Asa Capsouto 13

Cole Houston 16

Raph Hubbard 16

Joshua Rosenthal 15

Mentors:
Kathy Capsouto
Kimberly Schwab

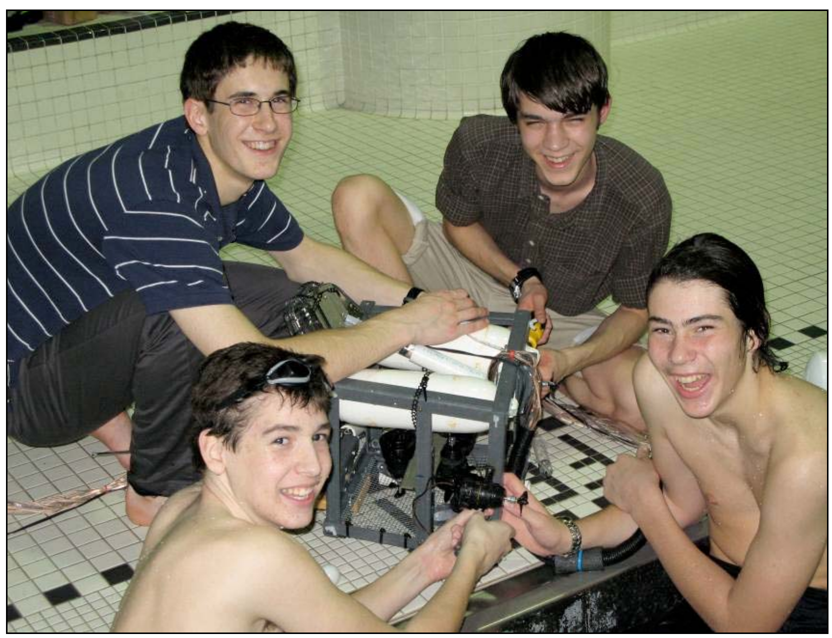
ROV ADD

Designed and built by:

The Official NYCHEA ROV Team

NYCBEES

NYCHEA: New York City Home Educator's Alliance
NYCBEES: New York City Builders of Elegant & Efficient Submersibles



The NYCBEES: Raph Hubbard (top left), Cole Houston (top right), Asa Capsouto (bottom left) and Joshua Rosenthal (bottom right). We are members of a New York City homeschool science group. We've been together for a number of years studying everything from *Friendly Chemistry* to building large-scale trebuchets. Every year we enter the NYCHEA science fair with innovative projects. Our building an ROV to compete in the 2007 MATE Competition is a way to take a science fair project to a new level and test our skills against other like-minded teens.

Abstract

The NYCHEA NYCBEES is a rookie team which designed and built an ROV that can complete the missions of the 2007 MATE competition.

Guided by MATE specifications and our constraints, we built a prototype fiberglass angle frame to serve as a testing platform. During our testing process we added six thrusters to our initial four to increase power, mobility and control. We also added a waterproof, color camera from Lights, Camera, Action. The view of this camera is expanded by the addition of a hydraulic tilt mechanism, a rear view mirror and a 3-D viewing system.

For mission #1, two hydraulic claws work in tandem to thread the messenger line. In mission #2, a hydraulic claw transports the acoustic monitor and collects the "jellyfish" while a non-powered payload tool collects the "algae." During mission #3, one hydraulic claw removes and returns the wellhead cap, while a second places the gasket. Our Velcro appendage transports the hot stab.

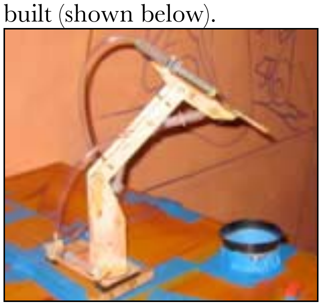
We built our ROV within our budget and transported it all over NYC for pool testing. During construction, we learned many things, including working with our hands, the procurement and fabrication of items, how to deal gracefully with the frustration of things not working, the importance of sea ice to Arctic cultures and how to have fun while working.

We look forward to the 2008 competition, no longer as rookies, but as a team who has developed technical skills, teamwork and a shift in how we think about design, engineering and ourselves.

ROV ADD at the edge of the Hudson River.

Our table at the 2006 NYCHEA science fair displayed the Sea Fox we built, as well as materials about hydraulics, ROVs and the MATE competition.

Cole helps science fair participants remotely place Legos in a cup, using the Pitsco hydraulic arm kit we built (shown below).



Contents

Design process

Our design process was guided by:

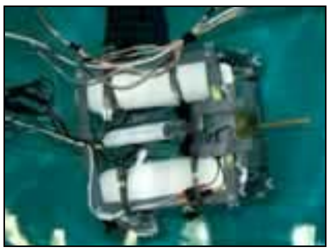
- MATE rules and regulations
- 2007 Mate Competition missions
- Need for easy portability throughout NYC
- Lowcost technology to keep us within our budget
- Technology we can fully master and troubleshoot
- Using fiberglass angle as a frame material
- The use of bilge pump cartridges for propulsion
- Syringe hydraulics to control payload tool motion

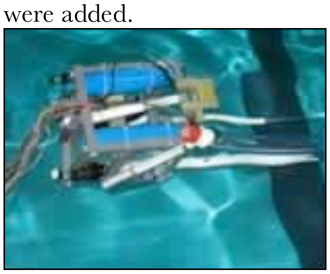
Some of these constraints were imposed on us. We, however, chose the fiberglass angle, bilge pump cartridges and syringe hydraulics because they enabled us to get into the water quickly and cheaply. We did not have specific schemes in mind to achieve our design goals. Our process for achieving them consisted of building and testing an easy-to-modify experimental platform, affectionately known as "Proto." Over the summer we made a prototype frame and attached thrusters and a camera. In the fall we began testing payload tools.

