEGA

- Operating Voltage : 5V
- Input Voltage : 7-12V
- Digital I/O Pins : 54 (15 Provide PWM output)
- Analog Input Pins: 16
- DC Current per I/O pin: 40mA
- DC Current for 3.3V Pin: 50mA
- Flash Memory: 256KB
- SRAM: 8KB
- EEPROM: 4KB
- Clock Speed: 16MHz

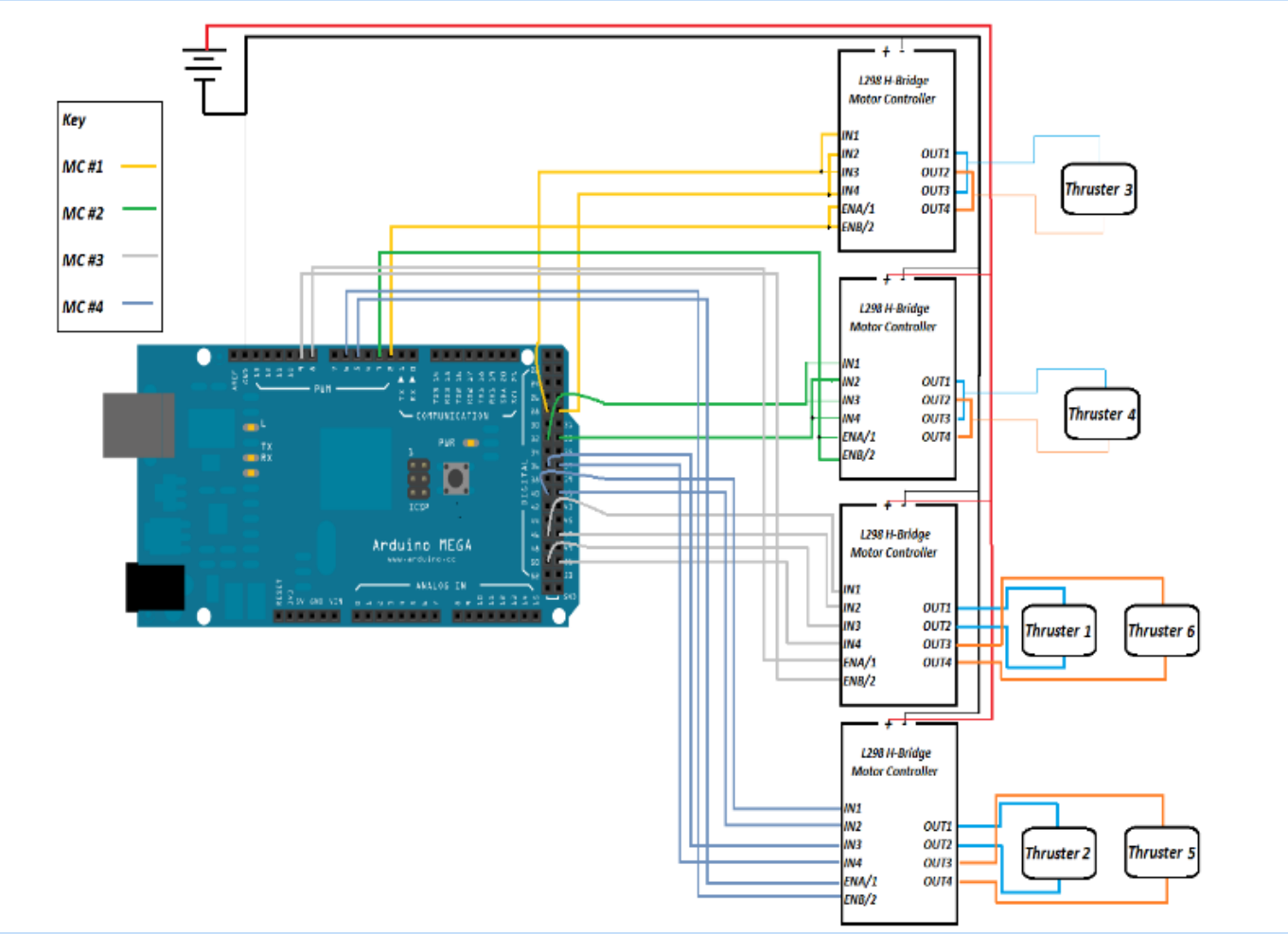


THRUSTER SYSTEM

- Seabotix SBT150 Thrusters
  - Require 0 - 19.1 V
  - Zotac powers Arduino Mega
  - Lithium Ion Battery Pack Connected to Motor Controllers



