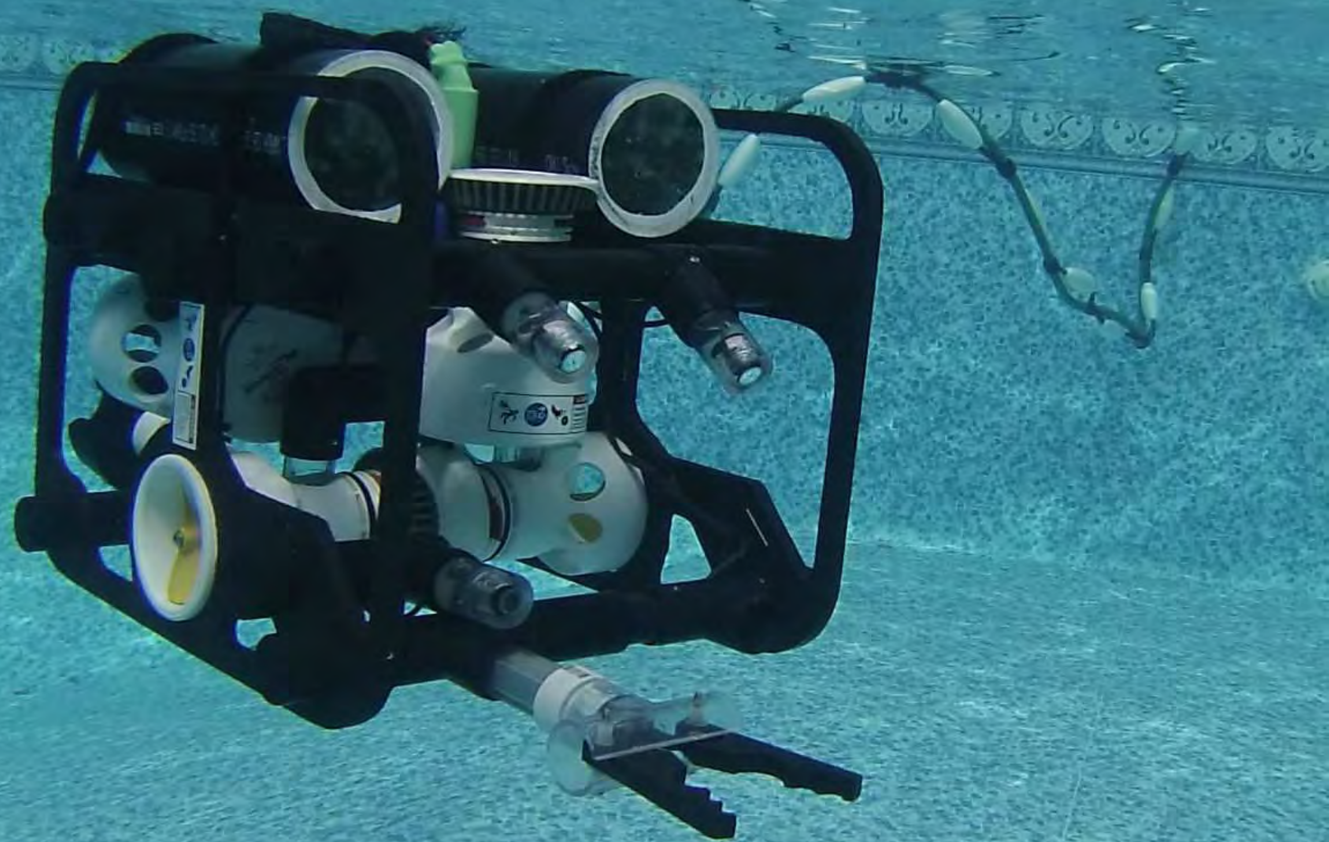
Technical
Documentation
NexGen 2017

First Flight ROV - NexGen

First Flight Middle School
Kill Devil Hills, NC



<u>Team NexGen</u>

Jacob Thomas	**CEO, Design and Manufacturing, Navigator**
Elliott Piland	**Payload Tool Specialist, Manufacturing, Pool-side Technician**
Travis Lawrence	**Marketing, Design and Manufacturing, Pool-side Technician**
Drew Whitehead	**Structural Engineer, Design and Manufacturing, Pilot**
Will Roepcke	**Electrical Engineer, Design and Manufacturing, Data Analyst**
Jack Voight	**CFO, Design and Manufacturing, Pool-side Technician**

<u>Mentor</u>
Andrew Thomas

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Abstract

First Flight ROV - Team NexGen is a group of eighth graders from First Flight Middle School. This is the second year that the company has competed in the MATE ROV Competition, but the first in the Ranger Class after winning the Mid-Atlantic Regional 2016 Scout class. The latest prototype, *NexGen 2017,* is a representation of the company's commitment to their goal of continually innovating new designs and technology as we advance our award winning ROVs. *NexGen 2017* underwent months of planning, designing, building, and testing all under strict safety protocols. While each member of the company has specialized skills and jobs, NexGen employees are required to be proficient in all areas of the ROV design, budgeting and construction.

NexGen has been asked to design a multipurpose Remotely Operated Vehicle (ROV) that can be easily deployed in and around the Port of Long Beach. The company has reviewed the Request for Proposal (RFP) and designed an ROV to suit the specific needs of the Port of Long Beach: design and construct the most efficient and effective machine to operate in multiple environments. The focus during design was size and portability, ease of use and maintenance, and safety. The current design will accept expansions and upgrades as the need arises to sustain the commerce of the port, preserve the cleanliness of the surrounding waters, maintain the entertainment systems, and keep the port as safe as possible for people and the environment.

Corporate Profile

First Flight ROV - NexGen has succeeded on the merits of a flexible corporate structure and job differentiation. NexGen is a spin-off of the parent corporation FFROV that saw great success by producing and marketing the top Ranger class ROV at the 2010 MATE International Competition. NexGen has upended the domination of First Descent Solutions (FDS) that has seen great success over the last 10 years in the ROV industry. By incorporating some of the corporate structure inherent to FDS and their award winning designs, NexGen has been able to rise to the top of the Mid-Atlantic ROV industry. NexGen is divided into different departments that collaborate on every aspect of the design, engineering, construction, and testing phases.

For example, each department was tasked with reviewing the RFP and mission documents, and collaborating on a design that fit the criteria. The CAD and modeling personnel then took the design ideas and created working models and 3D mock-ups of *NexGen 2017*. The engineering department was then able to start creating electronics packages for controls, wiring schematics, and tool options for completing tasks. After designs were finalized and engineering confirmed the specifications, the construction department was able to begin building the frame, thrusters, cameras, and tools.