We thought we had good control over our machine until we attempted to perform missions. We struggled with both lack of power for vertical motion and lack of fine control over all movement. Our propeller-matching process – described in the propulsion section – increased our thrust, increasing our need for control even more. This led to our using potentiometers and eventually building our own power resistors as we describe in the control system section. During our testing process we gradually added six thrusters to our initial four, to increase power, mobility and control.

Payload tools also evolved during our testing process. We tested the alligator clip and plumbing grabber, along with several other payload tool options that we did not adopt. Initially, these two tools were spaced several inches apart. After much testing, we realized that, if we combined these two arms, we would never need to release the messenger line. The plumbing grabber conveys the messenger line down and positions it through the u-bolt and then the alligator clip is positioned to grab it on the other side. The effectiveness of these arms was magnified by combining them. This is just one example of how we came to our final ROV through our design process of making a prototype, learning from it and then making more prototypes until we were satisfied.


Joshua testing Proto during the summer.


Proto before payload tools were added.


Proto with separate hydraulic arms.


Paired hydraulic claws demonstrate line threading.


After testing in Hudson River currents, we added two more forward/reverse thrusters.

Frame and buoyancy

Our frame's size, shape and material choices were guided by our design goal of building an economical ROV that is easy to transport and modify.

We live in various neighborhoods in Manhattan and don't have easy access to a pool. Thus, when we built our small, cube-shaped prototype, we didn't know where we would be able to test it. Only one team member's family has a car, so we needed to be able to transport the ROV via public transportation or cab. The small size of our ROV also allows it to move faster than a larger ROV with the same size thrusters. After testing, we found this small size and cube shape to be very functional. When we built our final frame, we kept the same dimensions.

Our past experience working with PVC pipe taught us that it was a challenging material with which to work. It is a difficult material on which to mount things precisely, and is hard to machine. Fiberglass angle solves these problems because it provides a flat surface for easier mounting and is easier to cut and shape. We use machine screws to hold the frame together because they are sturdy and allow the ROV to be easily taken apart and modified.

Over the summer, we experimented with a variable buoyancy system, but we decided to use a simpler adjustable buoyancy system instead because we did not need variable buoyancy to complete the missions. We chose to use inflatable boat bumpers mounted at the top of the frame and foam pipe insulation on the tether for flotation. Lead fishing weights serve as ballast and allow us to fine-tune our buoyancy. This provides a stable platform for performing a variety of tasks.

We used a stroller to transport our vehicle when we traveled by subway.

When we traveled with mission props and tools, we traveled by cab or we shared the load as depicted below.

We used various vehicles to transport all of our supplies across Central Park.

Our frame prior to attaching thrusters and payload tools.

This view from below shows Proto's completed frame and floats.

We built a plexiglass frame to house our board camera before encasing it in epoxy.

We attempted to seal our camera and connectors in a Pelican case. Unfortunately, the gasket admitted water. We then epoxied it shut, only to have the condensation inside the case short out the camera.

This rear view of the camera tilt system shows the syringe attached to a hinged piece of angle on which the camera is mounted. This enables our camera to tilt almost 180 degrees.

Sensors

What at first seemed to be one of the most straightforward systems on our ROV has turned out to be one of the most vexing. Our attempts to create a low cost, reliable board camera system met with challenges and were ultimately too time consuming, but they helped us improve our skills in splicing, waterproofing, troubleshooting and decision making.

Our original camera was a very cheap ($12.00), black and white board camera. We started with this to see if we could waterproof it successfully without great loss if we failed. After potting the camera in a PVC pipe housing, we realized that the focus was set incorrectly. During efforts to test the strength of the epoxy we found that the camera came out of the PVC pipe with the epoxy intact. This discovery gave us the idea of making a mold for the camera and the waterproofing epoxy. The epoxy then could be drilled and manipulated for attachment to the ROV.

This led us to devise a camera mounting system built with fiberglass angle and hinges and controlled by our syringe hydraulics system. The efficiency and simplicity of this system was highly adaptable to whatever camera we tried. Most importantly, it allows us to perform all of the missions with only one camera.

Other problems plagued us, however. Our failing battery did not produce enough voltage to power our camera adequately. We had problems splicing video cable and waterproofing connections that were outside the epoxy. To avoid this problem, we placed the camera and video connections inside a small Pelican case. However, this case leaked at the gasket. With the competition deadline approaching and our camera still unreliable, we checked our budget and decided that we needed to upgrade and purchase a submersible camera. Thus, we took advantage of MATE's offer from Lights, Camera, Action to sell their submersible cameras to teams at cost.

We augmented this camera with a rear view mirror so that we can check if we really did collect a pingpong ball in the second mission. Also, we are testing a 3-D viewing system from eDimensional to see if it will aid our performance.

Joshua fabricating the "Bazooka," our thruster force-measuring device.

Raph and Joshua test propellers in the tub in our bathroom "lab."

This is our data sheet with some of the propellers we tested.

