ROVEN Sealion: Designing an Underwater Remotely Operated Vehicle for Deep Sea Energy Wells

Brad Bailey, Greg Bailey, Gimo Barrera, Aren Johansen, Shannon Ketcham, and Kevin Malehorn

Advisors: Prof. Mustapha S. Fofana, Mechanical Engineering
Prof. Fred J. Looft, Electrical and Computer Engineering

Abstract:

Recent events have shown that the failure to monitor and control the various systems used during offshore oil production can lead to environmental disasters. The purpose of this project was to design and build an ROV capable of monitoring the condition of underwater structures. After studying current industry standards for deep sea observational ROVs, the team designed a prototype which can perform similar tasks in shallow waters. This prototype ROV was able to provide feedback from several sensors, including a video camera, a temperature sensor, pressure sensors, and a compass. The ROV is designed as a lightweight open frame with adjustable thruster and battery locations and space for the addition of an extra payload.

Motivation:

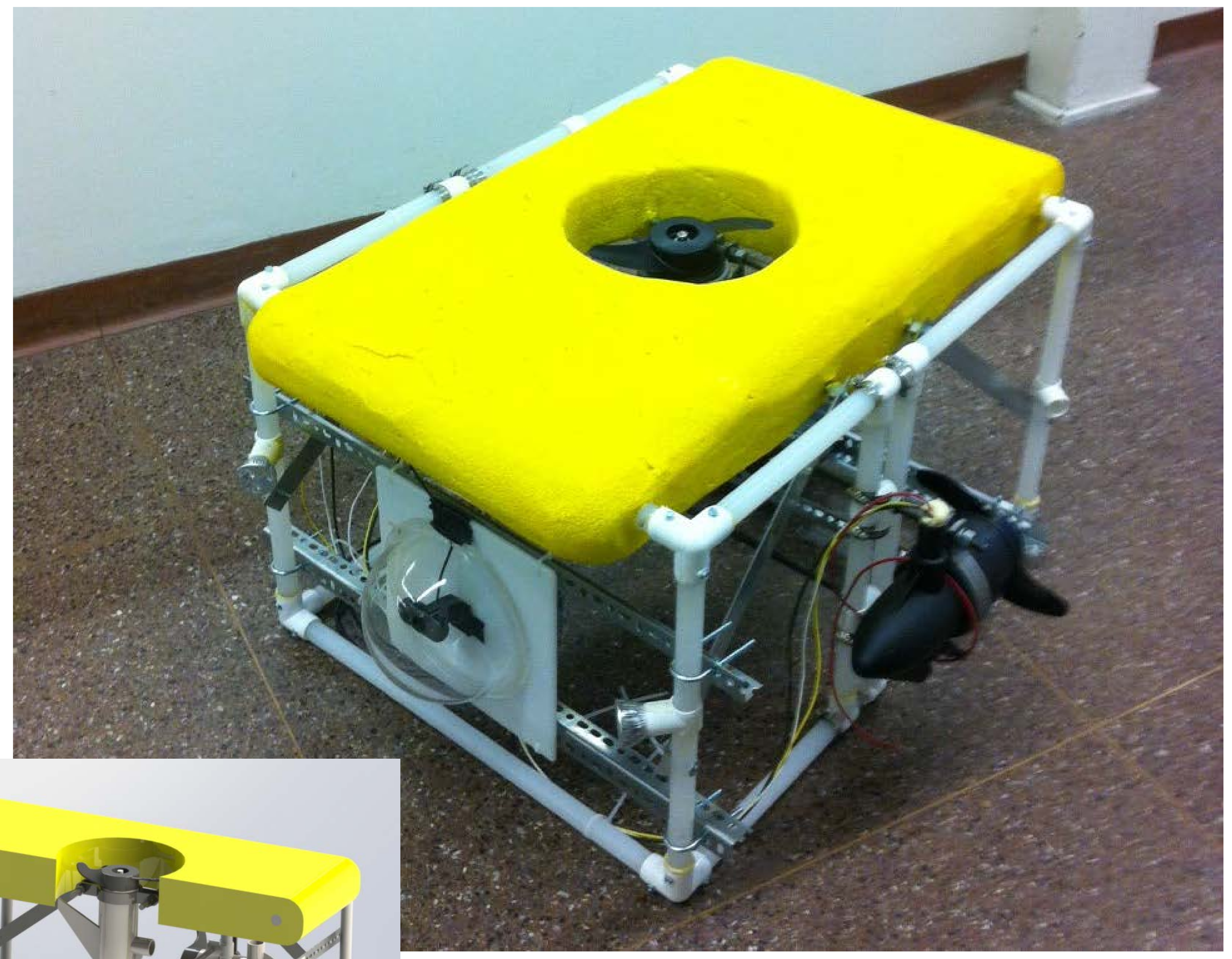
- April 20th, 2010 *Deepwater Horizon* explosion
  - Blow-out preventer (BOP) fails to stop flow of oil from the well
    - Correct drawings of BOP lost in explosion
    - ROVs used to cap the well and provide visual feedback to operators above