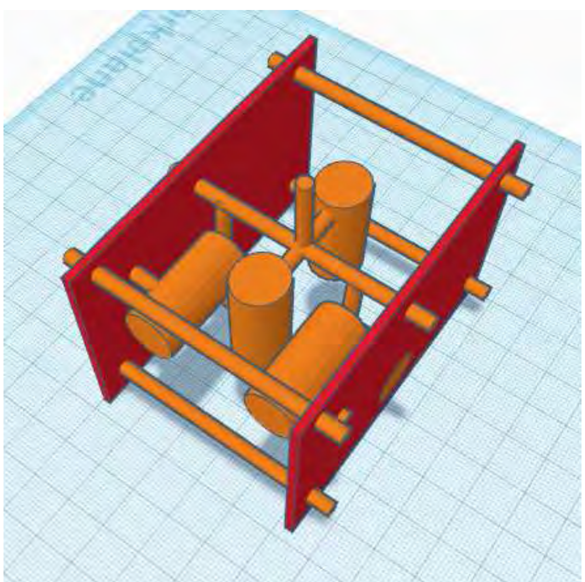
One unique aspect of NexGen’s task assignment is that each member of the team has been assigned to more than one department so that there is overlap and continuity throughout the company. This allows for more collaboration and idea generation at each critical step of the ROV design up to testing a finished product.

Design Rationale

Frame

For the 2017 NexGen ROV, the company looked for inspiration from the 2010 First Flight ROV team that won the international competition in Hawai'i. The team mascot from 2010, Jacob Thomas, is the current CEO of First Flight ROV-NexGen and was insistent on the use of technology and design that had been successful in the past. NexGen was committed to building an ROV that had all of the thrusters safely tucked inside a frame structure and propellers that were shrouded inside of Kort nozzles that enhance efficiency and provide another layer of safety. To comply with the Port of Long Beach's Request For Proposal (RFP), NexGen set out to contain the ROV design within the 48 cm circumference.

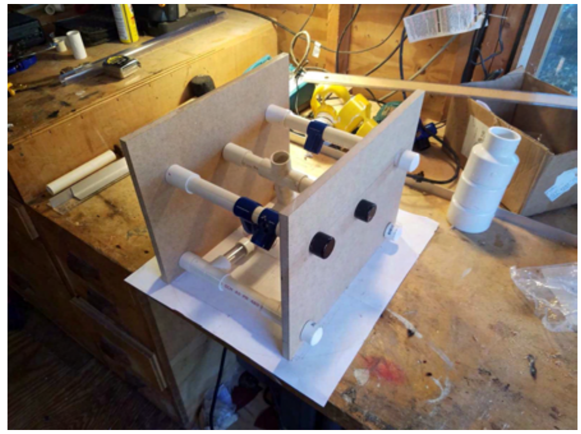
To design a machine within 48 cm, NexGen began with a paper layout that had a 48 cm circle drawn out. This allowed our designers to set out the minimum spacing required for six thrusters, tools, cameras, and the ROV frame visually. After drawing in the thrusters on the blueprint, the designers were able to calculate the spacing of the thrusters and locations within the frame. While drawing out the spacing the designers gave themselves extra "wiggle room" in their measurements to ensure that the finished ROV would satisfy the requirements for the smallest design in the RFP. After the paper layout was completed, the engineers designed a 3D model in TinkerCad as depicted below.



Left: TinkerCad layout of *NexGen 2017* with thrusters, frame structure and PVC connectors. (J. Thomas)

With the 3D model of *NexGen 2017* on hand, the design was then sent to the engineering department to create a mock-up of the machine. The frame was cut from medium density fiberboard (MDF) and the sides were connected with ¾" PVC fittings and pipe. Tool, camera and thruster mounts were also included in the mock-up so that their dimensions could be included in the final 48 cm diameter ROV. The frame walls were initially set at 28 cm apart and the walls measured 38 cm × 38 cm. This represented the maximum frame size that would fit inside the 48 cm diameter.

Right: Frame mock-up of *NexGen 2017*. Mock-up sits on the paper layout to ensure it fits within the 48 cm circle. (Photo: NexGen)



After spacing the thrusters and laying out the basic design of the ROV was finished, the company was then faced with the task of lightening the ROV. Our engineers began the process of deciding where to cut material away and how much. The first idea was an abstract shape designed using French curves. The end product resembled a butterfly. See below.

Left: The “butterfly” design beside the more symmetrical second design. At NexGen innovation is a cornerstone of our company. (Photo: Thomas)

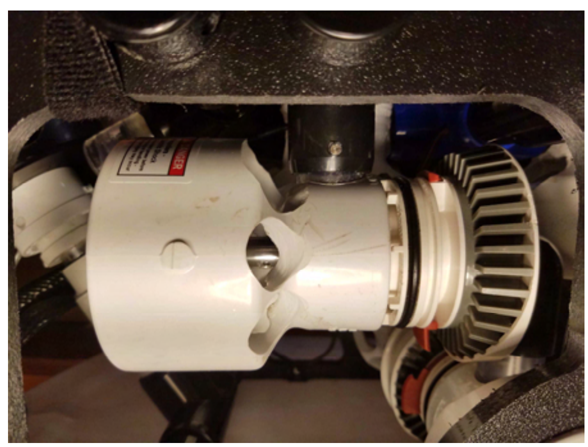
When the ‘butterfly’ frame was surveyed by the company, it was rejected in favor of the more symmetrical design. One reason was that the company wanted the finished ROV to resemble the machines built in years past by First Descent Solutions (FDS). Our sister company, FDS, always built ROVs with straight edges and symmetry that were more aesthetically pleasing. NexGen wanted to continue the success of previous years, and that included using more time tested frame ideas. The engineers drew out a new frame on MDF that was more symmetrical, and consequently, weighed less. The MDF was cut out using a drill press and router. Because the router is a dangerous tool, team mentor, Andrew Thomas, helped to cut out the frame template. Once the template had been shaped and sanded, the template was copied onto polyethylene Seaboard. The seaboard sheets were carefully cut out using the same methods used on the MDF with the router. The two seaboard sheets were then sanded to make holes smooth, and no jagged edges were left over from the router. The finished products were then connected together by 25.4 cm PVC pipe sections and PVC fittings. See below.

Left: Jacob Thomas with finished frame walls. (Photo: Thomas)

Thrusters

On *NexGen 2017* there are a total of six thrusters in the center of the ROV frame. They consist of two vertical drive motors, two horizontal, and two strafe motors. All sit inside the frame as to keep the ROV compact and thrusters tucked away from fingers and loose bits of clothing. The thrusters are powered by Tsunami 1200-gph bilge pump motors. The Kort nozzles are constructed from 1-1/2” to 2-1/2” PVC reducer couplings. To allow water to freely flow through the Kort nozzle, 2.54-cm holes are drilled around the circumference of the reducer coupling. In order to attach the Kort nozzle and thruster to the frame we inserted and epoxied 3/4” PVC pipe into the 1-1/2” end of the coupling. Octura 1470 propellers are fitted with Master Airscrew prop adapters and drive dogs to attach them to the bilge pump motors. The inside diameter of the Kort Nozzles measure 73-mm which allows the propellers to rotate without hitting the sides. The propellers are 70-mm across which leaves 3 mm of space between the wall of the Kort nozzle and propeller tip. Kort nozzles are a form of ducted propeller. Ducted propellers are used to improve the efficiency of propellers with a limited diameter and improve safety. See below.