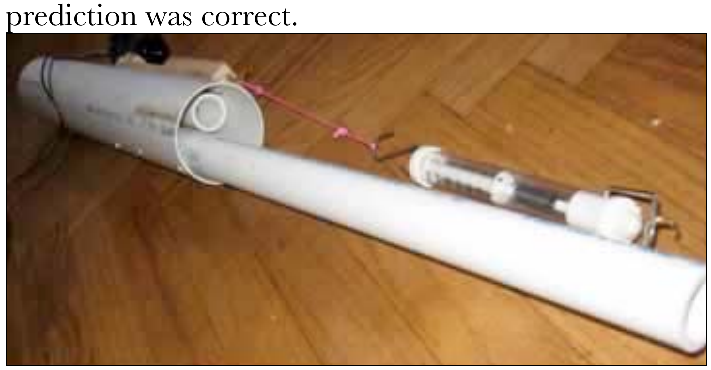
Propulsion system

Our ROV's propulsion system is designed for movement in any necessary direction. The vehicle has four forward/reverse thrusters which provide it with the ability to move forward and backward and to spin, and four vertical thrusters for vertical movement. Each of these thrusters can be adjusted for finer movements by a stepped potentiometer that we built. We also have a pair of thrusters to control pivoting motion. All thruster pairs spin in opposite directions to ensure good tracking.

The thrusters on our ROV – 3,785 LPH Mayfair bilge pump cartridges – were chosen because they were very inexpensive, already waterproofed, and in the form of cartridges which did not need any modification before mounting. This enabled us to get Proto in the water very quickly to begin our testing process. We didn't need to wait to learn how to waterproof motors before we began.

The next step after selecting our thrusters was to choose propellers. For initial work, we used very easy-to-mount propellers, because they enabled us to get in the water right away. Later, we tested to determine the most efficient propeller for our ROV.

We tested a range of propellers differing in diameter, pitch and number of blades. We built a force-measuring device – known as the "Bazooka" – out of PVC pipe, a spring scale, a block of wood, a hook and a thruster (as shown below). We connected the thruster to the battery and tested each propeller in a bathtub, measuring the thrust produced with the spring scale and the amperage drawn with a multimeter. We analyzed the data and assigned each propeller an efficiency number calculated by the ratio of the force each propeller produced to the number of amps it drew. Based on our initial data, we predicted that another propeller – a three-bladed prop slightly smaller than the ones we already had – would meet our needs most efficiently. Our prediction was correct.



The "Bazooka," our thruster force-measuring device.

This propeller delivered over 5 Newtons of thrust while drawing 3.5 amps, within the 4-amp range of our thrusters. We were thrilled to discover that, in changing to these more efficient propellers, we more than doubled our thrust and reduced our amperage draw.

We could not find a readily available system for mounting these propellers to our thrusters. Testing many propellers led us to devise mounting systems that would allow propellers to be attached quickly and removed without permanently changing either the propellers or the thrusters. Our quick release system was great for testing. In the end, however, we also needed the propellers to stay attached strongly. It took several tries and the great frustration of watching many propellers fall off during testing to fabricate a system for the props to be mounted straight on the shaft and stay securely.

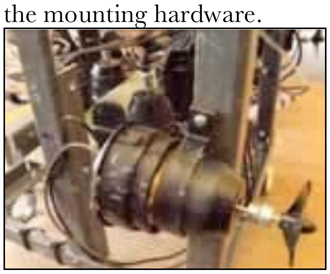
We also experimented with how far away the propellers should be from the thrusters. Increasing this distance gave us a considerable force boost going in reverse. The location of the vertical thrusters within the frame, however, limits the length of the propeller shaft, costing us efficiency when operating in reverse. We worked around this by having two pairs of thrusters mounted in opposite directions to power vertical movement. We use the pair facing down for upward propulsion and the pair facing up to move our vehicle down. We also can use both pairs at once for maximum vertical thrust.

We gradually added more thrusters to our prototype to give us more power and control. In addition to the pair of thrusters added for vertical motion, we added a pair of forward/reverse thrusters to help us overcome current, and a pair of pivioting thrusters to help us fine-tune our positioning around the mission props.

This is one of the first mounting systems we devised.

This later mounting system allowed for more precision when centering the propeller on the shaft.

We covered the thrusters with bicycle inner tubes so that they would fit snugly into the mounting hardware.



This shows our thruster mounting system prior to installing propeller shielding. The holes and cuts in the frame indicate where things were attached previously in different incarnations of Proto's life.

This shows the positioning of the left thruster and the two pairs of vertical thrusters mounted diagonally at the center of the ROV.

Payload tools

We have four payload tools on our ROV. One of them has the task of bringing down the hot stab. Another is dedicated to collecting the algae (pingpong balls). The other two are more versatile and can do many tasks.

The arm that we use to transport the hot stab is very simple. It is a piece of wood covered with Velcro and mounted at a 45-degree angle. Before the mission, we attach Velcro to the handle of the hot stab. This holds the hot stab at the correct angle to be inserted into the port. To release the hot stab, we simply drive to the wellhead, insert the hot stab in the port, drive down and back, and the hot stab is released. To retrieve it, we ram the block back into the handle of the hot stab, then drive up with the hot stab stuck to the Velcro. We remove the Velcro on the hot stab shaft at the end of the mission.

The hot stab grabber demonstrating the insertion of the hot stab into the wellhead.

The payload tool we use to collect our sample of algae is also very simple. It is a wire drawer with half the wires removed. When we drive up against the ice we force the wires to bend slightly, allowing the pingpong balls to be caught. Once inside the wire framework, the buoyancy of the pingpong balls is not strong enough to bend the wires and escape.

The pingpong ball collector.

Our other two arms are much more versatile. One uses a big alligator clip for its claw, and the other uses a plumbing grabber, which was designed originally for fishing little objects such as wedding rings out of drain pipes. Both arms are powered by syringe hydraulics. With this system, a syringe is located at each end of a tube filled with potable anti-freeze. The master cylinders are located in the control box and the slave cylinders are attached to the arms. When either master cylinder is pushed or pulled, the slave cylinder, attached to a claw, will make it open or close. With these two claws, working individually or in tandem, we can do anything from collecting a jellyfish to inserting the messenger line through the u-bolt.