Blow-out preventer with and without frame and control panel

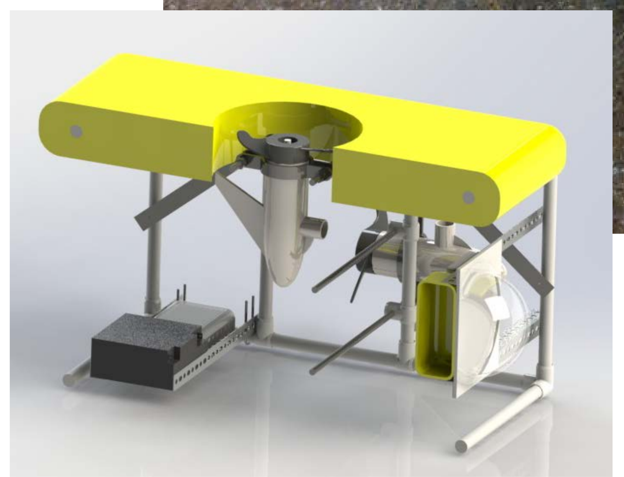
Goals:

- Design and build an Observational ROV
  - Mimic the abilities of professional grade deep-sea observation ROVs while maintaining a budget suited to a college project

ROV Design:



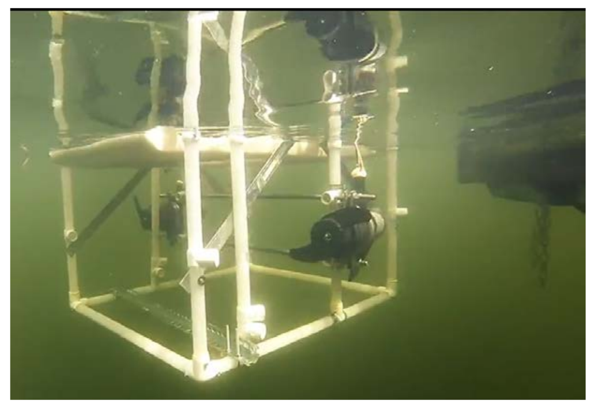
The ROVEN Sealion



Cross-sectional view of final ROV design

Results:

- The ROV was successfully constructed
- Tested in Quinsigamond Lake
- The ROV remained stable and performed to expectations



Initial Floatation Test

Final Specifications	
Weight	122 lbs
Size	2.5 x 2.0 x 1.5 ft
Maximum Speed	3 – 5 knots (estimated)
Degrees of Freedom	3
Depth	Avg: 25 ft Max: 100 ft
Visibility Range	5 ft
Operating Range	2094 ft^3
Battery Life	20 – 60 min

Conclusion:

- The final ROV was lighter than other similar models and it had adjustable components
- ROV can be fitted for additional applications
  - Ocean/lake bed scanning and shallow water structural health monitoring
- The project integrated multiple engineering disciplines
- The results from the experiment were inconsistent with the theoretical values

Future Work

- The design allows for 40 lb of weight that could be used for payload option
  - Robotic manipulators, cleaning tools, CP probe, MPI
- Additional thrusters, increased battery life, camera position control, wireless control, more complex thruster analysis

