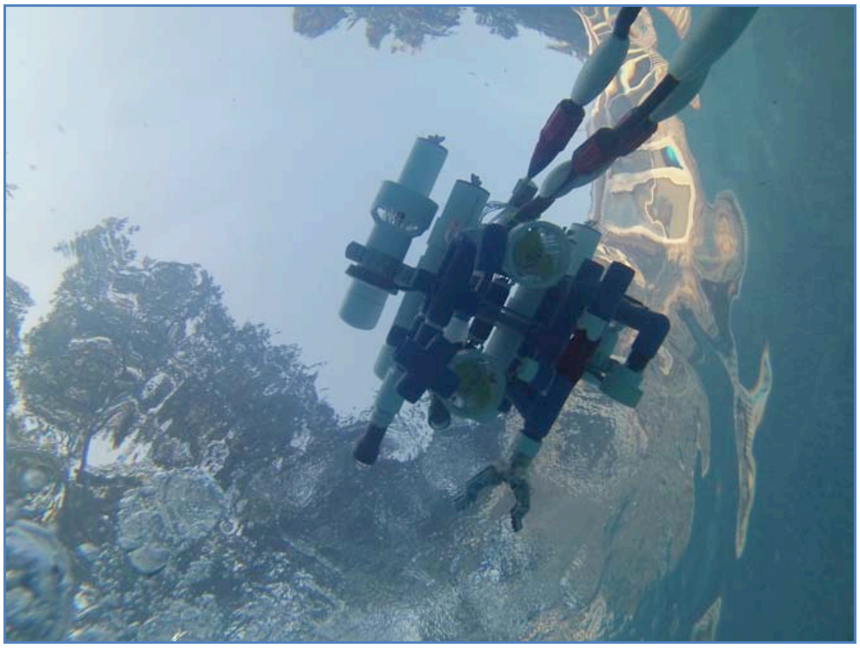
First Descent Solutions - First Flight ROV

2016 MATE International Competition

From the Gulf of Mexico to Jupiter's Moon Europa
ROV Encounters in Inner and Outer Space



MATE
MARINE ADVANCED TECHNOLOGY EDUCATION CENTER

Suppliers of Reliable and Affordable ROVs

FDS 2016
Technical Report

Our People

- Samuel Weybright, CEO, Pilot, Senior, 3rd Year with Company
- Richard Carroll, CFO, OSHA Compliance, Animal Control, 3rd Year with Company
- Luke Potter, Data Analyst, Construction, Machinist, 3rd Year with Company
- Jonathan Lawson, Payload Specialist, Poolside Technician, Construction, Programming, Junior, 1st Year with Company
- Richard McClary, Navigator, Electronics and Video, Electrical Engineering, Sophomore, 1st Year with Company

Mentor/Faculty Advisor - Andrew Thomas, Physics and Oceanography Instructor

"We hail from Kill Devil Hills, North Carolina, the location of Orville and Wilbur Wrights' first historic flight. They took the world to new heights; at FDS we take ROVs to new depths."

First Flight High School, 100 Veterans Drive, Kill Devil Hills, North Carolina

Abstract

First Descent Solutions (FDS), located on the Outer Banks of North Carolina has designed and produced award-winning Remotely Operated Vehicles (ROVs) since 2007. The latest request for proposal (RFP) from NASA and Ocean Engineering has tasked FDS to design a ROV that is suited to the rigors of space travel and the Gulf of Mexico. The 2016 FDS ROV, dubbed *FDS-2016*, has been specifically tailored to the needs of our clients while maintaining flexibility for future tooling needs. This sleek ROV platform was designed with varying consumer demands in mind. The base ROV is equipped with a multifunctional manipulator, sonar, and ample camera views that can satisfy all exploration needs. Custom add-on tools fit securely in the expansion port in perfect view of the wide angle tool camera. These include magnetic sample collector and the "S.P.A.T.U.L.A." The most significant design requirement for the RFP was the ROV's overall dimensions. It has been stated that the consumer would like the ROV to comply to strict overall dimension and mass parameters of 48 cm and 11 kg for space flight aboard a Europa bound space vehicle. Six thrusters, and four cameras are standard on our base model giving FDS ROVs maximum agility, thrust, and viewing angles. FDS has incorporated additional conductors in the tether for add-on sensors and an additional 2-conductor power wire for additional tooling needs. Throughout the design and build process, the team logged over one thousand hours and employed significant real-world problem solving techniques. The result is an exceptionally capable and professional product backed by a team of professionals ready to serve your needs.

