Autonomous Underwater Robots

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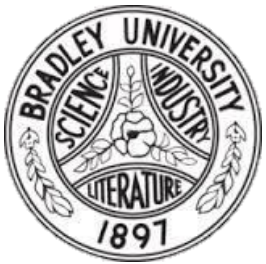


Outline

- Background
- Design Approach
- Economic Analysis
- Milestones
- Division of Labor
- Societal and Environmental Impact

Problem

- Map underwater terrain using multiple autonomous robots
- Avoid collisions
- Generate a final image of the terrain

Literature Review

- AUV history
- AUV swarm research
  - Underwater minefield
  - Cocoro

Source: http://www.wired.com/2013/03/powers-of-swarms/all/

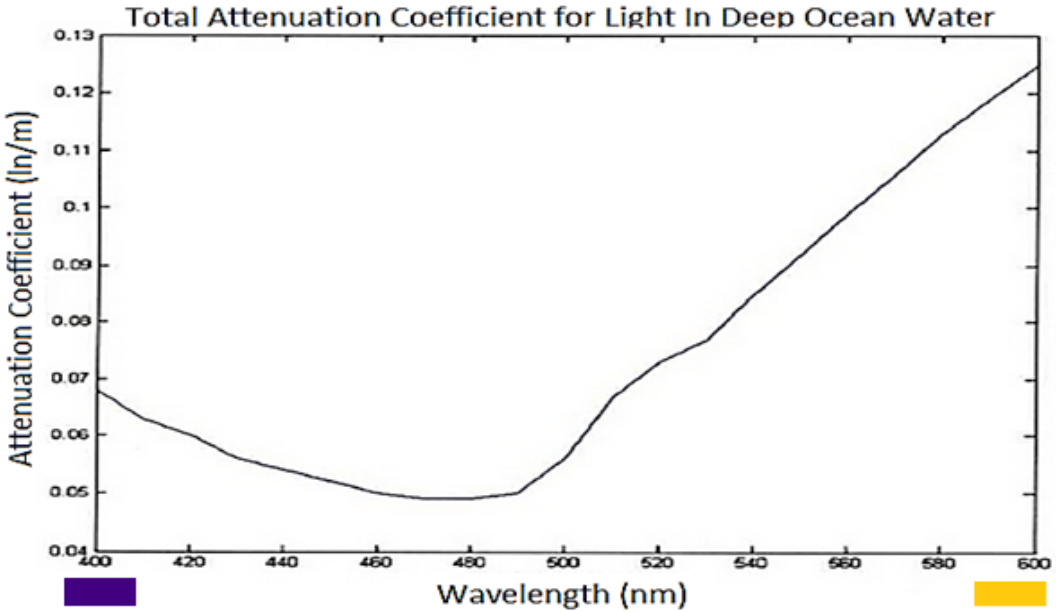
Constraints

- Avoid harming underwater organisms
- Battery life
- Functional up to two feet of water
- Robots must be reasonably sized

Detection Methods

- Acoustic
- Electromagnetic
- Optical
  - Image processing
  - LEDs

Blue LEDs - Visibility



Source: http://www.academia.edu/4161991/Designing_a_Wireless_Underwater_Optical_Communication_SystemDesigning_a_Wireless_Underwater_Optical_Communication_System