Right: Tsunami bilge pump cartridge fitted with NexGen designed Kort nozzle and PVC mount. Propellers are shrouded and not exposed. (Photo: Thomas)



Left: Strafe Thruster. Ducted propeller with tight fit inside Kort nozzle. Warning label in place to alert user of danger. Safety Labels are NexGen designed and custom printed. All thrusters contained inside frame and shrouded for safety. (Photo: Thomas)

Payload Tools

The Multi-Functional Rotator

The multi-functional rotator is a direct current (DC) motor housed inside ¾" thin wall PVC and PVC fittings. The multi-tool was designed to tackle two of the tasks; rotating the valve that controls water flow to the fountain in Task 2, and the collection of the sediment sample (agar) in Task 3. A hub attached to the end of the DC motor shaft acts as a connection point for a mounted 1" PVC bushing. The tool is mounted to the back of the ROV and has a dedicated camera view. Two tools are designed to fit over the bushing and can be quickly exchanged by pulling a ball-bearing clevis pin that slides in and out for quick and easy use. See below.

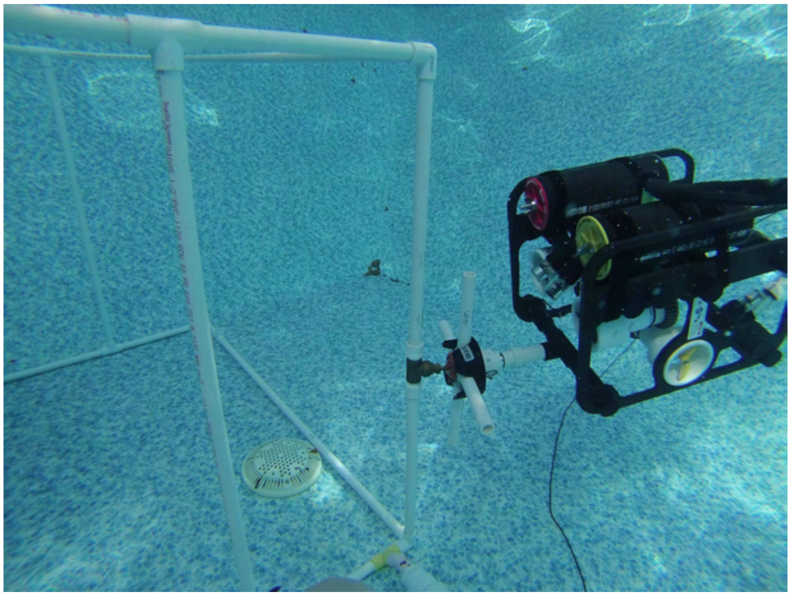
Left: DC motor housed in the PVC. Grommets, marine grease, and epoxy seal out water. The PVC bushing on the end accepts the valve tool and agar drill. Other tools can be designed and fitted to work along with the multi-tool upon request. (Photo: Thomas)

For Task 2, turning the fountain water supply on and off, NexGen designed the tool below for the Mid-Atlantic regional demonstration. The company discovered that the tool was inconsistent in practice and at the regional demonstration.

Left: 1st tool designed to rotate the fountain valve in Task 2. (Photo: Thomas)

Right: redesigned valve tool. The new tool is shaped to the exact dimensions of the shut-off valve for the fountain. (Photo: Thomas)

A new tool has since been designed and prototyped with much better results. See above. The new tool has been tested and performed up to NexGen Standards. See below.



Left: Multi-tool w/ valve attachment hooked up and turning the fountain valve. (Photo: Piland)

For Task 3, Health and Environmental Cleanup, the contaminated sediment sample, simulated by agar, will be collected with the Agar Drill**.** The Agar Drill is constructed from a 200 milliliter section of graduated cylinder with sharpened teeth so that it drills into the agar when spun by the multi-tool. NexGen added a lip to keep the agar in with friction to fight the force of gravity. This process has worked very well for the company, and the only limitation now is how fast the agar can be drilled. The Agar Drill attaches to the bushing on the multi-tool in the same way as the valve tool, ball bearing clevis pin. See below.

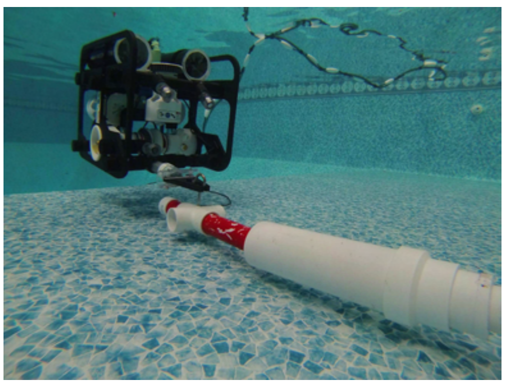
Right: Agar Drill. Attaches to the rotating multi-tool with a clevis pin. Custom tools can be attached to the multi-tool to allow consumers flexibility and expansion. (Photo: Thomas)

The Manipulator

The Manipulator is made from polyethylene Seaboard, PVC fittings and a linear actuator that was sealed with machine lubricant and encased in silicone and potting compound. This combination of sealants makes the casing watertight to guard against unwanted leaks. This tool was modeled and refined after proven years of use from NexGen's parent company FFROV-FDS. This is by far the most versatile tool on the machine and indispensible when designing work class ROVs. Two cameras are specifically placed to give the pilot multiple views of the manipulator.

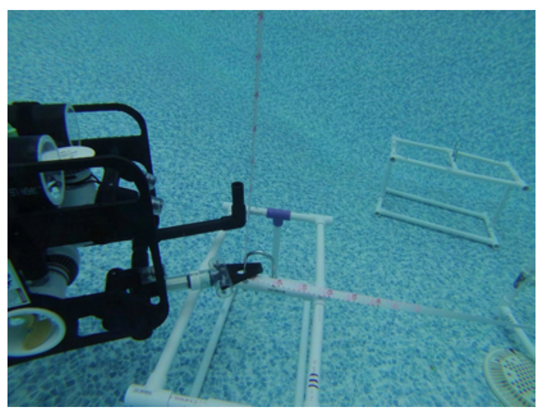
Left: Manipulator. Fingers are driven by an Actuonix DC Linear Actuator. (Photo: Piland)

The manipulator is used in every task in one fashion or another. Examples of its versatility can be seen below.