Joshua fabricating the hydraulic syringe system for the alligator clip hand.

The open plumbing grabber.

During our prototype phase we built other electrically powered payload tools, including a slurper powered by a bilge pump to suck up pingpong balls. In the end, though, we chose the hydraulic and non-powered payload tools because they do not draw any power from our 25-amp limit. They also are light, cheap and simple, which makes them very easy to troubleshoot, fix and replace, if needed.

Control systems

Our current control box is enclosed in a hard rifle case. The switches are mounted on two plexiglass panels inside the case. The pilot's controls are on the left and are used to operate the forward/reverse and pivoting thrusters. The co-pilot's controls are on the right, and include the vertical thruster controls as well as the kill switch and the camera switch. The hydraulic syringes that operate the robotic arms and the camera tilt mechanism are free floating in the middle of the box. They are controlled by the hydraulics operator. We came up with this system after a long process of research and development.

Building the Sea Perch and the Sea Fox ROVs last year taught us basic wiring skills and provided examples of different control systems. One major lesson learned and applied to our competition vehicle is that reliable electrical connections are essential. Through building and testing, we chose to use crimp on quick disconnects to avoid problems. These connectors also allow us to replace defective parts rapidly and allow for flexibility and modification during our experimental phase. For our final model, however, we chose to solder our connections.

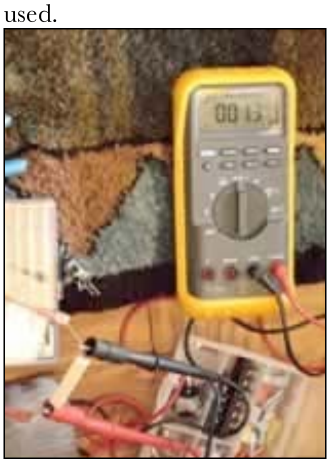
Our first control system was housed in a single project box with On-Off-On switches that controlled the direction of the various thrusters. After testing this version, we decided that we needed finer control over the amount of thrust generated by each thruster. Accordingly, in the next incarnation, each thruster also was connected to a potentiometer that controlled the amount of thrust generated by the thruster.

After much testing and piloting of the ROV, we came to the conclusion that having potentiometers connected to both of the forward/reverse thrusters was needless and annoying. We determined that one potentiometer would suffice for both forward/reverse thrusters. This worked well, but the potentiometers we were using had too much resistance and thus did not give us the amount of control we needed, especially after we increased our thrust by changing propellers.

Not only did we need potentiometers with a better range for control purposes, we also needed ones that didn't melt. After melting several pots, we discovered that one of the ratings that applies to potentiometers is wattage. We found that the watt settings on the pots we were using were far too low. This caused them to melt.

Asa piloting our ROV using one of our later control boxes.

We melted the first pots we used.



We tested various power resistors when we were designing our stepped pot.

We used adhesives, power resistors and heat sinks to build our own high-power resistors.

The pilot's side of the final control box.

We shared our knowledge about hydraulics at the 2006 NYCHEA science fair. The Pitsco hydraulic arm kit we used at the fair, depicted on page 2, taught us a great deal about how we could use syringe hydraulics in our control system.

Joshua fabricates the hydraulic control system for our alligator clip claw. We were able to adapt what we learned to create a versatile control system for our claws and camera tilt mechanism.

After searching for pots with higher watt ratings, we discovered that very few pots which met our specs were on the market at any price range, let alone ours. We decided to fabricate our own stepped pots using high-power resistors and a rotary switch to create a multi-speed switch. This gives us more control than a pot because we can customize the switch to determine exactly what resistances we want. Use of a rotary switch also makes it harder to turn the switch, making sure that the resistance level will not be changed by mistake.

Since we couldn't find any high-power resistors in our price range, we fabricated these as well by attaching power-resistors to heat sinks. We then attached these to the different leads of the rotary switch and connected all the leads to the vertical motors. This has worked very well and cost us less than a tenth of the price of buying ready-made high-power resistors.

We considered using electrical power to control the payload tools and camera tilt system, but chose instead to use hydraulics. The limited efficiency of the thrusters we used didn't allow for much more electrical power use. We knew from previous experience that a syringe controlled hydraulic system is a cheap and easy way to operate our payload tools.

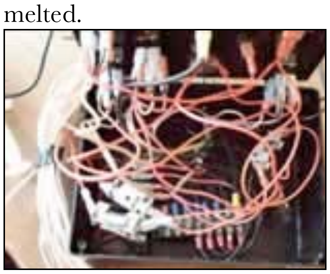
When the water in our hydraulic tubes froze one Saturday night while transporting our ROV to the pool for testing, we realized that water would cause problems at the competition during the ice tank mission. Adding potable antifreeze, used in RVs and pools, instead of water, solves this problem.

The tether for our ROV is composed of 18 gauge stranded speaker wire, 3.175 mm ID potable anti-freeze-filled PVC tubing and a camera cable that transmits both power and video signals. We chose speaker cable because it was cheap and readily available. It also has the advantage of being very easy to use during the design and testing process; we can change the number of conductors in the tether at will. Our 22 m long tether is enclosed in black, split-loom tubing. This serves to contain all the lines in a neat bundle. Since the tether is negatively buoyant, foam pipe insulation is attached to the tether at regular intervals to make a slightly positively buoyant tether. This prevents the tether from impeding our ROV's motion while getting it out of the way of propellers, payload tools and mission props.