Table of Contents

Company Philosophy

FDS' core philosophy is one of simplicity and efficiency. All of our components and tools are designed in-house and manufactured by trained, safety certified FDS machinists in our state of the art workshop. Our ROVs are designed to be large enough to fit all required tools without wasted space while keeping the ROVs light and compact. A multifunctional manipulator and four cameras providing multiple angles are standard on all models. FDS ROVs integrate expansion space for a variety of tools. Upgrading and swapping tools topside is quick and efficient which means more time in the water at a lower cost. Our flexible base ROV platform improves simplicity while maintaining maneuverability. The *FDS-2016* control system is composed entirely of switches and relays; we believe this substantially reduces complexity while maintaining superior functionality and reducing down time, saving our clients time and money.

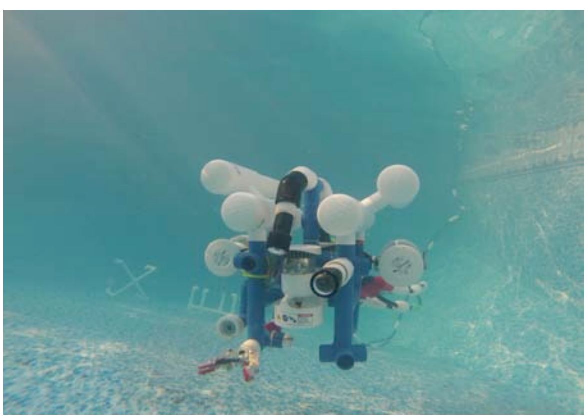


Figure 1: Completed *FDS-2016* on a testing and training mission (Photo: L. Potter)

Design Rationale – Task Integration

FDS has designed and constructed an ROV that meets the needs for working in the Neutral Buoyancy Lab in Houston, Texas. By using the tasks set forth in the request for proposal offered by NASA and Ocean Engineering, FDS prioritized a step-by-step design and planning process to build the current ROV. The mobility and versatility of *FDS-2016* allows for precise movements with ease of task completion within a timely manner. The ROV was completed according to strict company design parameters, including rapid design to construction timeframe, safety, and a strict financial budget.

The complexity of each task was carefully considered to develop the tools that met the FDS standard philosophy of simplicity, functionality, safety, and cost to output effectiveness. While some of our tool solutions seem too simple for complex machinery, our core philosophy remains our guiding principle. We believe we have built an industry leading ROV that is simple to operate, maintain, safely deploy, at a cost option that is both competitive and fair.

Task 1: Outer Space: Mission to Europa

Keeping in mind that *FDS-2016* must be sent to Europa, 6.3 million kilometers from Earth, FDS has simplified and streamlined all mission tasks. In line with our company philosophy, FDS attempted to use the simplest method to measure the temperature of a fluids coming out of underwater vents. By siliconing a 1½" to 3" PVC coupler around a Vernier temperature probe, the team made the process of inserting the probe into the vent easier. The oversized ledge inside of the coupler gives the team flexibility and room for error as the probe is guided into the fluid stream. The temperatue probe leads to a surface readout on a Vernier LabQuest inteface operating through our topside computer.

By integrating a SparkFun Pressure Sensor Breakout that utilizes I2C serial communication protocol through an Arduino into the machine, the team is easily able to measure both the depth of the ocean and the thickness of the iceberg. This software was compared to other means of collecting this information and was deemed the most reasonable.

To pick up and transport the ESP through the two waypoints and into the port on the communication hub, FDS decided on using the manipulator hand. This allows the team to make adjustments easily in regards to grip on the ESP while still limiting the amount of mission time lost. Piloting skills are imperative when using the manipulator arm, but central to the FDS core philosophy, use of one tool for multiple operations is imperative where reliability is paramount to mission success.