Left: The manipulator grabs and stabilizes the fountain power plug to be unplugged and plugged back in for Task 2. (Photo: Piland)

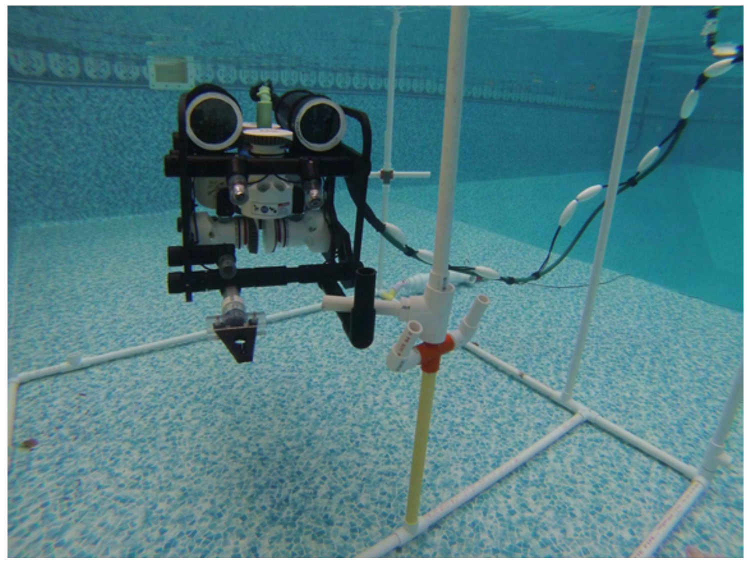
Right: The manipulator and cameras are used to stretch the tape measure between containers to create the map in Task 4. (Photo: Thomas)



Additionally, the manipulator can be used to effectively complete Task 1, hyperloop construction. This includes inserting two rebar reinforcement rods into position in the steel baseplate, installing the frame onto the baseplate, removing a pin to release the chains holding the frame, transporting and positioning the hose for pouring concrete into the frame, and retrieving the three positioning beacons and returning them to the surface.

“L” Tool

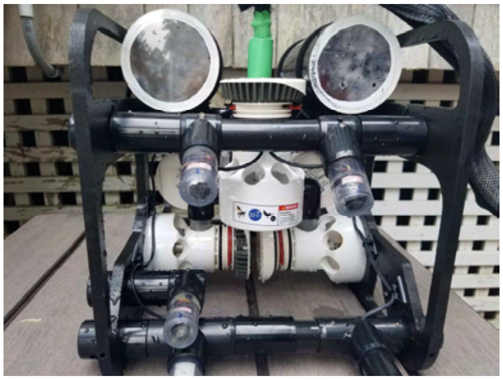
The L tool is designed to disengage the locking mechanism on the fountain in Task 2. This works by the ROV maneuvering under the fountain platform, for which the ROV is specifically designed to fit in the smallest opening. After positioning the ROV the “L” Tool can catch the locking mechanism and disengage the broken fountain. The design is innovated so that the ROV can get out quickly in order to complete as many of the missions as possible. The tool is one of many interchangeable parts. By extending the reach it makes using the tool easier for the pilot. It is created using one PVC elbow and two varying lengths of pipe.



Above Left: “L” Tool attached to the ROV utilizing the expansion port. Other tools can be designed to meet the needs of individual consumers and be attached to the ROV with the expansion port. Above Right: *ROV NexGen 2017* using the “L” Tool to disengage the locking mechanism on the fountain. (Photo: Thomas/Piland)

Cameras

The cameras on *NexGen 2017* are constructed on sight using car/truck back-up cameras. By further refining cameras used by our parent company and predecessor, NexGen waterproofed the reverse cameras using clear PVC pipe, acrylic, and potting compound. 18-m cameras were spliced into the camera lines to extend the wires to the surface. The soldered connections were made close enough to the camera so that they could be submerged in the potting compound. Last year, FDS had issues with the silicone, heat-shrinked connections pulling apart and allowing water to penetrate the wires. NexGen is very confident in the 2017 cameras; after hours of testing and demonstrating, the cameras are still fully functional. Four cameras were built for the machine and incorporated in the design process. NexGen keeps parts on hand to deliver more at a moments notice in case of failure. However, for less than $50/camera, it is difficult to find a better value. See below.



Left: 3 of 4 on-board cameras focused on the manipulator and tool expansion slot. (Photo: Thomas)

Tether

The tether is a vital part of any ROV system, as it is the sole connection from the control box to the ROV. If something is not properly connected inside of the tether, then *NexGen 2017* will not run properly. NexGen's main tether is an 18/18 AWG continuous flex cable that has been recycled from the 2010 ROV. With control systems and motor controllers on the surface, the tether supplies power to each motor. There are 8 DC motors (6 thrusters, 2 tools) on the ROV which require two conductors each to operate. The LED-RAMAN Laser also requires 2 conductors for a combined total of 18 conductors.

However, there is tradeoff in using this tether. The 18 AWG wires do limit the voltage supplied to the DC motors over the 15-m tether; 13.6 V leaving the power supply and 11 V reaching the thrusters and tool motors. Additionally, the cable is heavier than individual conductors because the conductors are paired and insulated inside the cable. The trade-off comes with enhanced safety and convenience. NexGen used individual speaker wires for each thruster in 2016, but the loose wires created tripping and tangling hazards and an increased risk of wire connections becoming frayed or loosened. Team NexGen is very confident in the tether and its durability. All connections to the machine are made using waterproof butt connectors and then sealed with silicone inside heavy duty heat shrink. The tether exit point from the ROV has also been fitted with a NexGen strain relief utilizing PVC and heat shrink.

Left: Tether for *NexGen 2017* which provides power and control to the ROV. Tether consists of 18/18 AWG conductors inside a single cable and 4 video cables returning signal to the surface. Gill net buoys are placed approximately every 30-40 cm for neutral buoyancy. (Photo: Thomas)

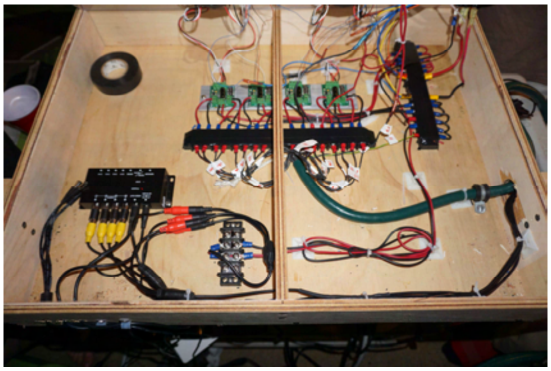
Ballast

In addition to the tether needing to be ballasted so that it is neutrally buoyant, the ROV is also ballasted, except it is slightly positively buoyant. Since there is not an electronics canister on the machine, all ballast must be added. The ROV frame was designed so that 3” ABS PVC canisters could be added. One end of the ballast canisters are permanently sealed with acrylic adhered to the PVC using 5200 Marine Adhesive/Sealant. Through a series of trial and error experiments, the correct length of PVC is determined and the second end is sealed using Cherne Test Plugs. The test plugs are fitted with a compression fitting that seals the inside of the PVC making it water tight. The tubes are mounted to the ROV using Velcro straps so they can be easily removed for maintenance and packaging.