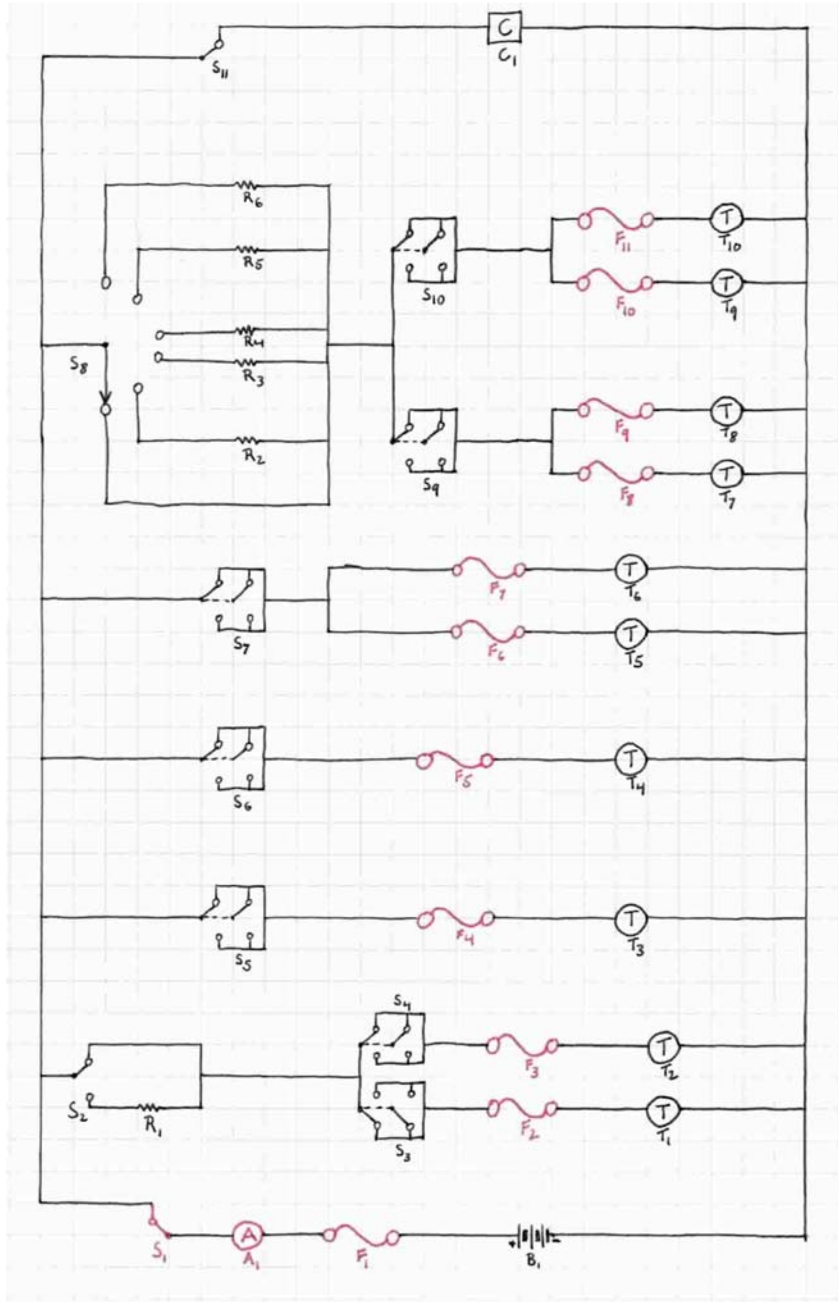
Schematic drawing

The key to the schematic drawing is located on the next page. Safety features are indicated in red on both the schematic drawing and the key to the schematic drawing.

This version of our control box includes the pots that we melted.



This is an inside look at of one of the many incarnations of Proto's control system.



The inside of the final rifle case control box.

Key to schematic drawing

	Description	Function
A1	30 Amp Ammeter	Keeps track of the amount of amps being drawn by the entire system.
C1	Fully Waterproofed Color Camera	Primary eye and the only camera for the ROV.
F1	25 Amp Fuse	System fuse.
F2 – F11	5 Amp Fuse	Protects the thruster.
R1	2 Ohm Resistor	Used in the 2 speed switch for the lower speed.
R2	O.5 Ohm Resistor	Used in the rotary switch for the lowest speed.
R3	1.0 Ohm Resistor	Used in the rotary switch for the next lowest speed.
R4	1.5 Ohm Resistor	Used in the rotary switch for the next lowest speed.
R5	2.0 Ohm Resistor	Used in the rotary switch for the next lowest speed.
R6	2.5 Ohm Resistor	Used in the rotary switch for the next lowest speed.
S1	SPST Illuminated Automotive Kill Switch	Used as a safety kill switch for the entire circuit and as a troubleshooting tool.
S2	SPDT On-On Switch	Operates the 2 speed switch for the forward/back thrusters and an integral part of the same.
S3	DPDT Center Off Switch	Controls the primary left thruster.
S4	DPDT Center Off Switch	Controls the primary right thruster.
S5	DPDT Center Off Switch	Controls the secondary left thruster.
S6	DPDT Center Off Switch	Controls the secondary right thruster.
S7	DPDT Center Off Switch	Controls side-to-side thrusters.
S8	6-position Rotary Switch	Operates the variable speed switch for the vertical thrusters and an integral part of the same.
S9	DPDT Center Off Switch	Controls the vertical thrusters.
S10	DPDT Center Off Switch	Controls vertical thrusters.
S11	SPST Switch	Turns the camera on and off.
T1	4 Amp Rated Bilge Pump 3785 LPH	Primary left thruster.
T2	4 Amp Rated Bilge Pump 3785 LPH	Primary right thruster.
T3	4 Amp Rated Bilge Pump 3785 LPH	Secondary left thruster
T4	4 Amp Rated Bilge Pump 3785 LPH	Secondary right thruster.
T5	4 Amp Rated Bilge Pump 3785 LPH	Side-to-side thruster 1.
T6	4 Amp Rated Bilge Pump 3785 LPH	Side-to-side thruster 2.
T7	4 Amp Rated Bilge Pump 3785 LPH	Up thruster 1.
T8	4 Amp Rated Bilge Pump 3785 LPH	Up thruster 2.
T9	4 Amp Rated Bilge Pump 3785 LPH	Down thruster 1.
T10	4 Amp Rated Bilge Pump 3785 LPH	Down thruster 2.