Task 2: Mission Critical Equipment Recovery

The team designed and constructed the S.P.A.T.U.L.A. (Special Payload Apparatus That Uncovers Large Alphanumerics) to flip the CubeSats, check the serial numbers, and move the mission specific CubeSats to the collection basket. The reach of this payload tool allows the pilot to easily visualize the actions they make and view the numbers to identify the CubeSats. The shape also slides into the various gaps in a CubeSat with ease, reducing time spent attempting to pick up the CubeSats.

Task 3: Forensic Fingerprinting

FDS-2016 is fitted with our newest generation manipulator. This newly designed hand allows FDS ROVs and pilots to complete different parts of the mission with both a vertical and horizontal hand position without resurfacing. In order to retrieve the oil samples, the ROV grips the sample with a vertical hand and moves up while twisting the hand, gently wiggling the sample free from the base to ensure the safest and most efficient results. Our data analyst has hours of experience with comparing chromatographs to get the best results from our collected data.

Task 4: Deepwater Coral Study

Our strategically located cameras on *FDS-2016* allow for approximately 300 degrees of vision around the machine. This makes photographing and analyzing the coral colonies quite easy. Again, our data analyst has spent hours comparing coral colonies to prepare for this mission. After many hours of deliberation the team collectively decided to integrate a magnetic payload tool to retrieve the coral samples which, after many studies, have been found to contain ferromagnetic metals.

Task 5: Rigs to Reefs

The continued versatility of the manipulator allows us to complete this mission. Without a rotating hand, we would have to install another payload tool to complete the task. But with the rotating hand, a trademark of *FDS-2016*, we are able to lift the flange, the cap, and the bolts and place them in their correct place. This saves time by limiting the number of trips the ROV must make to the surface.

Design Rationale - ROV Systems and Tools

While designing the components of our newest ROV, FDS focused on manufacturing our own parts out of PVC whenever possible. By primarily constructing all of our components out of PVC we minimized cost while maintaining build flexibility. Our machine, designed to be multi-functional, preserves its simplicity through the wide variety and abundance of readily available PVC fittings at reasonable cost. FDS has also become adept at machining existing PVC fitting options to our own specifications.

Frame

For the 2016 ROV prototype, FDS began with a collaborative discussion of possible design options. Our design process involved rapid prototyping and judgment of potential frames (figure 2) constructed in our shop with PVC fittings. This allows us to easily visualize placement of thrusters and tools. Once finalized, the completed frame was then fit with cameras and thrusters. One significant design change for 2016 incorporates the manipulator into the frame structure of the ROV. In years past, the manipulator seemed to be more of an afterthought and was external to the frame structure. The frame was also quite large and used 1” PVC, leaving much empty space in the frame of the ROV.

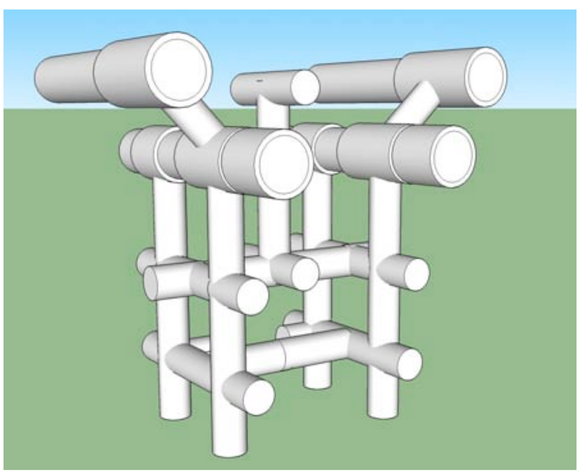


Figure 2: A rendering of the 2016 frame structure
(Render: J. Lawson)

This year’s frame structure was designed with a heavy emphasis on keeping the size and weight of the ROV low. The frame structure includes all ¾” PVC pipe and fittings. This stark difference was apparent to our team when the 2015 ROV frame was set next to the 2016 frame.