Left: Ballast tubes on *NexGen2017*. The ballast tubes are sized to make the ROV positively buoyant and lead weights are added to the lower frame to fine tune ballast. (Photo: Thomas)

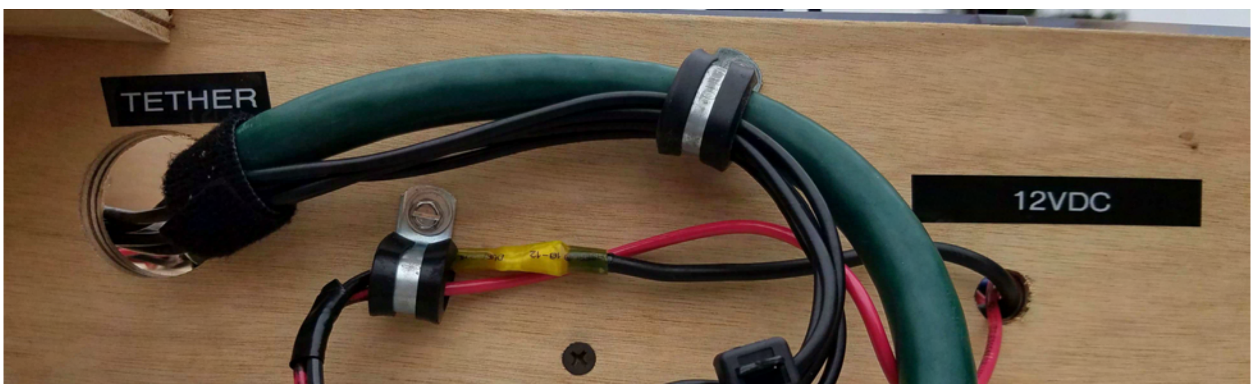
Control Station

The control station can be divided into three parts; control box, video compiler/quad splitter, and ROV control system. The video compiler and control system are housed in a new control box that is oversized to allow adequate space to neatly and safely lay out the wiring and systems.



Left: Control box neatly organized utilizing adhesive pads and strain relief. (Photo: Roepcke)

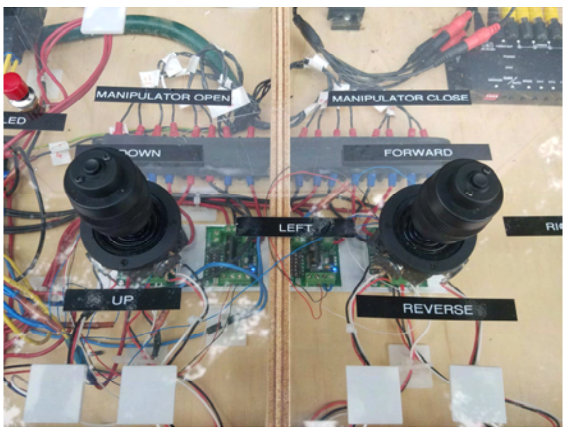
The 12 V DC power cables, 120 V AC power for the video display and compiler, and tether are separated and labeled at individual entrance points into the box. See below.



Above and Left: Entrance points for the tether and power. Strain relieved and labeled for safety. (Photo: Roepcke)

Control System

ROV NexGen 2017 is controlled using two 3-axis + button joysticks and four 12V5A Sabertooth Dual Motor Controllers. The potentiometers in the joysticks are wired to the inputs on the motor controllers, and the buttons on the joysticks are wired to activate DPDT relays. The DPDT relays control the opening and closing of the hand, and the motor controllers are directed to the thrusters and multi-tool. After using only relays last year, NexGen realized that speed control was the largest limiting factor from 2016. For *NexGen 2017,* the designers, pilot, and engineers committed to using the Sabertooth motor controllers and joysticks. The analog inputs from the joysticks paired with the motor controllers offer the perfect balance of simplicity, consistency and durability for a reliable ROV design. As NexGen worked through the mission and RFP, the company realized that a software driven/controlled ROV was not necessary. This simplified design and increased reliability.



Left: Analog 3-axis joysticks wired to the Sabertooths. (Photo: Roepcke)

Video Compiler

Video signals from the ROV are sent back to the control station via four individual cables. The signals are processed in a Toughsty Quad Splitter that compiles the feed into one split screen. This perspective gives the pilot and navigator full views of the ROV's orientation and progress underwater. NexGen opted to use a quad splitter on the surface for video control because it offers the simplicity and reliability that is a trademark of the company's ROVs. The Toughsty is packaged with a remote that is mounted to the top of the control box acrylic. This allows the user to select from multiple combinations of multi-camera or single camera views.

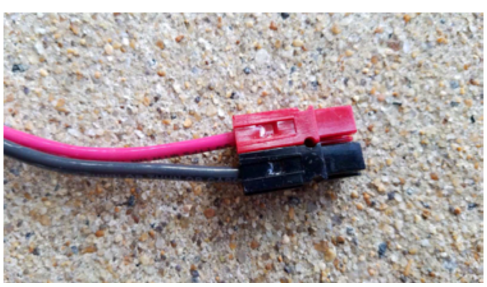
Left: Toughsty Mini Quad Splitter. (Photo: Thomas)

Safety

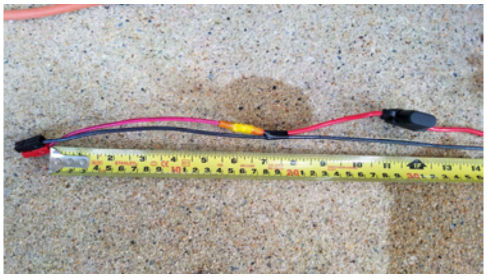
NexGen's number one concern is for the safety of its employees, end users and the general public. NexGen ROV firmly believes that design can enhance both performance and safety. This goes beyond the safe operation of the ROV and the environment where the ROV is operating. Workshop safety is essential during the manufacturing and testing phases of development. Strict safety protocols are adhered to in and around the shop as well as the test tank. In addition to closed-toe shoes and safety glasses, all employees are required to operate machinery with a spotter and firmly clamp all parts before drilling or cutting.

Safety protocol has been established during testing and demonstrations of the ROV. A safety checklist has been in use since the early formation of FFROV and continues on today in NexGen. A sample of the pre-demonstration and testing safety protocol can be found in the Appendix.