Blue LEDs - Detection

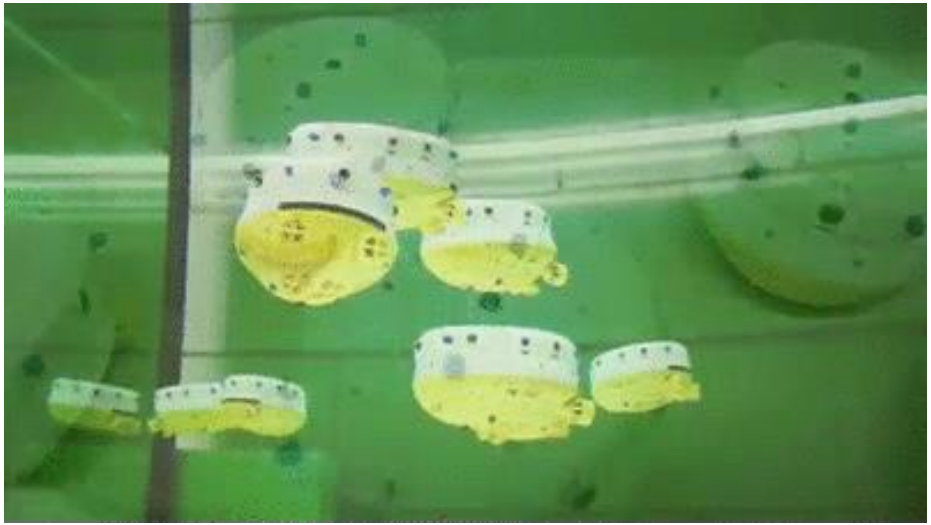
	Photoresistors	Phototransistors	*p-n* Photodiodes
Speed	Slow *<1 Hz*	Moderate *<250KHz*	Fast *Tens of MHz to tens of GHz*
Size	Small	Small	Small
Gain	Little	100-1500	Unity
Linearity	Over small regions	Good	Excellent
Ambient Noise Performance	Very good	Excellent	Very Good

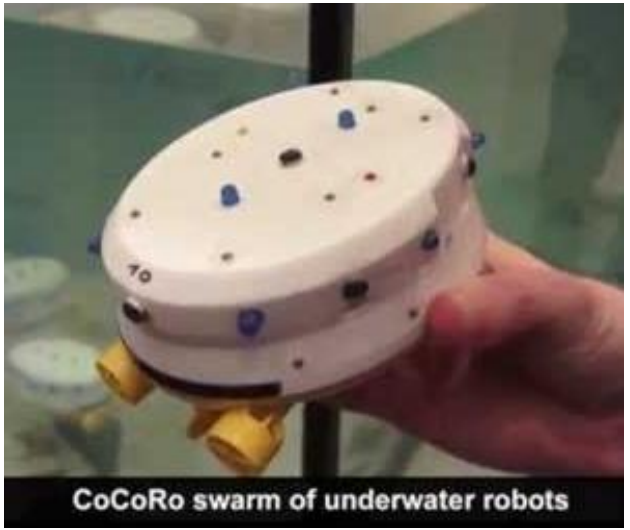
Source: http://www.academia.edu/4161991/Designing_a_Wireless_Underwater_Optical_Communication_SystemDesigning_a_Wireless_Underwater_Optical_Communication_System

Related Patents

- **CN 102916744 A** - Underwater LED visible light communication system
- **US 20140212142 A1** - Underwater optical communication system
- **US 20050232638 A1** - Methods and apparatus for underwater wireless optical communication

Cocoro





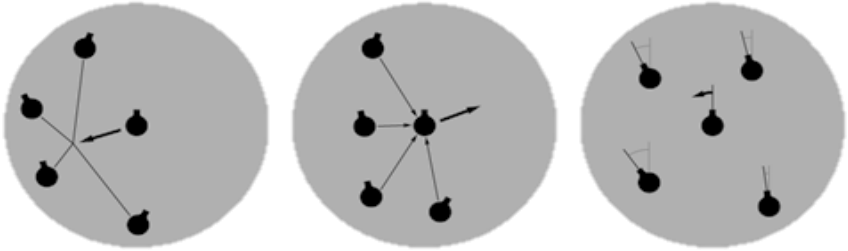
Source: https://www.youtube.com/watch?v=Hjkmm13Scm4

Source: http://i.ytimg.com/vi/XUk-qLfiwlc/0.jpg

Swarming Techniques

Boids

- Simulates the flocking of birds
- Criteria include cohesion, separation and alignment