The use of PVC allows for virtually no wires to be visible to the naked eye. All wires are routed through the PVC frame and to a single point of connection to the tether. This improvement becomes a key safety feature and also contributes to the overall hydrodynamics by reducing drag and increasing agility. Thruster and tool wiring is not exposed to sharp surfaces or handling during the launch and recovery process. FDS believes that simple design choices can increase efficiency and safety while reducing cost.

Thrusters

In accordance with our company philosophy, FDS tested many differing designs before committing to the finalized thruster. We tested several propellers of varying diameters and pitch, and found that dual blade, 70 mm, 1.4 pitch propellers provided us with the most thrust. Alternatives propellers included 35mm, 1.4 and 1.2 pitch as well as a 1.2-70 mm propeller. In each case, the 1.4-70 mm propeller had the highest output. FDS has found that the thrust and efficiency of the thrusters are greatly increased when the props are housed in Kort nozzles. The nozzles are machined from 2½” to 1½” PVC couplers to which we added large flow holes. The housings prevent prop wash and direct thrust, while improving overall safety. (Figure 3). The thrusters are mounted to the ROV PVC framework with 1½” conduit hangers.

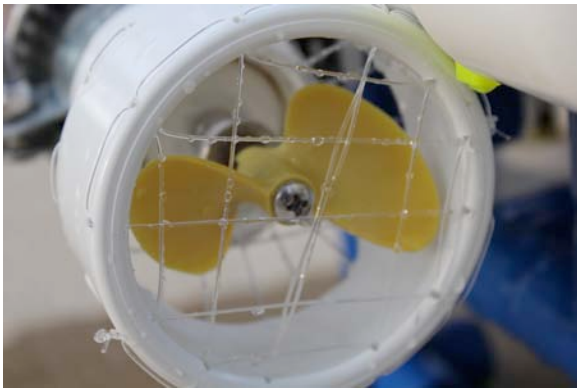


Figure 3: The Kort nozzles with safety netting
(Photo: R. McClary)

Each year FDS attempts to improve its thrusters' output. Because of our 25-amp power limit, we are restricted from increasing the power consumption of the thrusters. Instead, we focus on design improvements related to the thruster's efficiency. This year, heeding the advice of our past engineering judges, we reduced the distance between the propellers and Kort nozzles by using 2½" to 1½" PVC couplers. In year's past several designs evolved out of initially using 1½" to 3" couplers. These were fitted with inserts to reduce the inner diameter between propellers and the housing. This year, we searched multiple online resources and found the 2½" to 1½" PVC couplers where our propellers fit exactly inside.

Our ROV contains two forward thrusters, two vertical thrusters, and two lateral action strafe motors for precision maneuvering. Each of our redesigned thrusters is capable of providing 11N in the forward and 8N in the reverse direction. FDS developed a netting system to prevent debris from contacting the propeller. Monofilament fishing line was woven in a tennis racquet-like pattern across all openings in each Kort nozzle. We have found this system to be most effective in preventing foreign debris, including ropes and lines used in the mission, from becoming entangled in the propellers.

Manipulator

Our manipulator consists of one linear actuator housed in a length of ¾ " clear PVC enclosed with rubber grommets, PVC bushings, and PVC tees. We coated the moving parts and the actuator's shaft in marine grease to prevent water intrusion. The linear actuator drives the opening and closing action of the fingers. The fingers are cut from aluminum stock to maximize durability while minimizing weight and bulk, and their tips are painted red to promote safety around the potential hazard they pose. The manipulator arm includes a high torque DC planetary gear motor which provides for 360 degree clockwise and counterclockwise rotation of the manipulator assembly. (Figure 4). The DC gear motor is only 1.9 cm in diameter while still providing high torque output. This allows the motor to be housed and waterproofed within ¾" PVC fittings and mating with the ROV frame. A PVC Slip-T allows the manipulator to rotate freely. (see Figure 5).