NexGen 2017 is loaded with safety features. In addition to the safety features included in the design rationale of the technical documentation, there are several more safety features included on *NexGen 2017*. See below for a couple more examples.



Left: Anderson Powerpole connectors for 30A current. (Photo: Thomas)



Left: 25A fuse located on the positive pole of the power source within 30 cm of Anderson Powerpole Connectors. (Photo: Thomas)

Cost Projection

NexGen established a budget after discussing options and proposed designs of $1000 in new investment. Since the company had resources of spare parts and materials left over from the parent corporation, NexGen felt the budget was very reasonable. Top priority for the build budget included new thrusters, joysticks, and Sabertooth motor controllers.

Projected costs for NexGen 2017 for Regional Competition

Frame	$40.00
Thrusters	$300.00
Joysticks	$80.00
Motor Controllers	$235.00
Tether	Reusing Old Tether
Control Box	$20.00
Tools (Linear Actuator/DC Motor)	$100.00
Shop Supplies	$100.00
Wire	$100.00
Total	**$975.00**

Budget

After purchasing parts, redesigning failed concepts, and purchasing replacements, NexGen exceeded the cash budget by $148.00. As the company begins to raise the necessary funds to travel to the international competition, NexGen needs to raise an additional $6000 to cover the costs. Donations received since April 24 have covered most of the cost for the airfare. Remaining funds will help cover accommodations, meals, and rental car fees. The following table records debits and credits for the company as of May 25, 2017.

Date	Debit	Donation	Description	Running Total
1/1/17	(Initial Loan to NexGen Based on Projected Cost)			$ 1,000.00
2/5/17 - 5/24/17	1148.09		ROV Parts (see appendix)	$ (148.09)
4/24/17		2500	Dare County Board of Education	$ 2,351.91
4/25/17		500	Nauticus	$ 2,851.91
5/16/17		1000	Midgett Insurance	$ 3,851.91
5/11/17		50	John J Burfete	$ 3,901.91
5/1/17		20	Liv Cook	$ 3,921.91
5/4/17		100	Thomas and Nancy Connell	$ 4,021.91
5/10/17		250	John Voight	$ 4,271.91
5/20/17		500	Austin and Gloria Lawrence	$ 4,771.91
5/17/17	5220		Airfare (9 Tickets)	$ (448.09)
Projected Costs				$ (448.09)
6/21/17-6/27/17	3600		Accommodations (Hotel Current)	$ (4,048.09)
6/21/17-6/27/18	1200		Rental Car x 2	$ (5,248.09)
6/21/17-6/27/19	720		Meals for the Team	$ (5,968.09)

Purchases

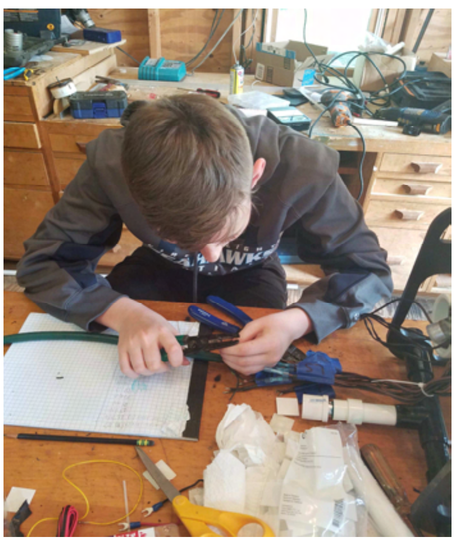
QTY	ROV Part	Part Description	Notes	New (N) Reused (R) *Leftover (L) Donated (D)	Value of Donated and Reused Parts	Cost to purchase new parts
1	Frame	Seaboard	Low Density Poly Sheet	N		$36.70
6	Thrusters	Tsunami 1200 GPH	Bilge Pump Cartridges	N		$174.00
6	Kort Nozzles	1-1/2" to 2-1/2" PVC Reducer Coupling		N		$25.20
6	Thrusters	Propellers	Octura 1470	R	$12.90	
6	Thrusters	Prop Adapter	Master AirScrew	R	$25.50	
1	Manipulator	Linear Actuator		N		$35.00
1	Multi-tool	DC Gear Motor	26 RPM Planetary Gear Motor	N		$27.99

1	Multi-tool	SS Coupler		N		$4.99
1	Multi-tool	Shaft SS		N		$0.69
1	Multi-tool	Aluminum Hub		N		$4.20
Box	Multi-tool/ manipulator	Grommets		N		$3.50
Box	Manipulator	Nylon Spacers		N		$2.00
Box	Multi-tool/ manipulator	SS Nuts/screws		N		$14.00
Box	Frame	SS Set Screws	Frame assembly	N		$12.00
2	Ballast Tubes	Pressure Plugs		N		$8.00
4	Cameras	Wide Angle Reverse Camera		N		$119.96
sheet	Cameras	3.175-mm Acrylic	Camera Housing	L	$4.00	
1	Cameras, Manipulator	Clear PVC 3/4"	Manipulator, Camera Housings	N		$4.30
4	Camera Cables	15-meter		N		$24.99
1	LED Light		RAMAN Laser	N		$4.00
1	Tether	18-8 AWG	Continuous Flex Cable	R	$120.00	
2	Frame PVC	Black Furniture Grade 3/4" pipe		N		$14.16
40	Frame and tools	Black Furniture Grade 3/4" Elbows, Tees, Cross, Couplers, End caps		N		$75.60
18	Electrical Systems	Butt Connectors	Heat Shrink, crimp and seal, waterproof	N		$5.40
40	Tether	Gill Net Buoys	Flotation	N		$32.00
1	Ballast Tubes	3" ABS Black Pipe		N		$14.50
	Frame and tools	PVC Fittings	Miscellaneous Sizes	N		$22.00
4	Control System	Motor Controllers	Sabertooth 12x5	N		$255.44
4	Electrical Systems	Busbars	8 contact	N		$28.00
1	Electrical Systems	momentary switch	Led Button	N		$3.00
1	Electrical Systems	30 A On/Off switch	Main Power Switch	N		$3.00
3	Electrical Systems	24 AWG wire	Hook-up wire	N		$30.00
100	Electrical Systems	Spade Connectors		N		$8.00
2	Control System	Joysticks	3-axis + Button	N		$79.98
1	Video	Quad Splitter	Toughsty	N		$49.49
	Frame	MDF	Model construction	L	$5.00	
	Control Box	Plywood		L	$6.00	

1	Control Box	46 cm x 61 cm Acrylic Sheet		N		$26.00
	Shop Supplies	Tape, Machine Grease, 5200, zip ties, epoxy, potting compound, adhesive pads, screws, labels, strain relief, wire organization, heat shrink, wire, etc	On-hand supplies	D	$125.00	
	Subtotal				**$298.40**	**$1,148.09**
*Leftover = scraps or cutoffs from materials on hand						
					Total ROV Parts Value	$1,446.49