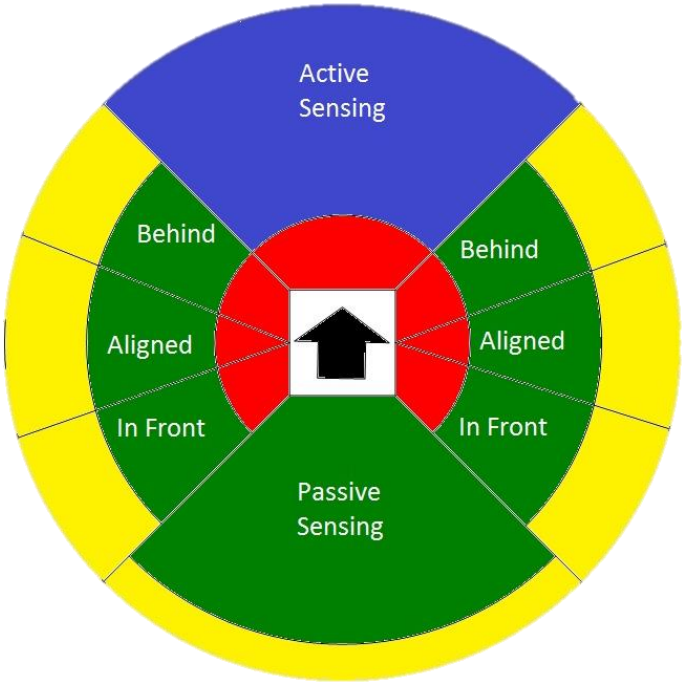
Cohesion Separation Alignment

Source: http://igeo.jp/tutorial/43.html

Swarming Techniques cont.

Minimalistic

- Based upon Boids
- Criteria include cohesion, separation and pseudo-alignment



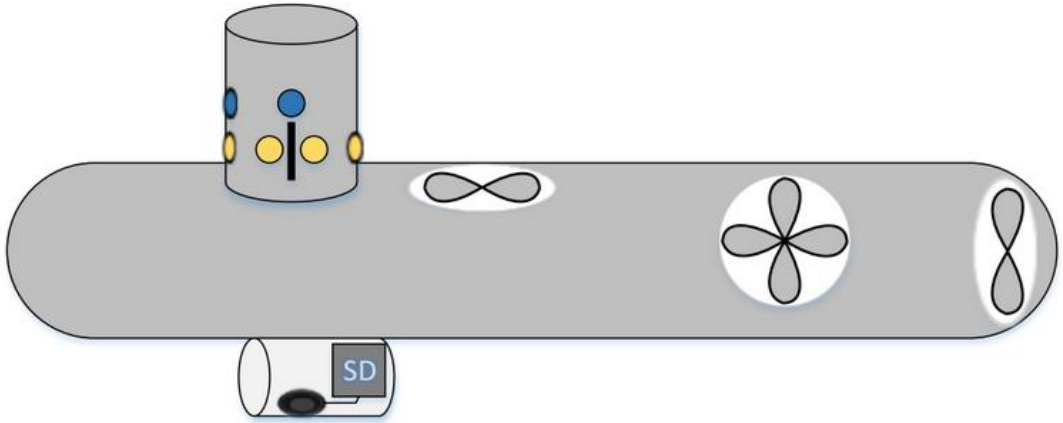
Source: http://igeo.jp/tutorial/43.html

Design Approach

- Standalone swarm
- Swarming techniques
- Directional guidance
- Project disciplines
- Testing

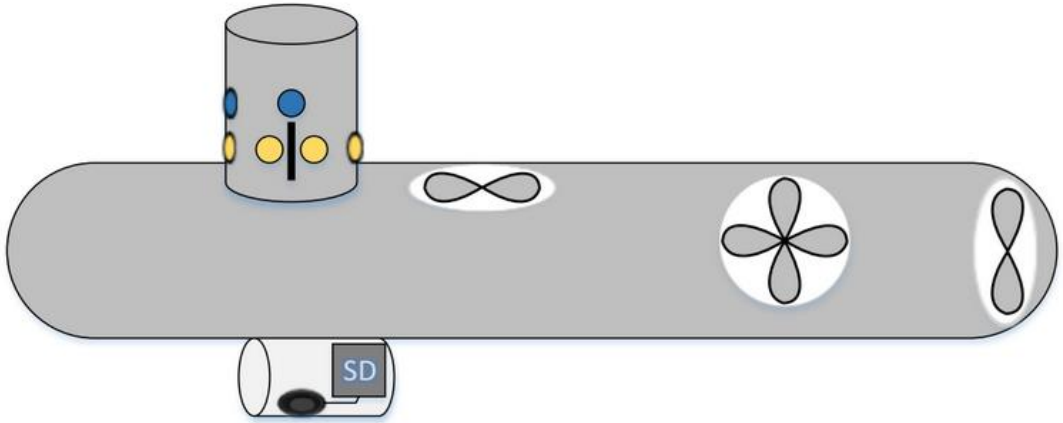
Design Approach - Individual Submarines

- Motorworks Seawolf
  - Static diving
  - Literature
- Power system
- Camera module



Design Approach - Individual Submarines Cont.