MOTOR CONTROLLERS



DEPTH SENSOR

- Depth Sensor powered from Lithium Ion Battery Pack
  - Requires a voltage between 8-28V
- Produces a 0-5V analog voltage
- Output read by the Arduino UNO

DETAILED SYSTEM DESIGN

SOFTWARE SYSTEM

TASK MANAGEMENT

- Tightly coupled with DMCS.
- Run as a thread.
- Uses a stack of MissionTask objects:

```
class MissionTask
{
public:
   stack<Types::TASK_COMANDS> TaskCmds;
private:
   string taskName;
   Types::TASK_STATE myState;
   bool isCompleted;
   bool isStarted;
};
```

TASK MANAGEMENT CODE SNIPPET

```
void TaskMrgMain()
{
  while(true)
  {
    if(missionTasks.empty())
    break;
    else if (missionTasks.top()-> getTaskName  == “TASKNAME”)
    {
      missionTasks.top()->gateCmds.pop();
      pthread_cond_signal(&taskIdentified);
      while (!missionTasks.top()->gateCmds.empty())
      {
        pthread_mutex_lock(&nextCommandWait);
        pthread_cond_wait(&cmdComplete, &nextCommandWait);
        missionTasks.top()->gateCmds.pop();
        pthread_mutex_unlock(&nextCommandWait);
      }
    } //all task have been completed
  }  //end taskManager loop
} //end TaskMrgMain
```

DECISION MAKING

- Done through the DMCS (Decision Making Control System).
- State machine.
- State corresponds to a task command at top of stack.
- Embedded in loop:
  - Checks if task is incomplete
  - Checks if task has not been aborted
  - Loops while there are still MissionTasks
- Also implemented as a thread.

DCMS CODE SNIPPET

```
while(!missionTasks.empty())
{
   if(missionTasks.top()->getTaskName() == "TASKNAME”)
   {
      submergeToOperatingDepth();
      myTask.setState(Types::TASK_STATE::IN_PROGRESS);

      while(myTask.getState() != Types::TASK_STATE::COMPLETED &&
      myTask.getState()!=Types::TASK_STATE::ABORTED)
      {
         switch(missionTasks.top()->TaskCmds.top())
         {
            case Types::TASK_COMMANDS::COMMAND_1:
            {
              /* do something */
             pthread_cond_signal(&cmdComplete);
             break;
           }
           default: break;
} } } }
```

VISION

- Hardware: 2 Logitech C615 Webcams
- Uses SLAM (Simultaneous Localization And Mapping).
- Uses OpenCV library.
  - SURF (Speed-Up Robust Features)
  - Color recognition.
- Already implemented, but applied only for Gate.
- Will modify and apply to other tasks.

STABILIZATION

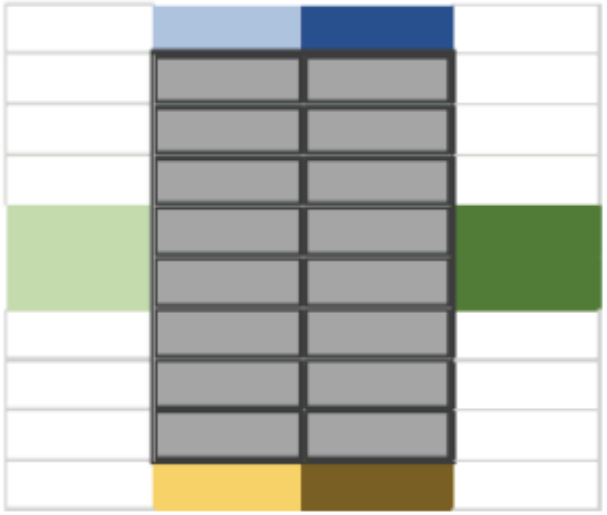
- Using Razor IMU
- Example:
  Pitch control

```
void* pitchController(void* arg)
{
  while(!Stopped)
  {
     measuredValue = myIMU->getPitch();
     error = setpoint - measuredValue;
     if(error > 4.0f)
     {
       pthread_mutex_lock(&heaveMutex);
       initialThrust = dataBuf[0];
       prevError = error + 0.2f;
       do
       {
         derivative = (error - prevError) / delayTime;
         prevError = error;
         output = kP * error + kD * derivative;
         tmp = convertPitchCtrlOutput(output, true);
         dataBuf[0] = initialThrust + tmp;
         measuredValue = myIMU->getPitch();
         error = setpoint - measuredValue;
       } while(error > 3.0f);
       // return to initial thrust once pitch is corrected
       dataBuf[0] = initialThrust;
     }
```

MOVEMENT

- Accomplished with the 6 thrusters.

