Waterborne Autonomous VEhicle (WAVE):
The Modular Underwater Robotics Platform

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Abstract

This project designed and realized the Waterborne Autonomous VEhicle (WAVE), a submersible modular robotic platform to enable research on underwater technologies at WPI at minimal cost. WAVE's primary design objectives were modularity and expandability while adhering to the regulations for the international competition held by the Association for Underwater Vehicle Systems International. WAVE's core features include a six degree-of-freedom chassis, a modular electronic infrastructure, and an easily configurable software framework.

Background

Robotic submersibles come in two varieties: Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs). ROVs are remotely controlled underwater vehicles that are physically tethered to a vessel while AUVs are non-tethered and autonomous.

The Association for Unmanned Vehicle Systems International (AUVSI) is leading international non-profit organization devoted to the unmanned systems and robotics community. They hold a yearly robotic submersible competition whose guidelines are being used in the development of this project. This international competition brings together high school and college students from the US and other countries and offers a cash prize to the groups that are able to navigate the course and complete objectives most successfully.

Specifications

System
- Max depth: 12 meters
- Run time: 20 minutes
- Desired speed: 0.5 m/s
- Max dimensions:
  0.91m x 0.91m x 1.83m
- Depth control accuracy: 12 cm
- Max mass: 54 kg

Mechanical
- Hydrodynamics
  - Buoyancy management
  - Minimum 0.5 m/s motion
- 4 degrees of freedom minimum
- Electronics housing
  - Watertight
  - Sufficient thermal dissipation
- Mechanical failsafes

Electrical
- Power distribution
- Standardized embedded computing platform
- Sensing
- Control of actuators for locomotion and additional accessory modules.

Software
- Distributed processing
  - Communication with Embedded Controllers
  - Custom Remote Procedure Calls (RPCs)
- Fully autonomous operation
  - Customizable mission planning
  - Centralized log system
- Multi-client poolside user interface
  - Monitor robot status
  - Sensor data visualization
  - Safety controls

Design and Analysis

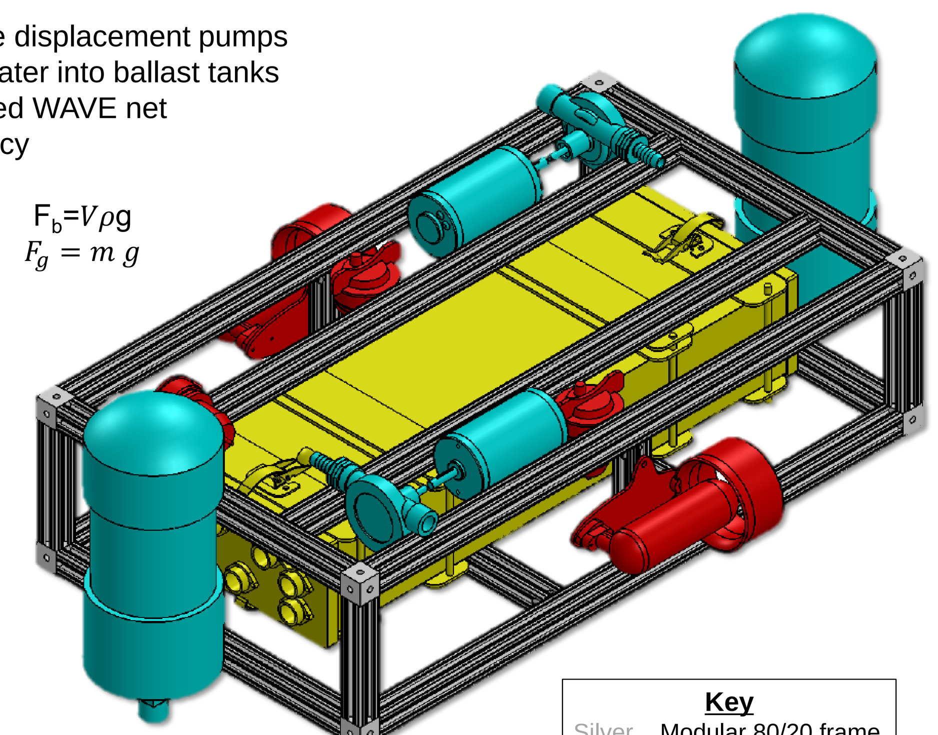
Mechanical Subsystems

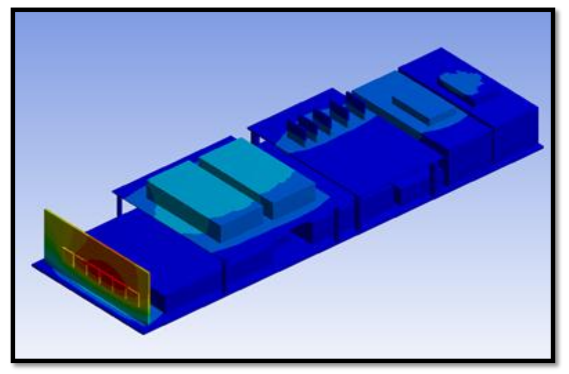
Electronics Housing:
- Rectangular tube:
  16cm x 8cm x 48cm
- Silicone gasket end-caps
- Easily accessible interior via sliding electronics rack