- Detection array
- Sensors
  - IMU
  - Compass
  - Pressure
- Motor control



Design Approach - Alternate Solutions

- Add leader boat to swarm
- Drop weight system
- Bottom detection system
- Spread out detection array
- DIY submarine

Testing and Metrics

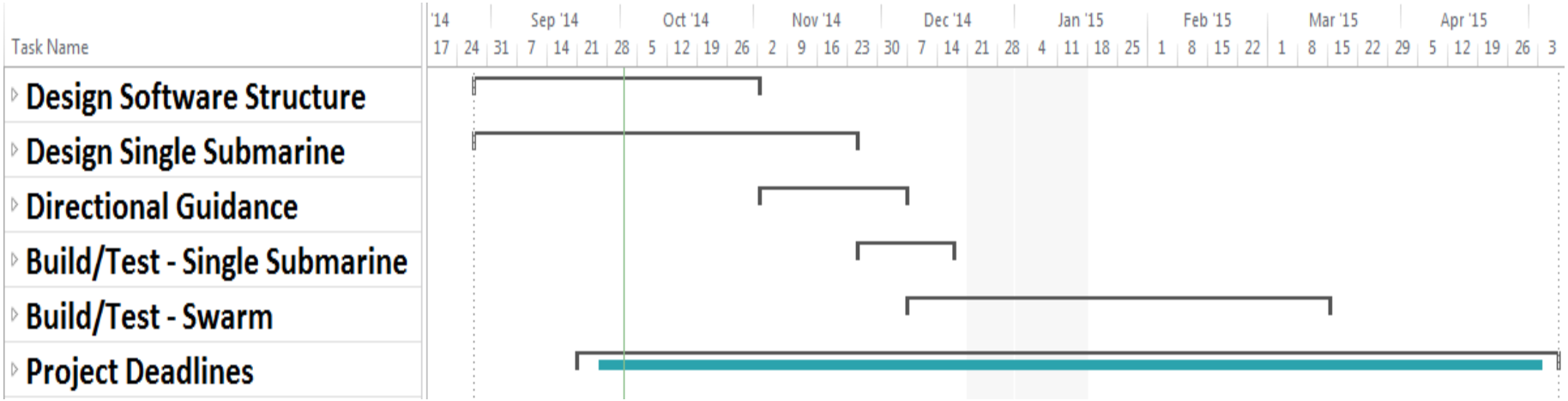
- Minimize cost
- Autonomous
- Durable
- Mobile underwater
- Portability
- Power efficiency

Economic Analysis

- Cost of submarine: $189.00

Description	Cost
Swarm cost	$756.00
Testing	$78.16
Total cost	$834.16

Milestones and Schedule



Division of Labor

- Detection array
- Camera circuit
- Construction of submarine
- PCB
- Program layout
- Controls
- Sensors algorithm
- Swarming algorithm

Societal Impact

- Development is ethical
- Aquatic industries/research will be affected
- Originally marketed as a toy RC submarine
- Submarines will navigate at relatively slow speeds
- Boats could collide with the swarm

Environmental Impact

- Low natural resources costs
- Lost submarines could pollute the water
- Plant life could be disturbed
- Large obstacles will be detected and avoided

Summary

- Design Approach
- Economic Analysis
- Milestones
- Division of Labor
- Societal and Environmental Impact

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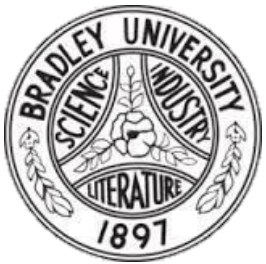