Co-pilot's part of the final control box.

Expense sheet

Last spring, before committing to this project, we drew up a rough budget of $1,500 to build an ROV for the MATE competition. Our plan, which we executed, was to stay within this budget and divide these expenses between the team members' four families.

Our fundraising strategy was to build a track record this year, using relatively cheap materials and systems. We now have a good reputation, a web site, a technical report and success at the regional competition when we seek outside funds. We feel well positioned to expand our fundraising efforts next year to fund a higher budget ROV for the 2008 MATE competition.

We sought and received some donations this year, both through discounted pricing and outright donations. Pool use was our single largest and most vital donation.

We rounded the numbers on our expense sheet to the nearest dollar amount.

	Description	**Expense**	**Donation**
Frame	Fiberglass frame material (6 meters)	$ 55	
	Nuts, bolts and cable ties	$ 30	
Buoyancy	Boat bumpers (2)	$ 26	
	Foam pipe insulation (4 meters)	$ 9	
	Fishing weights	$ 10	
Sensors	Waterproof color bullet camera	$ 280	$ 280
	Mirror	$ 6	
	eDimensional 3-d viewing system	$ 10	$ 50
	Monitor		Loan
Propulsion	Mayfair bilge pump cartridges (10)	$ 210	
	Thruster & prop mounting hardware	$ 15	
	Propellers (10)	$ 25	
	Aluminum square stock	$ 20	
Payload tools	PVC pipe	$ 10	
	Velcro	$ 9	
	Alligator clip (1)	$ 2	
	Plumbing grabber (1)	$ 6	
	Elfa drawer	$ 12	
Hydraulics	Syringes (3)	$ 6	
	Tubing (66 meters)	$ 20	
Control box	Rifle case	$ 30	
	Plexiglass	$	Found
Tether	Split loom (22 meters)	$ 18	
	Double-sided Velcro	$ 30	
Electronics	Ammeter	$	$ 58
	Switches (11)	$ 40	
	High power resistors (6)	$ 25	
	Bus bars	$ 30	
	Crimp-on connectors	$ 20	
	Fuses and fuse holders	$ 20	
	Speaker wire (214 meters)	$ 140	
	Hookup wire	$ 6	
	Heat shrink tubing	$ 10	
Props	PVC pipe	$ 15	
	Hardware	$ 10	
	Oil drain pans (2)	$ 12	
	Concrete	$ 20	
Misc.	Adhesives	$ 35	
	ROV cart		Found
	Casters		Loan
	Pool time		In-kind
Contributions	Individual contributors		$ 100
	Family contributions ($308/family)		$ 1,232
	Total direct cash contributions		**$ 1,332**
	Total expenses	**$ 1,332**	

The Fluke, loaned to us by Deborah Crowell, was a vital troubleshooting and testing tool.

Packed up and waiting for a cab to take us to another Saturday night testing session.

Asa and Proto in the water at Stuyvesant High School Pool.

Troubleshooting

Throughout the process of designing our ROV, we have been forced to troubleshoot many times. One example of this is the process we went through to attach our propellers to our thrusters. As mentioned previously, during this process we had to re-evaluate our design many times when it did not work. Also, as described above, our struggle with waterproofing our board cameras and video cables provided many frustrating but rich opportunities for troubleshooting.

We have insured that there will be many ways for us to troubleshoot any problems that might occur during the competition. First, we devised our control box to have a transparent control panel that is easily accessible. Our ammeter allows us to monitor our amp draw. Our kill switch functions as a troubleshooting device in addition to being a safety device as it lights up when it is stopping current flow. This feature enables it to serve as a built-in circuit tester.

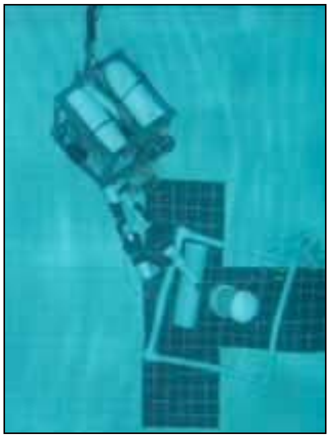
Our most important troubleshooting strategy is prevention. We devised a systems check protocol to make sure that all of our systems are ready before we put our vehicle in the water. We also travel with a full complement of tools, replacement parts, and supplies whenever we operate our machine.