Buoyancy Control:
- Controlled buoyancy of WAVE
- Positive displacement pumps force water into ballast tanks
- Analyzed WAVE net buoyancy

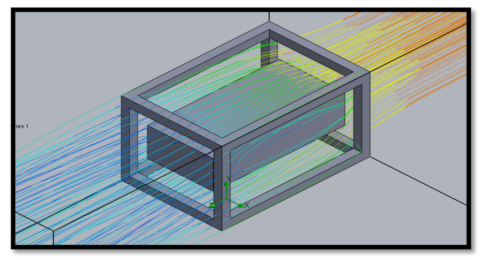
Thermal:
- Aluminum housing conducts heat to exterior
- Able to dissipate heat from batteries and motor drivers

$F_b = V\rho g$
$F_g = m\,g$

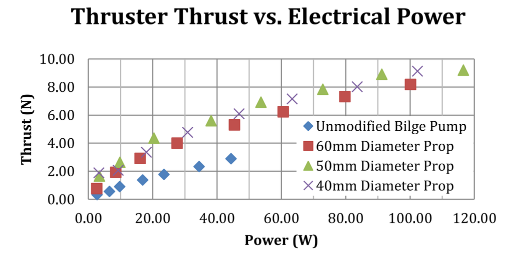




Key	
Silver	Modular 80/20 frame
Red	6 thrusters
Cyan	Active ballast
Yellow	Electronics housing

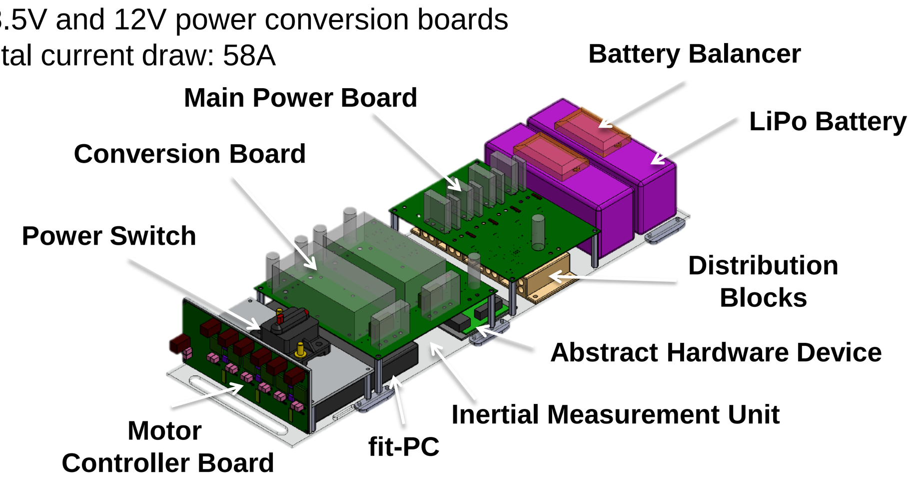


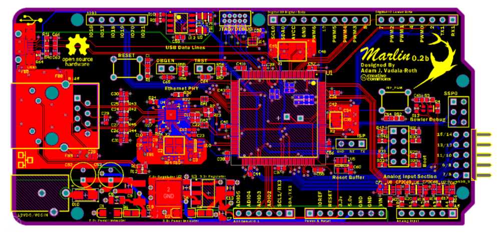
Drag & Thrust:
- Used SolidWorks flow simulation to estimate drag
- Compared simulated values to analytical values:
  $$F_D = \frac{1}{2}\rho C_D A_c v^2$$
- Determined power needed to overcome drag at spec velocity
- Tested motors and props to determine suitability for WAVE



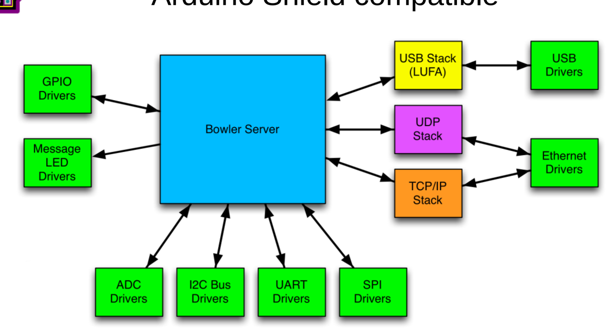
Electrical Subsystems

Power Distribution:
- 18.5V and 12V power conversion boards
- Total current draw: 58A