References

- http://neuron.tuke.sk/hudecm/PDF_PAPERS/DesignAndControlOfAutonomousUnderwaterrobotsASurvey.pdf
- http://www.wired.com/2013/03/powers-of-swarms/all/
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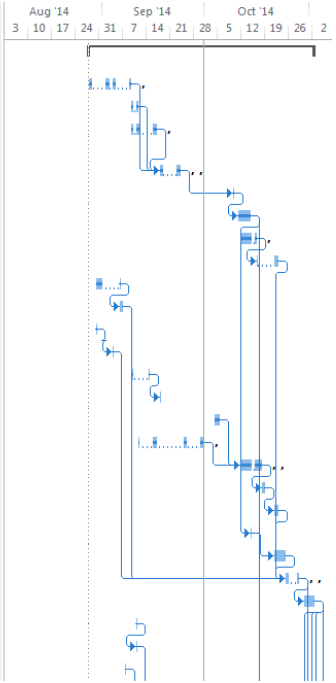
- https://www.youtube.com/watch?v=Hjkmm13Scm4
- http://i.ytimg.com/vi/XUk-qLfiwlc/0.jpg

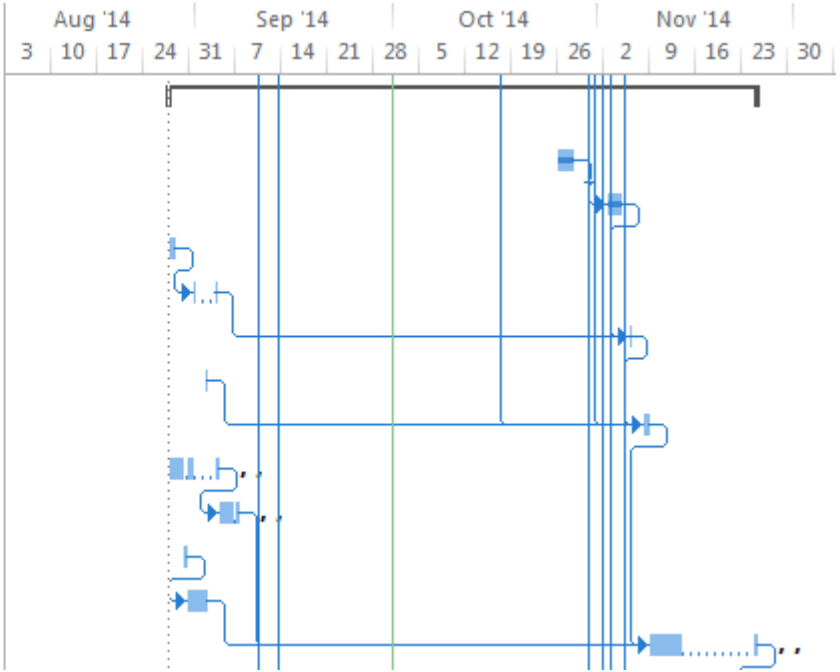
Gantt Chart – Design Software Structure

Task Name	Duration
Design Software Structure	**200 hrs**
Research - Sensors – Sub Communication – Hydrophones	10 hrs
Research - Sensors – Sub Communication – Image Processing	4 hrs
Research - Sensors – Sub Communication – LED Communication	8 hrs
Research - Sensors – Sub Communication - LEDs	6 hrs
Research - Sensors – Sub Communication - Photodiodes	2 hrs
Design - Amplifier Circuit	12 hrs
Research - Sensors - Pressure	11 hrs
Research - Sensor Algorithms - Pressure	6 hrs
Research - Sensors - Compass	10 hrs
Research - Sensor Algorithms - Compass	3 hrs
Research - Sensors - IMU	2 hrs
Research - Sensor Algorithms - IMU	3 hrs
Research - Sensors - Bottom Detection	3 hrs
Research - Sensor Algorithms - Bottom Detection	2 hrs
Research - Submarines – Model Submarines	9 hrs
Research - Submarines – DIY	10 hrs
Research - Submarines – Motorworks	15 hrs
Design - Motor Control - Overview	3 hrs
Design - Motor Control – Software version	3 hrs
Design – Testing Methods – Amplifier Circuit	1 hr
Research - Sensor Algorithms – LED Communication	10 hrs
Research - Microprocessor	8 hrs
Design - Software Structure	9 hrs
Research - Photo Stitching Software	3 hrs
Testing/Tuning - Photo Stitching	1 hr
Research – Surfacing Techniques – Upward Propoulsion	1 hr