Methodology:

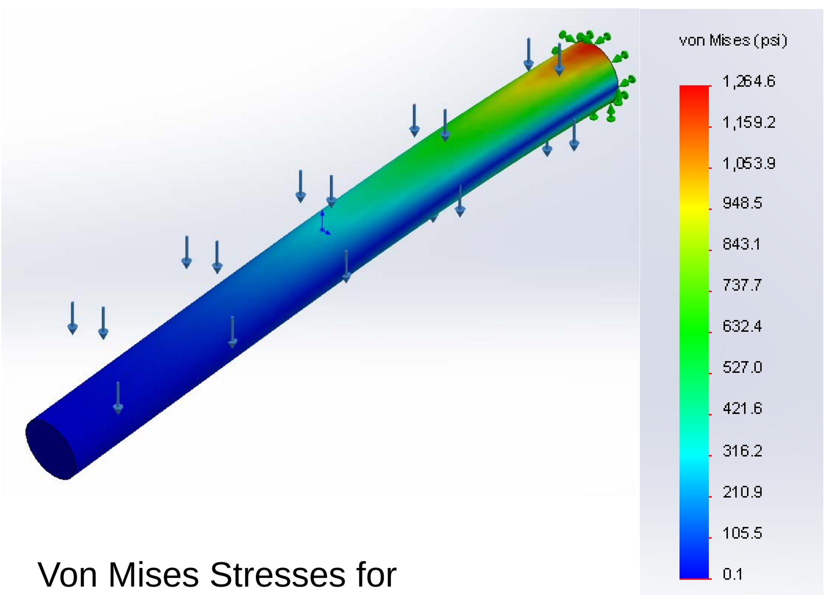
Material Properties:

Frame:

- Polypropylene rods
  - 1 inch diameter
  - Density: 55 lb/ft^3
  - Tensile Strength: 4-6 ksi

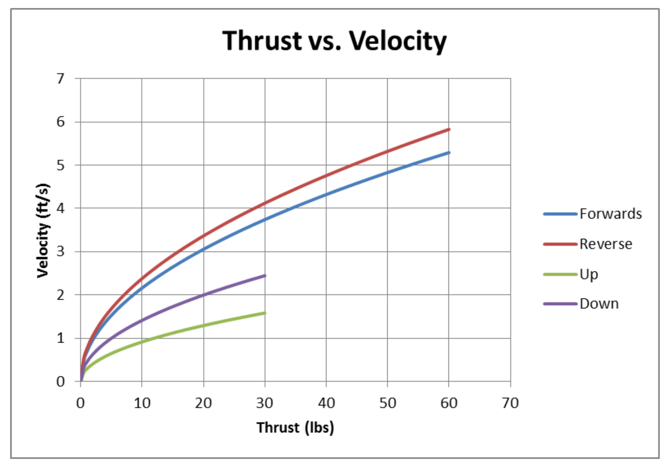
Floatation:

- Polyurethane Foam
  - Buoyancy: 58 lb/ft^3
  - Density: 4 lb/ft^3
  - Tensile Strength: 225 psi
  - Compressive Strength: 90 psi