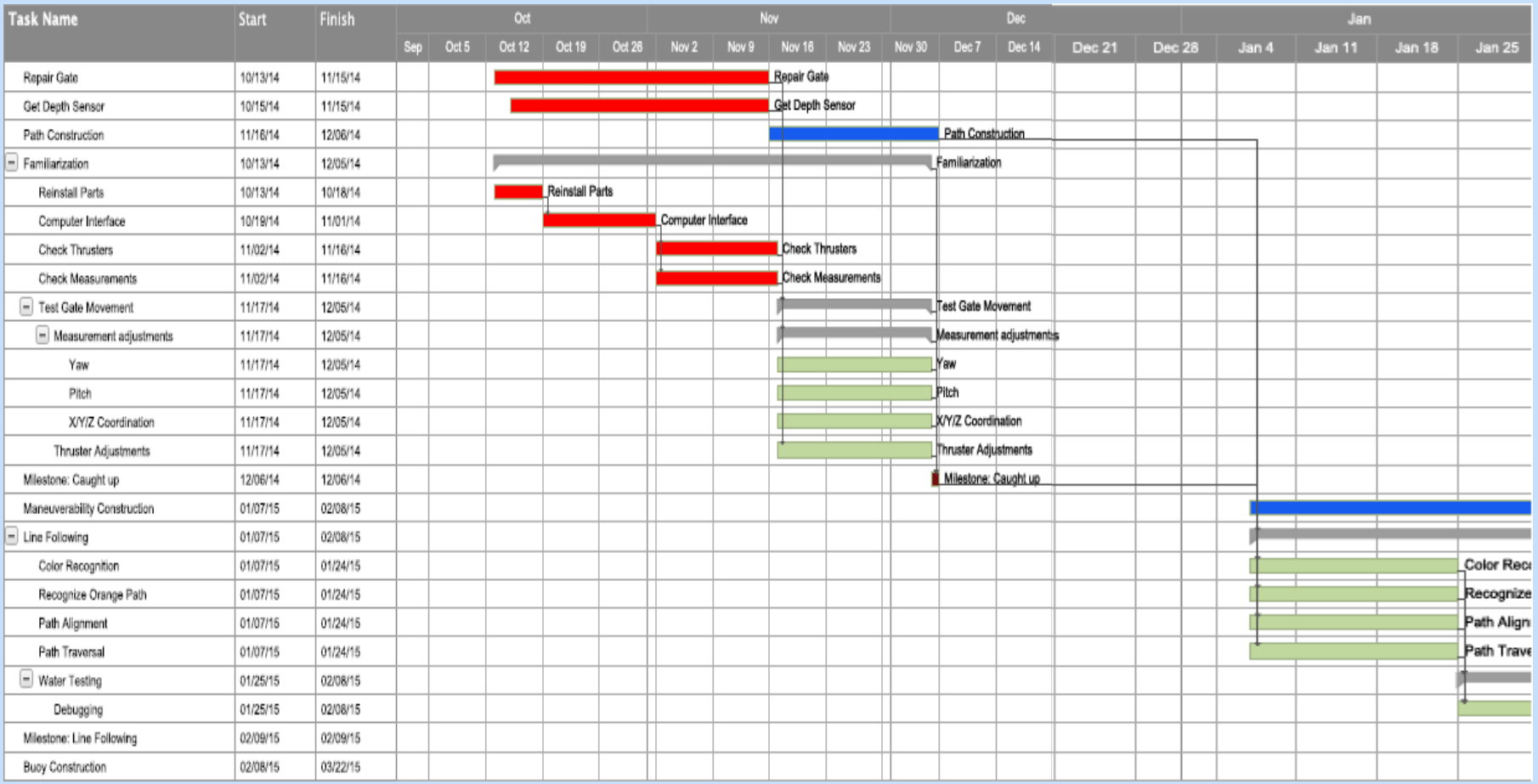
	Location of Thrusters and State					
Type of Movement	Front Left	Front Right	Back Left	Back Right	Left Side	Right Side
Forwards	Off	Off	Off	Off	Positive - On	Positive - On
Reverse	Off	Off	Off	Off	Negative - On	Negative - On
Rotate Left	Off	Off	Off	Off	Off	Positive - On
Rotate Right	Off	Off	Off	Off	Positive - On	Off
Ascend	Positive - On	Positive -On	Positive - On	Positive - On	Off	Off
Descend	Negative - On	Negative - On	Negative - On	Negative - On	Off	Off



