



# MATE Underwater Robotics:

## Providing Pathways to the STEM Workforce

Marine Advanced Technology Education (MATE) Center at Monterey Peninsula College

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The **Marine Advanced Technology Education (MATE) Center** uses underwater robots (remotely operated vehicles or **ROVs**) as a way to get middle school, high school and college students excited about science, technology, engineering, and math (STEM). From ROV designing and building workshops to competitions that focus on real-world ROV missions, these activities expose students to STEM careers and help them envision pathways to these careers.

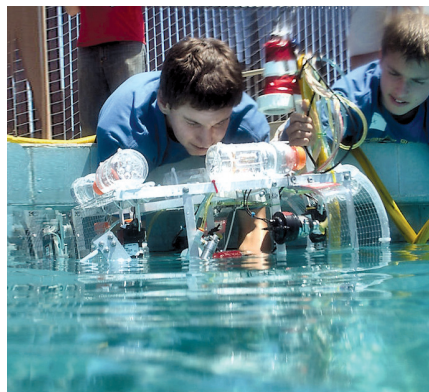
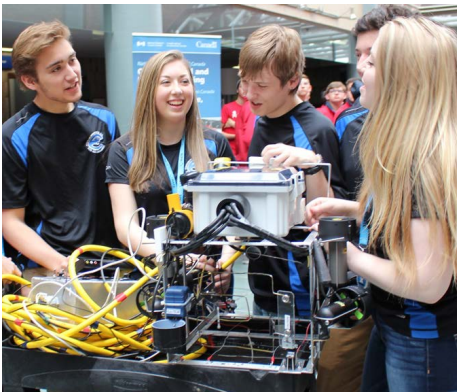
ROVs are also a great way to introduce engineering design, entrepreneurship, and project management to upper elementary, middle and high school students, as described in *the Next Generation of Science Standards*. Designing and building an ROV for a specific mission takes students through the design process, encouraging them to think creatively and research, test, and evaluate solutions. It also challenges them to organize their time and resources, all the while working towards a deadline, just as if they were in the workplace.

There are few opportunities for students as real-world as the MATE ROV competition. For the past 15 years, the MATE Center and the Marine Technology Society (MTS) have worked together to create and carry out ROV competitions across the country and around the world. MATE's competitions use ROVs as a platform to instruct students in STEM and demonstrate how these disciplines are applied in the real world. The competitions challenge students to think of themselves as entrepreneurs and transform their teams into companies that manufacture, market, and sell "products and services." From developing ROVs to cap oil wells and survey WW II shipwrecks for environmental hazards, MATE's competitions require students to solve problems in new and innovative ways, work as part of a team, and develop an understanding of the breadth of business operations – all important 21st century workforce skills.

In addition to constructing an ROV, each year the students are required to submit technical documentation and deliver engineering presentations to STEM professionals who serve as judges, solidifying the connection to real-world industry practices as well as showcasing examples of potential careers. Students are also required to create a poster display that communicates to the layperson information about their vehicle design, their company (team), the problems they were tasked to solve, and how these problems relate to real-world events.

The program currently consists of one international and 28 regional competitions held annually. To date, the competitions and their supporting professional development workshops have impacted more than 25,000 students and 2,000 teachers at more than 2,000 formal and informal educational institutions (middle schools, high schools, home schools, community colleges, universities, 4-H clubs, and public aquaria, among others).

Visit [www.marinetech.org/videos](http://www.marinetech.org/videos) to view MATE competition videos.



# Knowledge and skills acquired while building an ROV & participating in a MATE competition

## Aligns with the Next Generation of Science Standards for Middle & High School Engineering Design

The MATE competition consists of four levels or classes: SCOUT > NAVIGATOR > RANGER > EXPLORER. The following learning objectives focus on knowledge and skills acquired at the first three levels (SCOUT - RANGER.) Please visit [www.marinetech.org/rov-competition/](http://www.marinetech.org/rov-competition/) for more information about MATE's ROV competition. It is implied that each class would have mastered the knowledge and skills in the proceeding class(es).