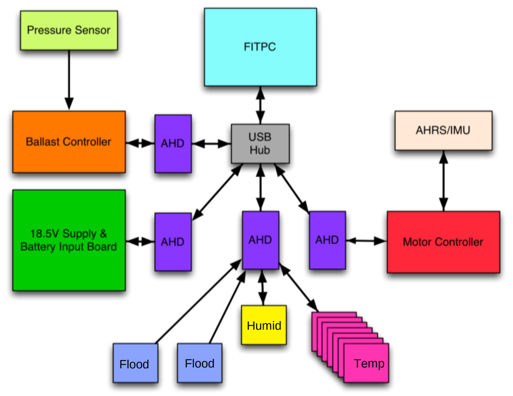




Abstract Hardware Device:
- ARM Cortex Dual Core Processor
- USB & Ethernet connectivity
- Multi-channel PID
- Arduino Shield compatible

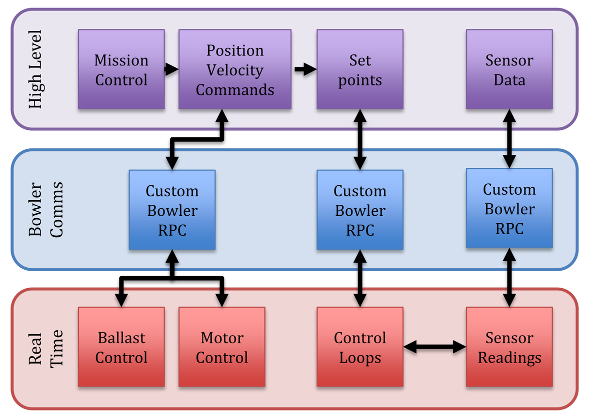


Embedded Architecture:
- Written in C
- Developed in LPCXpresso
- Bowler Comm. Protocol



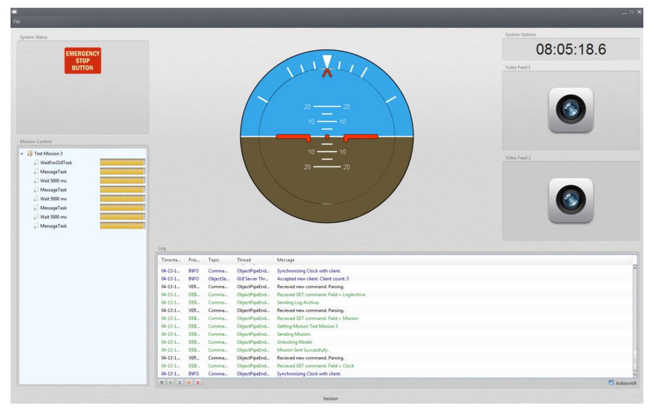
Sensor Suite:
- Inertial Measurement Unit
- Temperature
- Humidity
- Depth
- Water leakage

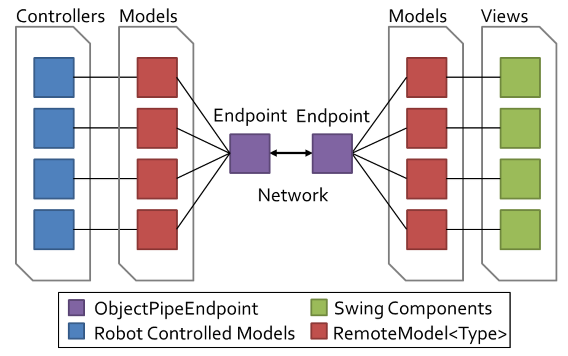
Software Subsystems



Distributed Processing:
- Utilizes Neuron Robotics SDK
- Bowler Communications Protocol(Neuron Robotics)
- Custom Remote Procedure Calls (RPCs)
- High-level functions written in Java
- Low-level embedded functionality written in C

Poolside Interface:
- Attitude indicator
- Current mission and individual task progress
- System timer
- Time-stamped and downloadable log entries
- Safety features
- Multi-client support





Mission Execution:
- Missions constructed from customizable XML file
- Missions comprised of synchronous and asynchronous tasks
- Asynchronous tasks run in their own thread while synchronous tasks are executed in order
- Tasks include sensor polling, locomotion, and emergency situation response

Discussion

Results

The numerous sub systems experienced individual successes:

The mechanical team designed and fabricated a waterproof enclosure capable of housing all vital electronic components. After rigorous thruster testing, adequate motor-prop units were selected and arranged to achieve mobility in five degrees-of-freedom. The sixth degree-of-freedom (pitch control) was achieved using the active ballast system.

The electrical team successfully created a high power distribution system with 18.5V, 12V, 5V, and 3.3V outputs. A sensor suite was constructed for sensing humidity, temperature, and water leakage. A custom high current actuator control board and high performance embedded control platform was created.

The mission control software was able to parse and execute several varieties of mission files. The mission files specified the order and duration of several synchronous and asynchronous tasks which were then executed by the task manager. System models and sensor data were relayed to multiple GUIs and recorded on the fit-PC. Robot configuration options were stored in plaintext files, then parsed, modifying WAVE's behavior. The cross-platform mission control software runs on Windows and Linux, allowing for rapid testing and prototyping.

New Project Possibilities for WPI

- Biomimetic propulsion and ballast systems
- Control surface design and analysis
- Underwater localization and mapping
- Underwater communications

Integrated System Rendering