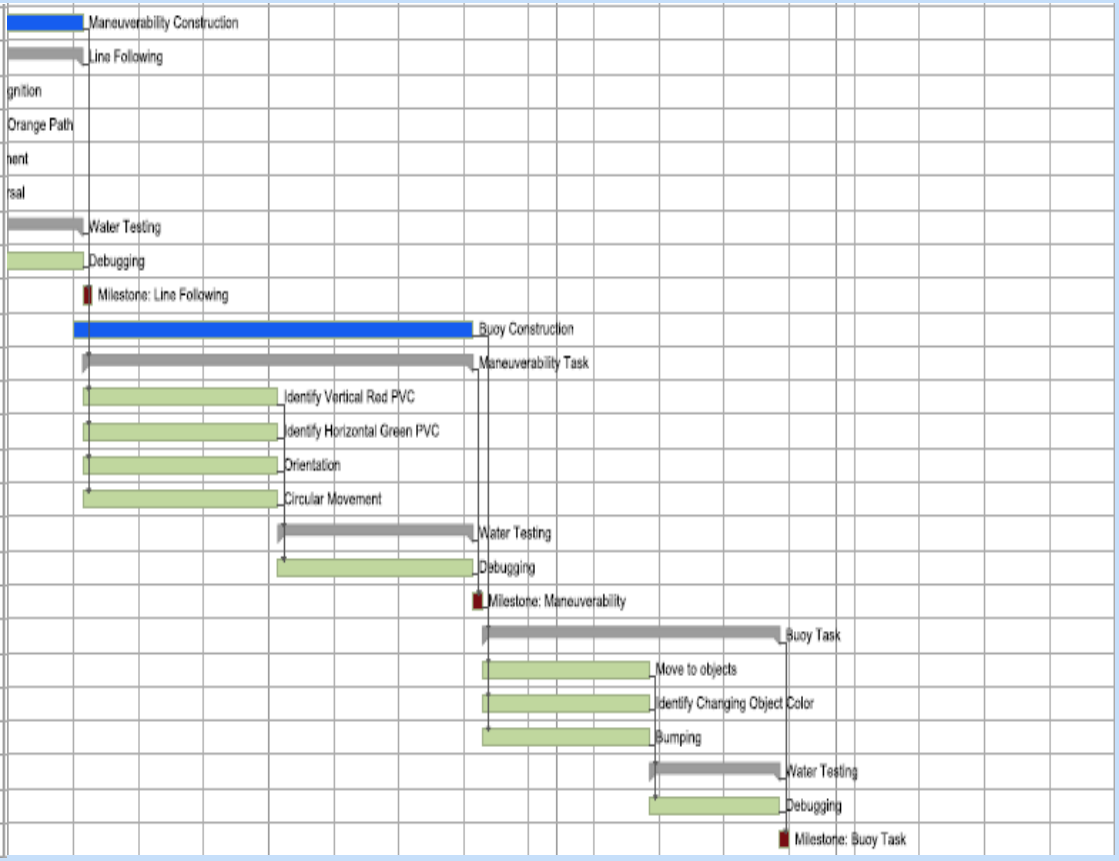
MOVEMENT CODE SNIPPET

```
void distributeThrust()
{
    std::stringstream leftFront, leftSide, rightSide, rightBack,
        rightFront,leftBack;

    std::string data;
    leftFront << (int)(dataBuf[0] * 0.01 * PWM_MAX_BRIDGED);
    leftSide << (int)(dataBuf[1] * 0.01 * PWM_MAX);
    rightSide << (int)(dataBuf[2] * 0.01 * PWM_MAX);
    rightBack << (int)(dataBuf[3] * 0.01 * PWM_MAX_BRIDGED);
    rightFront << (int)(dataBuf[4] * 0.01 * PWM_MAX);
    leftBack << (int)(dataBuf[5] * 0.01 * PWM_MAX);

    data = leftFront.str() + "," + leftSide.str() + "," +
        rightSide.str() + "," + rightBack.str() + "," +
        rightFront.str() + "," + leftBack.str();

    myArduinoMega << data;
}
```