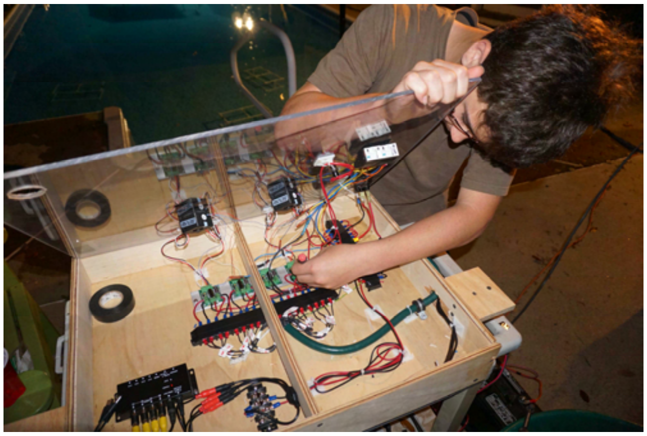
Team NexGen

NexGen is a group of aspiring, young designers, engineers, and writers. NexGen believes this staff has the perfect mix of personnel to meet the demands and expectations of the ROV industry.



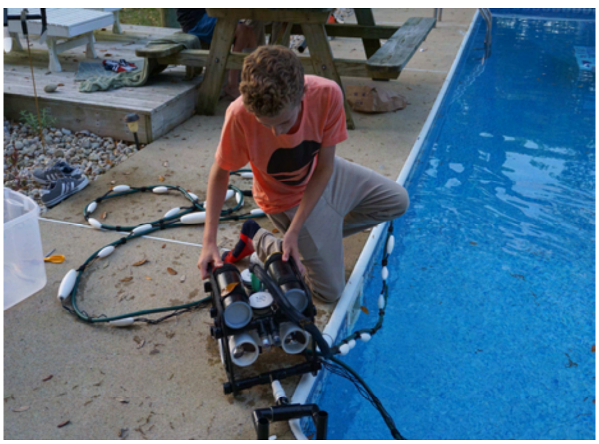
Left: Drew Whitehead attaching the tether to the motor wires on the ROV. (Photo: Thomas)
“This competition has really worked on my skills of being a part of a tea. Being able to control myself while piloting the ROV was perhaps my biggest challenge this year. As a member of this company I had to work on my self control, and I will be able to walk away and say that I am much calmer now under stressful situations.”

Right: Jacob Thomas rounding off camera lenses using a table router. (Photo: Thomas)
“The MATE ROV competition has opened my eyes to engineering, and has certainly influenced my future career choices. After being the high school mascot for eight years I have always been fascinated by the competition. Now after having my own team and competing in the competition I enjoyed myself more than I originally thought I would.”



Left: Will Roepcke checking the control box for loose connections. (Photo: Thomas)
"I was always pretty good with electronics before joining NexGen, but after being with NexGen for two years I can say that I now know a lot more about the complexity of electronics. This competition is very good at bringing out the best in the people involved, and I can safely say it had a positive influence on my learning."

Right: Travis Lawrence creating Metric measuring tape for measuring the distance between containers. (Photo: Thomas)
"Throughout the time the team and I spent on our ROV, I had lots of fun and learned a lot about robotics. The time we spent working on the machine allowed for bonding and learning, and overall I think it was a great experience."



Left: Jack Voight preparing to put *NexGen 2017* into the test tank for practice. (Photo: Thomas)
"ROV has given me an insight to the work of engineer and the challenges and problems the face everyday. I was not very interested in engineering, software, and technology construction before ROV, but since I joined I have found that I really enjoy it. Engineering would be something I would definitely think about as a future occupation."

Left: Elliott Piland setting up the fountain prop before *NexGen 2017* is placed in the pool for testing. (Photo: Thomas)
"Choosing to join NexGen was one of the best choices I've ever made. This first year with the company has been amazing, and I have loved being the Payload Tool Designer. The chemistry between the members is great. Everyone knows the other members really well, and that has really helped us succeed this year."

Critical Analysis

Testing and Troubleshooting

There were several things that NexGen had to test and troubleshoot during the construction of the ROV. The system that required the most testing was the ballast as the machine had to float just under the water where it was perfectly buoyant. In order to do this, the right sized ballast tanks were necessary, and these were made from 3" ABS PVC with caps on both ends. The company intelligently made the decision to allow the caps to be removable in anticipation of the need to modify the tanks. Of course, we had to do so as at first the ROV was too buoyant. When it was placed in the water it only went about a foot into the water, and couldn't go any deeper. The tanks were shortened, but they were too short, so new tubes were cut for the ballast. The shortening process continued, as more of the PVC was cut off until the sizes of the ballast tanks was perfect. Good buoyancy with our tether was also essential because if it floated too much, it would slow down the ROV and get in the way of the obstacles through which it had to maneuver. If the tether lay on the floor of the pool, it would pull the ROV down or drag which would also slow down the ROV and possibly damage the environment. To solve this, floats were added to our tether. When the tether was dropped in the water, it wasn't perfectly buoyant so it was adjusted several times in order to reach the ideal level of buoyancy.

NexGen had to make sure the cameras worked, so they were tested by plugging them into a television set in the company workshop. All of them were put through this process, one at a time, as they were being finished. Fortunately no problems were encountered.

When the machine's control box was first tested, the two strafe motors were spinning when they were not activated. When the control was set in the off position, they would spin, and they would stop in the on position. The control box was inspected, and it was found that the ground and wiper wires were reversed on the inputs of the motor controllers. This error was quickly fixed, and consequently so were the strafe motors.

Challenges

There were several challenges NexGen faced during the construction of the ROV and at the regional competition. The most noteworthy challenge, and most troubling, was that at the competition, the ROV failed to collect any agar as the agar collector did not have a sharp enough end to pierce the surface of the agar. A lot of time was spent trying to drill into it, but without success. This failure is unacceptable, so NexGen will address the tool and its capabilities before the international competition.

Another challenge was that when the ballasts were inspected after the regional competition, each of them was about a quarter full of water. The company agreed that the leakage was due to the caps not being on tightly enough. To remedy this, the caps will be glued on once the ballasts have been stabilized.