## Engineering Design/Project Management

A student finishing the **SCOUT NAVIGATOR RANGER** class will be able to do all of the below:

1. Form a mock company; function as entrepreneurs and develop products and services to solve real-world problems (see MATE ROV competition manual for example).
2. Describe and implement the engineering design process.
3. Identify specific strategies to address common design and building challenges (keeping on schedule, on budget, team dynamics, safety, etc.)
4. Define project criteria (e.g. competition mission) and constraints (time, money, expertise, vehicle depth and size, etc.) to ensure a successful solution.
5. Evaluate competing design solutions using a systematic process such as a tradeoff matrix.
6. Build a functioning, shallow diving ROV using hardware-store technology.

## Technology and Society

A student finishing the **SCOUT NAVIGATOR RANGER** class will be able to:

1. Describe what a robot is and how robots are used to support work that has been traditionally performed by people.
2. Explain the common types and uses of modern underwater vehicles.
3. Conduct an underwater mission and relate this mission to what ROVs are doing in science and industry (see MATE Center ROV competition for examples).
4. Summarize the type of occupations that support the marine robotics industry.
5. Identify motivating factors and key historic events in the evolution of underwater vehicles.
6. Name and define the major subsystems of a modern work class ROV.
7. Explain some of the major challenges confronted by developers of early underwater vehicles and describe how they were overcome.

## Electrical Knowledge:

A student finishing the **SCOUT NAVIGATOR RANGER** class will be able to:

1. Define current, voltage, and resistance and explain their relationship to Ohm's Law.
2. Draw a complete circuit.
3. Summarize the operation of a switch.
4. Safely operate basic electrical tools (soldering iron, desoldering pump, multimeter).
5. Discuss how a battery works and how long you might expect your vehicle to run on a given battery.
6. Recognize the importance of good electrical connections.
7. Describe how an electric DC motor works.
8. Identify a method for changing the direction of rotation of a DC motor.
9. Describe what a short circuit is and the purpose of a fuse.
10. Demonstrate proper safety procedures when working with electrical power.

11. Describe the difference between energy and power.
12. Calculate series, parallel and combination circuit values using Ohm's Law.
13. Calculate the resistance value and power rating of series resistors.
14. Explain the purpose of Pulse Width Modulation for motor control.
15. Describe the use of a MOSFET switch in a motor control.
16. Establish criteria for selecting a motor controller and select an appropriate motor controller for the job.
17. Demonstrate best practices for soldering electronic components.
18. Design a simple filter circuit to protect cameras from motor spikes.
19. Describe the need for filter capacitors.
20. List methods of video transmission.
21. Describe the operation of a computer controlled motor speed controller.
22. Practice advanced safety procedures when working with electrical equipment.

## Mechanical Knowledge:

A student finishing the **SCOUT NAVIGATOR RANGER** class will be able to:

1. Demonstrate the ability to make accurate measurements by using plumbing pipe and fittings to build a simple ROV frame.
2. Safely operate basic hand-held tools (screwdrivers, wire cutters, PVC cutters, pliers, wire strippers, hot glue gun, heat gun).
3. Apply proper methods when attaching cables to the frame and preventing injuries from propellers.
4. Demonstrate proper wire routing and sealing methods.
5. Use the Bollard test to explain how to match a propeller with its motor to maximize the output thrust and efficiency.
6. Use a Computer Aided Design program to build a complex ROV frame with materials other than plumbing fittings.
7. Describe at least one method for enclosing electronics in a water environment.
8. Outline safety procedures for working with fluid power.
9. Explain the basic components of a standard hydraulic system and how these systems can be used to transfer force, motion, and power from a prime mover to an actuator.
10. Design a gripper using hydraulic or pneumatic controls.