SCHEDULE


Task Name
Start
Finish
Oct
Nov
Dec
Jan
Sep
Oct 5
Oct 12
Oct 19
Oct 26
Nov 2
Nov 9
Nov 16
Nov 23
Nov 30
Dec 7
Dec 14
Dec 21
Dec 28
Jan 4
Jan 11
Jan 18
Jan 25
Repair Gate 10/13/14 11/15/14
Get Depth Sensor 10/15/14 11/15/14
Path Construction 11/16/14 12/06/14
Familiarization 10/13/14 12/05/14
Reinstall Parts 10/13/14 10/18/14
Computer Interface 10/19/14 11/01/14
Check Thrusters 11/02/14 11/16/14
Check Measurements 11/02/14 11/16/14
Test Gate Movement 11/17/14 12/05/14
Measurement adjustments 11/17/14 12/05/14
Yaw 11/17/14 12/05/14
Pitch 11/17/14 12/05/14
X/Y/Z Coordination 11/17/14 12/05/14
Thruster Adjustments 11/17/14 12/05/14
Milestone: Caught up 12/06/14 12/06/14
Maneuverability Construction 01/07/15 02/08/15
Line Following 01/07/15 02/08/15
Color Recognition 01/07/15 01/24/15
Recognize Orange Path 01/07/15 01/24/15
Path Alignment 01/07/15 01/24/15
Path Traversal 01/07/15 01/24/15
Water Testing 01/25/15 02/08/15
Debugging 01/25/15 02/08/15
Milestone: Line Following 02/09/15 02/09/15
Buoy Construction 02/08/15 03/22/15
Repair Gate
Get Depth Sensor
Path Construction
Familiarization
Reinstall Parts
Computer Interface
Check Thrusters
Check Measurements
Test Gate Movement
Measurement adjustments
Yaw
Pitch
X/Y/Z Coordination
Thruster Adjustments
Milestone: Caught up

Maneuverability Construction	01/07/15	02/08/15
Line Following	01/07/15	02/08/15
Color Recognition	01/07/15	01/24/15
Recognize Orange Path	01/07/15	01/24/15
Path Alignment	01/07/15	01/24/15
Path Traversal	01/07/15	01/24/15
Water Testing	01/25/15	02/08/15
Debugging	01/25/15	02/08/15
Milestone: Line Following	02/09/15	02/09/15
Buoy Construction	02/08/15	03/22/15
Maneuverability Task	02/09/15	03/22/15
Identify Vertical Red PVC	02/09/15	03/01/15
Identify Horizontal Green PVC	02/09/15	03/01/15
Orientation	02/09/15	03/01/15
Circular Movement	02/09/15	03/01/15
Water Testing	03/02/15	03/22/15
Debugging	03/02/15	03/22/15
Milestone: Maneuverability	03/23/15	03/23/15
Buoy Task	03/24/15	04/24/15
Move to objects	03/24/15	04/10/15
Identify Changing Object Color	03/24/15	04/10/15
Bumping	03/24/15	04/10/15
Water Testing	04/11/15	04/24/15
Debugging	04/11/15	04/24/15
Milestone: Buoy Task	04/25/15	04/25/15



ESTIMATED BUDGET

PERSONNEL COSTS

A. Personnel	Total Hours	Hourly Wage	Total Pay
Dennis Boyd	360	$30.00	$10,800.00
Samantha Cherbonneau	360	$30.00	$10,800.00
Bjorn Campbell	360	$30.00	$10,800.00
Kevin Matungwa	360	$30.00	$10,800.00
Elliot Mudrick	360	$30.00	$10,800.00
		Wage Subtotal	$54,000.00
B. Fringe Benefits			$15,660.00
C. Total Personnel Cost			$69,660.00