Lessons Learned

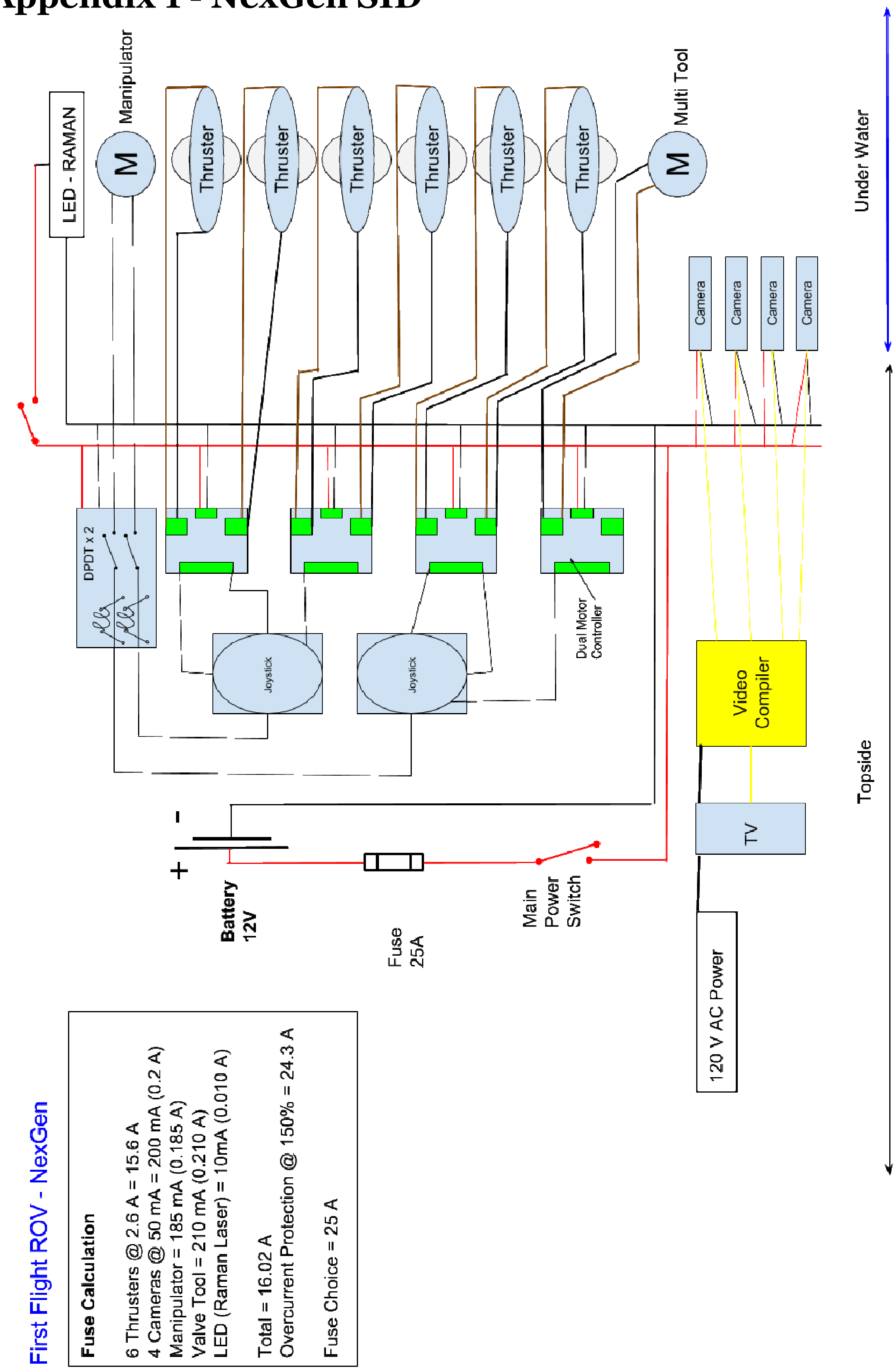
Many valuable lessons were learned as the company constructed the ROV. Mistakes were made while building it, and some mistakes were discovered when the ROV performed at the regional competition. The first major lesson was learned during the numbering of the measuring tape. One company member dedicated two hours to numbering it, only to notice at the end that it was numbered upside down. Luckily it was only the numbers that were upside down, so the tape was still legible and it would give accurate numbers. From this lesson, it is clear that NexGen has to check and double check that everything functions in the way it is supposed to before committing to an irreversible action.

Lessons were also learned at the competition. One of those was that the whole company needs to understand the mission order better. The pool-side technicians found that they did not know which mission the pilot was currently working, so they did not know which tools to put on the machine. All of the company needs to study the mission and practice a lot more before the international competition, talk thoroughly about the order in which the mission will be completed, and decide what tools will be used and when.

Future Improvements

This year, NexGen does not intend to make too many changes to the ROV befoe the international competition. However, there are plans to do so next year. For the next ROV, NexGen intends to put the motor controllers and an arduino on the machine in order to communicate from the surface to the machine. The inputs from the joysticks would lead to an arduino in the control box that communitcates to another on the ROV in a main control canister. By not having the motor controllers on the surface the thrusters would communicate directly with the motor controllers instead of sending a signal up the tether. Currently the ROV loses two volts on each motor by sending the power through the individual conductors in the tether, but with the arduino method, only about a half a volt would be lost.

Appendix 1 - NexGen SID



Appendix 2

NexGen/First Flight ROV Safety Checklist

Physical ROV

- ☐ All items attached to ROV are secure and will not fall off.
- ☐ Hazardous items are identified and protection provided.
- ☐ Propellers are enclosed inside the frame of the ROV or shrouded such that they will not make contact with items outside of the ROV.
- ☐ No sharp edges or elements of ROV design that could cause injury to personnel or damage to pool surface.

Electrical ROV

- ☐ Single attachment point to power source.
- ☐ Anderson Powerpole connectors are utilized
- ☐ 25 amp Single Inline fuse or circuit breaker within 30 cm of attachment point.
- ☐ No exposed copper or bare wire.
- ☐ No exposed motors.
- ☐ All wiring securely fastened and properly sealed.
- ☐ Tether is properly secured at surface control point and at ROV.
- ☐ Any splices in tether are properly sealed.
- ☐ Surface controls: All wiring and devices properly secured.
- ☐ Surface controls: All control elements are mounted with wiring inside an enclosure.

Mission Control Station

- ☐ Monitors set up and not in jeopardy of tipping.
- ☐ AC power is plugged into a surge protected and GFI outlet
- ☐ Chairs are sturdy
- ☐ Extension cords and plugs are in dry environment
- ☐ No tripping hazards from extension cords and cables

Mission Deck

- ☐ Tether is not a tripping hazard
- ☐ All tether and launching personal are wearing life vests (if applicable) and sturdy, closed toe shoes
- ☐ OSHA Safety Officer is on site
- ☐ A-Frame has been cleared and in shape for the days tasks

Pre Launch – all hands clear: perform check

- ☐ Power supply voltage
- ☐ Thrusters and controls are operating on command
- ☐ Cameras are operational and pointing in correct direction
- ☐ Manipulator is operating on command

Signature ____

Print Name ______________________________________ Date ________________

Acknowledgments

John J. Burfete
Thomas and Nancy Connell
Liv Cook
Austin and Gloria Lawrence
John Voight

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