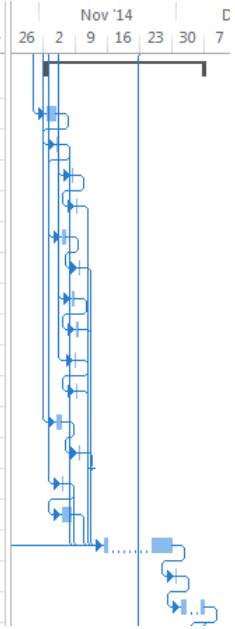
Gantt Chart – Design Single Submarine

Task Name	Duration
Design Single Submarine	**266 hrs**
Research - Image Capturing - Cameras	6 hrs
Research - Image Capturing – Image Storage	4 hrs
Research – Power System - Battery	3 hrs
Research – Power System – Voltage Regulators	3 hrs
Design – Power System	3 hrs
Research - PCB Construction Method	1 hr
Design - PCB Circuit Layout	4 hrs
Research - Sealing/Pressure Containers	12 hrs
Testing/Tuning - Sealing/Pressure - Container Rig	8 hrs
Research - Surfacing Techniques - Drop Weights	4 hrs
Design - Mock Drawings	8 hrs
Design - Submarine Layout	17 hrs



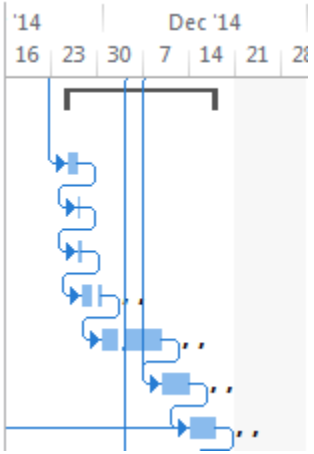
Gantt Chart – Directional Guidance

Task Name	Duration
Directional Guidance	**102 hrs**
Design – Algorithms – Communication Array	4 hrs
Design – Testing Methods – Communication Array	1 hr
Design – Algorithms - Pressure	2 hrs
Design – Testing Methods - Pressure	1 hr
Design – Algorithms - Compass	4 hrs
Design – Testing Methods Compass	1 hr
Design – Algorithms - IMU	2 hrs
Design – Testing Methods - IMU	1 hr
Design – Algorithms – Bottom Detection	1 hr
Design – Testing Methods – Bottom Detection	1 hr
Design – Algorithms – Motor Control	5 hrs
Design – Testing Methods – Motor Control	1 hr
Assembly - Testing Rig - Communication Array	2 hrs
Testing/Tuning – Bench Top – Communication Array	4 hrs
Design – Position Guidance Algorithm	20 hrs
Assembly - Testing Rig – Directional Guidance	2 hrs
Testing/Tuning – Bench Top – Directional Guidance	8 hrs



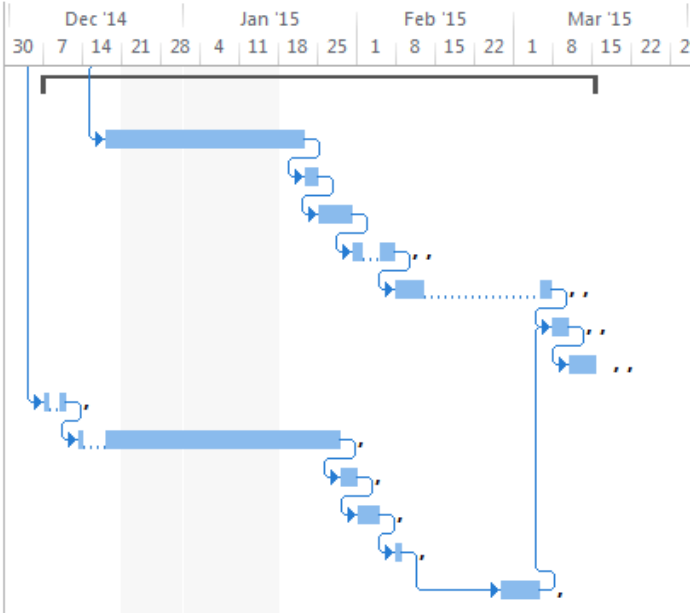
Gantt Chart - Build/Test – Single Submarine