## Ocean Engineering/Physical Science Knowledge:

A student finishing the **SCOUT NAVIGATOR RANGER** class will be able to:

1. List and describe the physical forces affecting underwater vehicle motion (Newton's Laws of Motion.)
2. Describe ways that the physical properties of water differ from those of air. Explain how each of those differences presents challenges and/or opportunities for those designing and operating underwater vehicles.
3. Explain why objects in water sink, float, or tip over and how buoyancy and ballast systems can be used to control these processes (Law of Gravity, Archimedes' Principle.)
4. Determine the difference between positive, negative, and neutral buoyancy and explain why the designers of most underwater vehicles strive for near-neutral buoyancy.
5. Calculate the buoyancy necessary to make any device neutrally buoyant.
6. Build a simple device to collect organisms or other samples.
7. Describe what a payload is and why it's important for an underwater robotic vehicle. Why are multiple and/or interchangeable payloads particularly useful?
8. Build a marine collection device with moving pieces.
9. Describe the causes and consequences of metal corrosion and discuss methods to control it.

## Computer Science

A student finishing the **SCOUT NAVIGATOR RANGER** level should be able to:

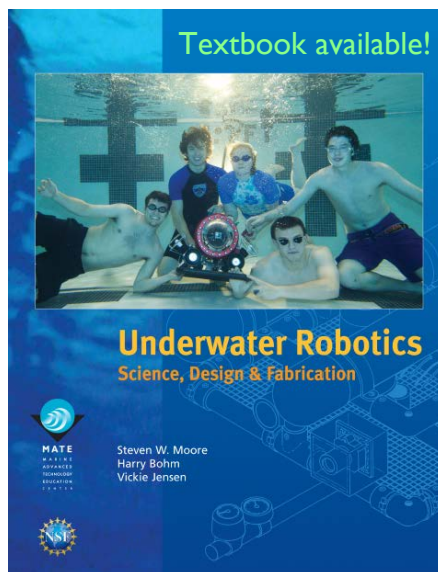
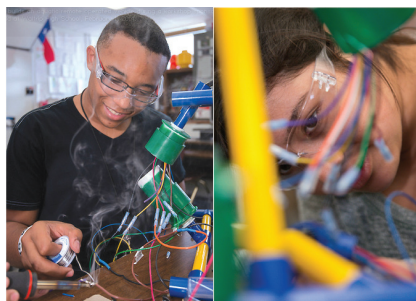
1. Graph sensor data using a spreadsheet program.
2. Use a spreadsheet to perform multiple solutions for buoyancy problems.
3. Explain what a microcontroller is and what role it can play in the control systems used for ROVs and AUVs.
4. Explain how a microcontroller can get commands from a pilot through buttons, knobs, and joysticks.
5. Describe how a microcontroller can operate thruster motors, video lights, gripper arms and other systems on a vehicle.
6. Give some examples of common algorithms; list some possible causes and solutions for common control system malfunctions.
7. Use a microcontroller to control motors.
8. Use a microcontroller to respond to human sensor inputs (joysticks & switches).
9. Use a microcontroller to read the results of sensors.
10. Use a microcontroller to scale sensor data into human understandable units.

## Common Core Standards

**Math** is involved in many aspects of designing, building, and controlling an ROV. Ohm's law, for instance, is central to designing the electrical systems for ROVs, even at the most basic level. Measuring and cutting, calculating buoyancy requirements, and building simple circuits all involve applied mathematics.

## Language and Arts

Through the competition, the students gain a variety of additional knowledge and skill sets that are critical to making them employable. For example, students demonstrate 21st century skills such as communication, teamwork, leadership, entrepreneurship, creativity, critical thinking, problem-solving, motivation, and time and resource management. These skills are assessed by teachers, surveys, and competition judges. In addition, technical writing and oral communication are practiced and assessed during the competition via reports, posters, and presentations.



**The Marine Advanced Technology Education (MATE) Center** is a national network of educational institutions, professional societies, marine industries and working professionals. MATE's mission is to use marine technology to inspire and challenge students to learn and creatively apply science, technology, engineering, and math to solving real-world problems in a way that strengthens critical thinking, collaboration, entrepreneurship and innovation. The MATE Center was established with funding from the National Science Foundation in 1997.

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