Team challenges

Technical challenges have been numerous from blown fuses to camera failures, but they pale compared to the fact that, as a homeschool group, we had other issues. Examples include finding a place to build our ROV and a pool that would allow us time to test it. Ultimately, these places were at the opposite ends of Manhattan. Much of the work took place at one of the member's homes – a NYC apartment. Team members did research on their own and came together to work on Mondays. Despite busy schedules with academic work, sports, Scouts, youth groups, theater work, music lessons and performances, the team dedicated their Saturday nights to testing the ROV. This was one of the few pool times we could get.

Transporting the vehicle, along with mission props, tools and spare parts made portability a critical design necessity. We received many odd looks when traveling with the ROV on the subway to the boat pond in Central Park or to pools. For us, this was an opportunity to discuss our work.

Cole attaches the acoustic sensor.



Mission accomplished!

Some of our catalogs.

We performed "marine archeology" at the Central Park Boat Pond.

Pool time was very limited, not even once a week, and at locations that were not convenient. This limited access forced us to become more efficient and to make plans for each pool session. When props fell off and cameras failed, precious working time for the week was sacrificed. However, while a lot of work took place, we did find time to enjoy ourselves and bond as a team.

Another team challenge shared by all members was developing reasonable phone skills. Since we are not working in a school or other existing club, we started from scratch, which meant we had to procure all types of materials, tools and supplies. We gained skills in speaking to vendors on the phone and communicating our needs.

Our ROV – "ROV ADD" – is named in honor of one of our big challenges. We were highly effective at getting things accomplished while working in pairs. When all of us were trying to work together, however, we had a lot of difficulty staying focused and accomplishing anything. ROV ADD reflects our effort to overcome our collective attention deficit. ☺

Skills gained

We gained myriad skills designing and building our first ROV for the MATE competition. Examples range from learning basic electronics to coping gracefully when things like cameras and propeller mounting systems do not work. One of the biggest skills that our team gained was how to procure different supplies that we needed in the building of our ROV. One of the lessons we had to learn in the quest to gain this skill was how to find various products we needed to use. As we worked on attempting to find all the materials and parts that we needed, we developed finesse in searching the web, catalogs and other people's stores of knowledge. We learned how to use search engines, such as Google, effectively and discovered new search engines, such as GlobalSpec. We also learned the advantages of printed catalogs. Additionally, we developed phone skills that we use when talking to people in various industries and picking their brains about what would work for us. We also learned how to ask companies for sponsorship as a method of fundraising. We did this by writing sponsorship request letters, and ended up having our ammeter donated as a result of our efforts in this arena.

If we couldn't find what we wanted, or if we found what we wanted, but it was too expensive for us, or we found what we wanted, but lacked the time to order it, we learned

Raph and Joshua conduct research to determine how to fabricate our high power resistors.

Whatever improvements we make, we plan to continue having fun. This sign in our workshop serves as a warning.

The “doughnut” was our first attempt at making a variable buoyancy system, which we hope to improve and include in next year’s ROV.

that we could fabricate what we needed ourselves. This taught us how to work with our hands and refined our skills. It also taught us how to adapt. For instance, as mentioned in the propulsion section, we could not find the proper connectors for our propellers, so we built them ourselves. When they did not work, we adapted to the situation and created new ones. The same thing happened with our potentiometers, as described in the control system section. When they melted and we could not find proper replacements, we built our own.

Future improvements

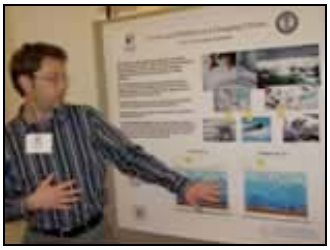
Our future improvements will focus on learning to master more complex technologies in the creation of next year’s ROV. One such example is making the pilot’s controls smaller by using more complex electronics systems. We also would like to make them more user-friendly by replacing the On-Off-On switches with joysticks. Fantasies in this realm involve working with Nintendo to adapt one of their game controllers, possibly the Wii, for ROV control.

Additionally, we would like to continue our efforts to develop a variable buoyancy system. We attempted to create one this year, but it became too complicated and time consuming, so we chose to postpone development and use a simpler adjustable buoyancy system. This allowed us to focus on the more necessary parts of the ROV. Next year, however, we hope to purchase an air compressor, a vital piece of equipment we lacked, and use it to power a variable buoyancy system. We believe this will improve our mission performance as we will be able to have more control over our buoyancy.

Another goal is to develop the skills to seal our own motors, allowing us to pair the motor of our choice with the most efficient propeller and freeing us from the limitations of the current bilge pump canisters we are using. This would permit greater thrust on our ROV while still staying well within MATE’s power constraints.

In addition, we eventually want to be able to use more advanced robotic arms. Instead of using the simple hydraulic arms we used this year, we would like to use jointed arms.

We want to explore new ways to raise funds to pay for these technologies as well. For example, many people in our homeschooling community have become interested in building their own ROVs after learning about our project. We are considering teaching a class in ROV building to provide matching funds for other fundraising efforts.



Dr. Andy Juhl, Associate Research Scientist at Columbia University's Lamont Doherty Earth Observatory, presents his work on Arctic sea ice at Polar Weekend, March 10 and 11, at the American Museum of Natural History. This event, attended by some of our team members, included lectures, films, hands-on activities, posters, presentations and performances in honor of the opening of International Polar Year.

New York City International Polar Weekend, American Museum of Natural History http://www.amnh.org/programs/specials/polar/ Internet.

Below is a link to Dr. Juhl's work: http://www.ldeo.columbia.edu/~andyjuh; Internet.