Task Name	Duration
Build/Test - Single Submarine	**68 hrs**
Assembly - PCB Construction - Single Submarine	3 hrs
Assembly - Soldering - Single Submarine	2 hrs
Assembly – Submarine - Single Submarine	4 hrs
Testing/Tuning – Sealing/Pressure – Single Submarine	4 hrs
Testing/Tuning – Bouyancy – Single Submarine	20 hrs
Testing/Tuning – Motor Control - Single Submarine	15 hrs
Testing/Tuning – In Water - Single Submarine	10 hrs



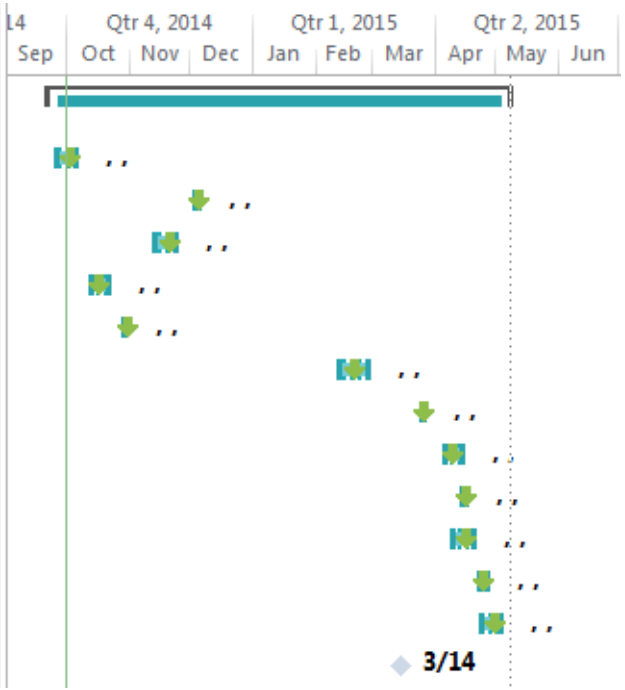
Gantt Chart - Build/Test - Swarm

Task Name	Duration
Build/Test - Swarm	**201 hrs**
Assembly - PCB Construction - Swarn	12 hrs
Assembly - Soldering - Swarm	8 hrs
Assembly – Submarine - Swarm	16 hrs
Testing/Tuning – Sealing/Pressure – Swarm	16 hrs
Testing/Tuning – Bouyancy – Swarm	22 hrs
Testing/Tuning – Motor Control - Swarm	8 hrs
Testing/Tuning – In Water - Swarm	18 hrs
Research - Swarming Techniques	10 hrs
Simulate - Swarm Algorithm	35 hrs
Design - Swarm Algorithm	11 hrs
Design - Testing Methods - Swarming Techniques	10 hrs
Assembly - Testing Rig - Swarming Techniques	6 hrs
Testing/Tuning - Bench Top - Swarming Techniques	21 hrs



Gantt Chart – Project Deadlines

Task Name	Duration
Project Deadlines	**589 hrs**
Proposal Presentation	40 hrs
Performance Review	10 hrs
Fall Progress Presentation	40 hrs
Proposal Paper	30 hrs
Webpage Release	15 hrs
Spring Progress Presentation	44 hrs
Project Demonstration	10 hrs
Final Presentation	30 hrs
Student Expo	10 hrs
Report Draft	40 hrs
ECE Advisory Board Poster Presentation	10 hrs
Final Report	40 hrs
End of Project Design	