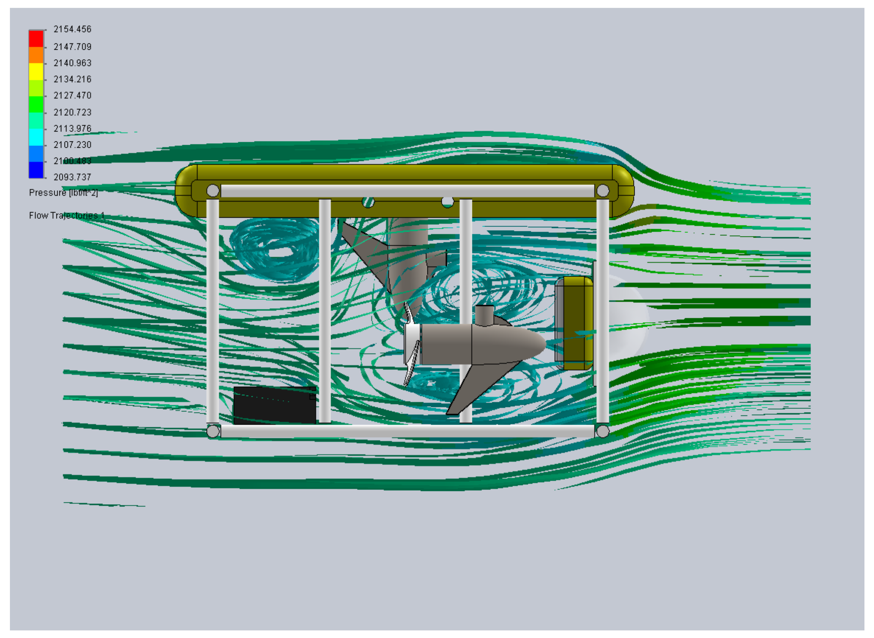


Von Mises Stresses for Polypropylene Rods

Flow Analysis:



Forward and reverse lines showing thrust from 2 thrusters. Up and down lines showing thrust from one thruster

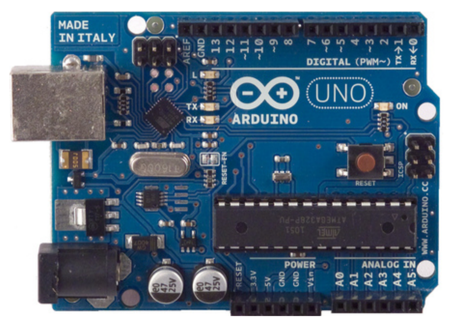


Flow analysis of ROV in forward direction

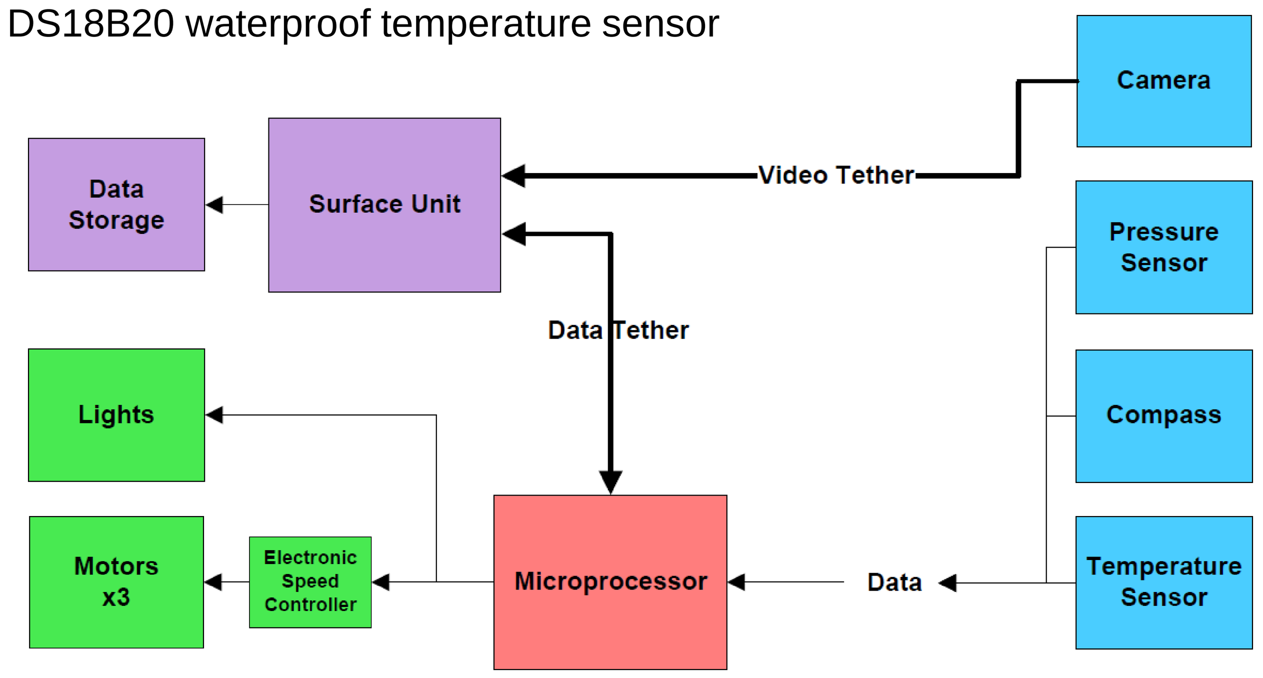
Electrical System:

- Power Consumption
  - Motor Current Draw – 15 Amps per motor
  - LED Current Draw – 2 to 3 Amps
  - Battery – 18 Ah
- Microprocessor
  - Arduino Uno R3
  - ATmega328 microcontroller
  - USB connection
- Sensors
  - Logitech C210 Webcam
  - NPC-1220 Pressure Sensor
    - Calculate depth and speed
  - HMC6352 magnetic compass module
  - DS18B20 waterproof temperature sensor

Magnetic Compass



Arduino Uno R3



Data Flow Chart

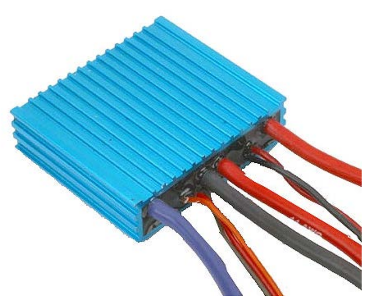
Thruster Experiments:

- Minn Kota Endura C2 trolling motor
  - Advertised 30 lbs of thrust
  - Uses 12 V
  - Thrust and Current measured at each speed
  - Force sensor and LoggerPro used
  - 5 forward speeds, 3 reverse speeds
- Experimental thrust is inconsistent with advertised thrust due to a possible pseudo-vortex ring effect caused by the recirculation of water in testing container

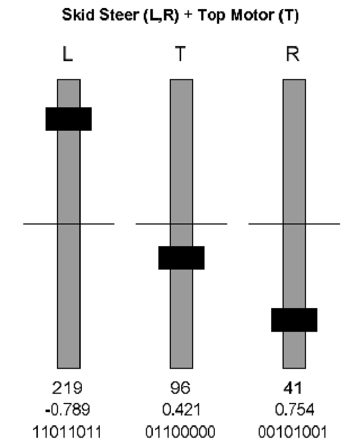
Speed	Current (A)	Avg.Thrust (lbs)
5	30	13 (projected)
4	16.4	11
3	13	8.8
2	9.4	5.9
1	7.2	4.4
-1	6.4	1.3
-2	12	2.5
-3	30	5.4

Thruster Control:

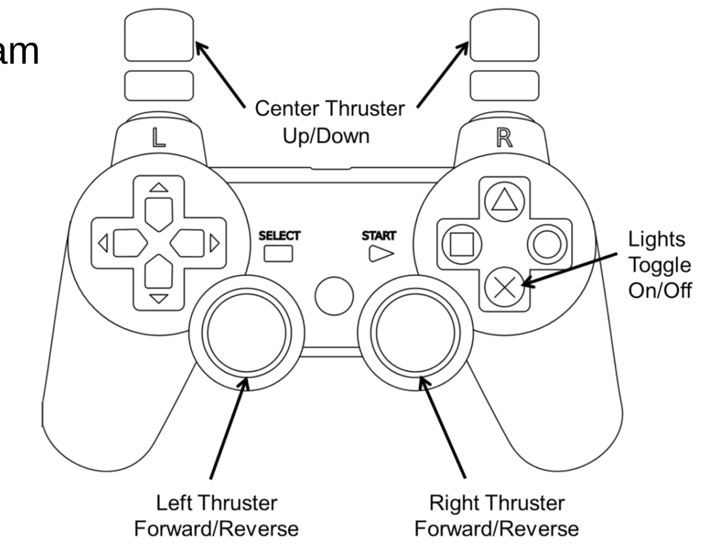
- User input interpreted with Processing program
- Data packets sent to Arduino
- Thruster control signals sent to electronic speed controllers



ProBoat Electronic Speed Controller



User Interface



Input Control Diagram