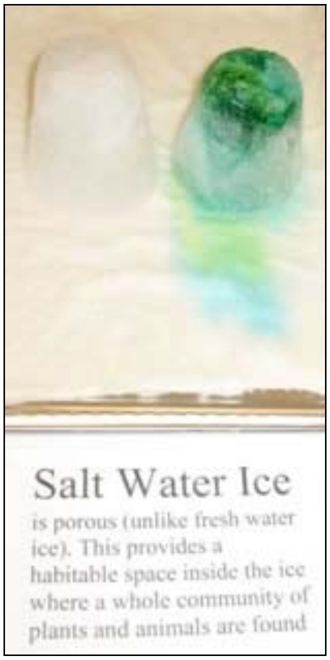
Sea ice and the Inuit

The American Museum of Natural History celebrated International Polar Year on the weekend of March 10 and 11, by sponsoring a polar weekend. Some of our team members attended and learned many things about polar history, exploration, technology and environmental issues. We were especially drawn to a presentation on polar ice by Dr. Andy Juhl, Associate Research Scientist at Columbia University's Lamont Doherty Earth Institute. We were attracted to his exhibit because he discussed sampling plankton under polar ice, just as we are modeling in mission #2. Even more interesting to us was discovering how significant polar ice is to the food chains and the human cultures that are sustained by them.

Sea ice is different from normal ice, though it often looks the same. As seas freeze, some of the salt is rejected, increasing the salinity of the sea water, but some of it remains. The remaining salt breaks up the structure of the ice crystals, causing tiny spaces to form. In these spaces small living creatures thrive. Phytoplankton is held near the sun's light, providing food for herbivores that, in turn, provide food for carnivores. Animals too large to fit within the ice pores live under the ice, feeding on the ice-dwelling life. Dr. Juhl explained that this ice-dwelling food chain increases productivity by extending the growing season, doubling its length over arctic waters without sea ice.

The reduced salt content of sea ice also is significant for productivity. When part of it melts, a band of less saline, less dense, water forms. This layer, which can extend for many kilometers from the edge of the ice, holds nutrients and organisms at the surface of the water, keeping them accessible to light and to each other, allowing great biological productivity. Dr. Juhl stated that this vastly increases the area in which primary productivity (photosynthesis) can take place and favors a pelagic (surface-dwelling) food chain with animals such as fish, seals and the polar bears that prey on them. Seals and polar bears use the ice as a substrate for rest, breeding and hunting purposes. Without the presence of polar ice, neither nutrients nor phytoplankton are held at the surface. Overall productivity decreases greatly and the food chain is altered to favor benthic (bottom-dwelling) creatures over pelagic ones, because surface nutrients fall to the bottom.

Polar ice currently is melting more rapidly than it can be replaced. Many climatologists at the Polar Weekend stated that, present trends projected, there will be no sea ice



Dr. Juhl prepared this demonstration to show how salt water ice and freshwater ice differ. When food coloring is dropped on a freshwater ice cube, on the left, the coloring runs off and is not absorbed into the ice at all. When the same colors are dropped on the porous salt water ice, on the right, the colors are readily absorbed deep into the ice cube.

This exhibit, also prepared by Dr. Juhl, demonstrates how the less dense melted water from the red ice cubes, representing sea ice, creates a layer on top of the blue water, representing sea water. This tangibly shows how phytoplankton and nutrients are held in this less dense layer near the surface of the water.

ice in the summer, in the Arctic, by the middle of this century. This reduction of sea ice will alter the food chain as described above. The Inuit cultures of the Arctic have adapted to their harsh environment by basing their livelihood and culture on the fish, seals, walrus and polar bears that share their home. What does a culture do if their food sources and cultural symbols are threatened with significantly reduced numbers? In this case, the Inuit are organizing themselves into groups like the Inuit Circumpolar Conference to face ecological challenges that disproportionately affect Arctic populations. They are working to help others understand the rich significance of polar ice that provides the food they eat as well as the fish caught in the Arctic and consumed elsewhere. They are trying to help others understand, as we learned, that Arctic life and culture, both human and nonhuman, is based on the rich biological productivity of sea ice. Scientists are studying the life that dwells within and in close proximity to sea ice to help understand what changes in sea ice mean for the cultures that depend on it.

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Reflections

The most important accomplishment for our team has been a permanent shift in the way we think about design, engineering and ourselves.

First, we learned that designs don't just come out of thin air, ready to be installed on our ROV. They may begin with a creative leap but they are implemented through the humble process of researching, trying different materials, working with our hands and lots of testing and creative problem solving. An important part of our team's story is that we didn't start out knowing much about ROV design or electronics. However, we just started simple and added and adjusted as needed. Almost none of our current systems were planned from the beginning to be the way they were finalized. While it is important to think ahead, trying to attain perfection on the first try is not a good way to do anything.

The way we think about engineering has been changed by the ROV competition as well. We now look at objects in our environment from the perspective of how they could be used to improve our vehicle. This type of thinking led us to many creative components for our ROV. More importantly, however, this thought process has led us to wonder about how other objects around us were designed and engineered. This active inquiry has expanded our understanding of the way things work. Our experience has given us a window into the thought, care, manual work and engineering that goes into the creation of anything well-made.

This experience has changed our thinking about ourselves. An example of this is when one of our team members had to register with GlobalSpec, an engineering search engine. He had to fill out a questionnaire that asked for his occupation. There were many choices, the most obvious being 'engineering student'. Instead, he clicked 'engineer' to define himself, something that he would not have done before he became involved in this project. Through our preparation for the MATE competition we have graduated from simply following plans to creatively designing and engineering our own vehicle. And we have gained the confidence to present our knowledge, not only for the competition, but in community settings as well. Our team name, NYCBEES (New York City Builders of Elegant and Efficient Submersibles), reflects this new professional attitude.