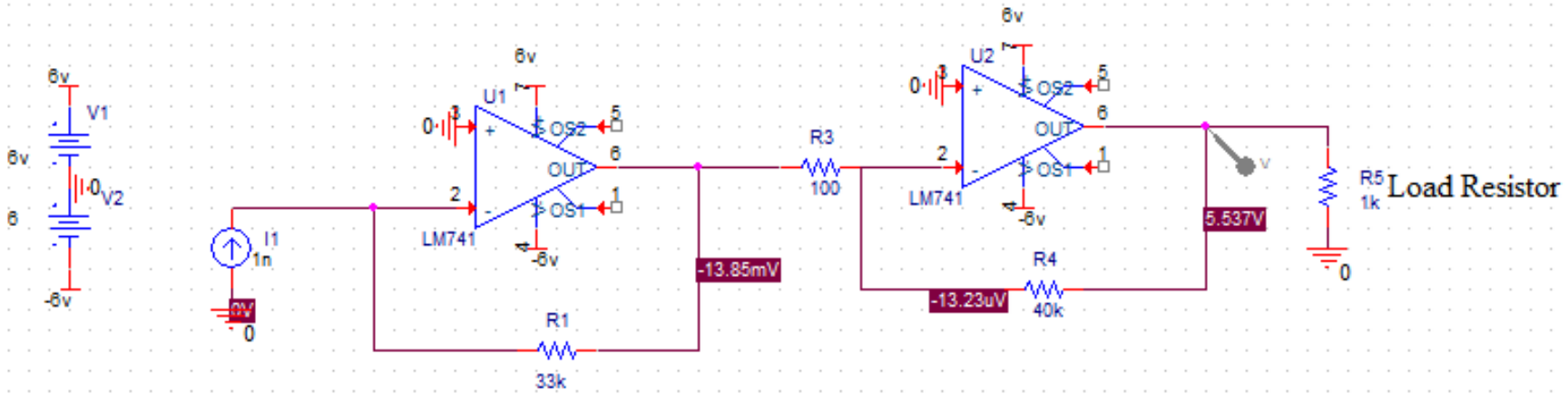
Detailed budget - Submarine

Quantity	Cost Per	Total Cost	Description
4	$10	$40	Pressure Sensor
4	$50	$200	Submarine
4	$5	$20	Surface mount processor
12	$3	$36	3 Watt blue LEDS
24	$10	$240	Blue Filtered Photodiodes
4	$10	$40	Compass and IMU
4	$10	$40	Camera Circuit
4	$20	$80	Surface mount Components
4	$15	$60	PVC material
4	$10	$40	H-Bridge Chips
	Total	**$756**	
	Per Submarine	**$189**	

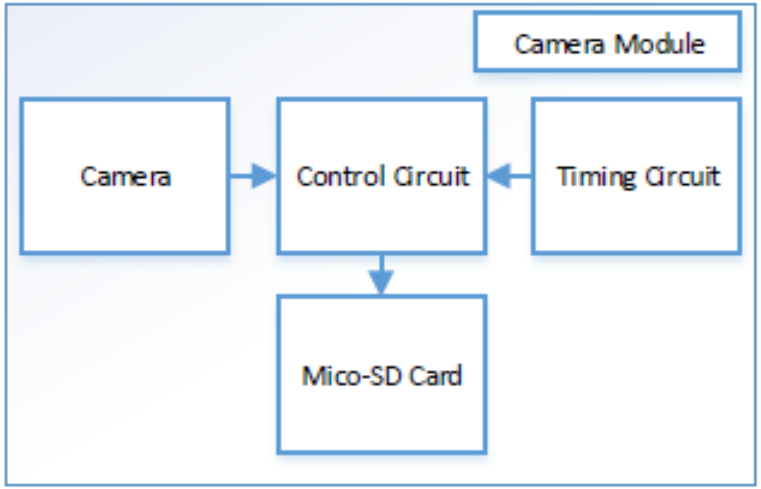
Detailed budget - Test Stand

Quantity	Cost Per	Total Cost	Description
3	5	15	Processor Chips
1	17.05	17.05	PVC Test Stands
1	46.11	46.11	PVC Test Container
	Total	78.16	

Circuit diagrams



Flowcharts - Camera



Flowchart Motor Control