PARTS

D. Expense	Purpose	Vender	Qty	Price	Total
3” Diameter x 10’ Long PVC	Center Horizontal PVC Pipe, Vertical PVC Pipes for Gate	Home Depot	2	$14.68	$29.36
90 Degree Elbows 3” PVC	Connectors for the Gate	Home Depot	2	$2.38	$4.76
R/O Specialty Camo Black Sray Paint	Color white PVC black	Home Depot	1	$3.76	$3.76
Blaze Orange Duck Tape	Vertical color of vertical PVC pipes	Home Depot	1	$3.37	$3.37
1”x6” – 8 FT Weather Shield Wood	Path Lines	Home Depot	2	$5.37	$10.74
Hallow Braid Poly Rope (1/4” x50’)	Needed for mooring lines	Home Depot	1	$5.60	$5.60
2” Diameter by 6’ Long PVC	Maneuvering parts, Horizontal and Vertical	Home Depot	2	$8.22	$16.44
90 Degree Elbows 2” PVC	Connectors for the Maneuvering Platform	Home Depot	2	$0.83	$1.66
2” Clean Out Tee PVC	Connect center PVC of Maneuvering Platform	Home Depot	1	$3.26	$3.26
Carriage Bolt (¼” X 3-1/2”)	Possible to need if Gate test fails	Home Depot	4	$0.78	$3.12
1/4” Nut	Possible to need if Gate test fails	Home Depot	4	$0.14	$0.56
PVC Glue	Need to seal maneuvering structure to become buoyant	Home Depot	1	$4.87	$4.87
2” PVC Caps	Seal vertical	Home	2	$1.64	$3.28
Acrylic 6” Cylinder	RGB Buoy	Lighting Louvers, Lenses, & Globes	2	$4.95	$9.90
LED Remote	Control the LEDs	100candles.com	1	$4.99	$4.99
Submersible LEDs (Red, Green Blue)	LEDs for RGB Buoy	100candles.com	5	$3.19	$15.95
16/19 V Ah LI-Ion Universal External Battery	Old Battery damaged, battery life is limited	AA Portable Power Corp	1	$74.76	$74.76
Depth Sensor	Required for sub		1	$354.00	$354.00

TRAVEL & OVERALL COSTS

D. Expense	Purpose	Vendor	Qty	Price	Total
Competition Entry Fee	Necessary to compete		1	$500.00	$500.00
Plane tickets	Necessary to compete	TBD	3	$250.00	$750.00
Sub Transportation	Necessary to compete	TBD	1	$150.00	$150.00
Car Rental	Necessary to compete	TBD	6	$75.00	$450.00
Expenses Subtotal (including tax)					$2,580.41
E. Total Direct Costs (C+D)					$72,240.41
F. Overhead Costs (45% of E)					$32,508.18
G. Total OCO (E+F)					$104,748.59

RISK ASSESSMENT

TECHNICAL RISKS

Transportation of Sub

- Probability
  - High
- Severity
  - Moderate/Severe
- Strategy
  - Move slowly and carefully
  - Possibly shock-absorbing wheels

Waterproof Seal

- Probability
  - Moderate/High
- Severity
  - Catastrophic
- Strategy
  - Check seal before use
  - Put dry sponges on inside of hull to easily check for water leakage

TECHNICAL RISKS

Plexiglas Lid

- Probability
  - Low
- Severity
  - Catastrophic
- Strategy
  - Be careful when tightening lid bolts
  - Monitor cracks

System Error While Moving

- Probability
  - Moderate
- Severity
  - Minor/Moderate
- Strategy
  - Have team member in water with sub
  - Kill switch

TECHNICAL RISKS

Lighting Under Water

- Probability
  - Low
- Severity
  - Moderate
- Strategy
  - Attach small light to camera
  - Perform white-out before each use

Component Burnout

- Probability
  - Low
- Severity
  - Moderate
- Strategy
  - Monitor heat closely

TECHNICAL RISKS

Universal Battery

- Probability
  - High
- Severity
  - Minor
- Strategy
  - Has occurred
  - Bought replacement battery

SCHEDULE RISKS

Pool Delays

- Probability
  - Moderate
- Severity
  - Moderate
- Strategy
  - Be aware of pool schedule
  - Plan back-up testing times

Official Rules Publication

- Probability
  - Very High
- Severity
  - Moderate/Severe
- Strategy
  - Make capabilities general enough to perform different tasks

SCHEDULE RISKS/BUDGET RISKS

Time Allocation

- Probability
  - High
- Severity
  - Severe
- Strategy
  - Perform tasks in parallel
  - Do best to finish each task on time

Going Over Budget

- Probability
  - Low
- Severity
  - Severe
- Strategy
  - Closely monitor budget
  - Thoroughly research parts before buying

QUESTIONS