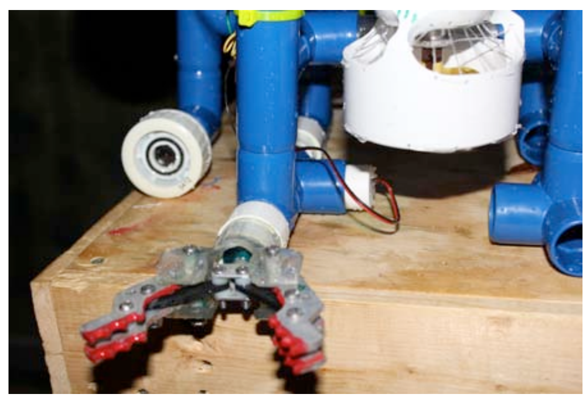


Figure 4: The Manipulator's fingers, with red tips (Photo: R. McClary)

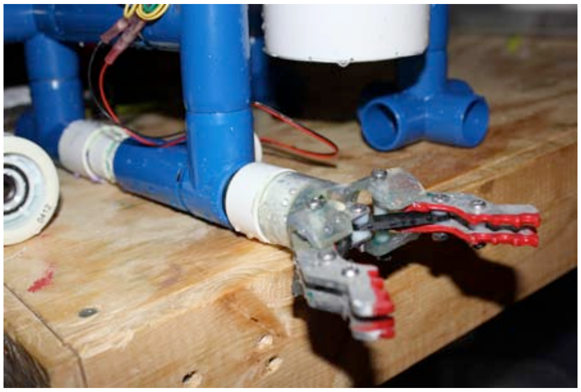


Figure 5: The Manipulator in horizontal configuration
(Photo: R. McClary)

Payload Tools

In addition to our standard manipulator, FDS-2016 features a depth sensor, a detachable magnet and a detachable Special Payload Apparatus That Uncovers Large Alphanumerics (The S.P.A.T.U.L.A.).

The depth sensor is a Sparkfun MS5803 pressure sensor breakout that is waterproofed to fit on the ROV. The depth sensor utilizes the I^2C serial communication protocol, which is decoded on the surface using an Arduino Mega and a laptop computer. (see Figure 6).

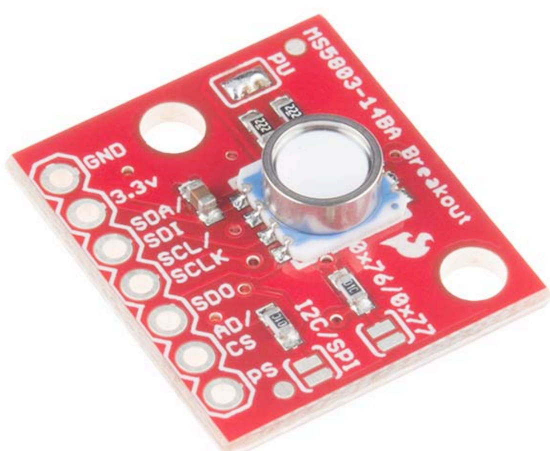


Figure 6: Sparkfun Pressure Sensor
(https://www.sparkfun.com/products/12909)

The magnet is a 200-N neodymium rare earth magnet. It is fitted to ½ ” PVC fitting that can be mated to the expansion slot on the ROV's frame. The S.P.A.T.U.L.A. is made from ½” PVC pipe. The S.P.A.T.U.L.A. is cut from a 25 cm piece of PVC with 15 cm of the top half of the pipe removed. This allows FDS to maneuver the S.P.A.T.U.L.A. into the sides of the CubeSats to flip them on to their numbered sides.

Ballast system

FDS-2016 incorporates four 2” ballast tubes for buoyancy and structural support. The ballasts are joined to the mainframe by 2” to 3/4” tees. 2” PVC end caps are glued onto one end of each ballast and 2” removable test plugs cap in the other ends. The 2” test plugs are used so that ballast can be adjusted for varying conditions. The test plugs have an expandable seal with a wingnut that can be easily removed. The ballast is incorporated into the frame structure to strengthen the design as well as provide protection for the thrusters which are nestled within their diameter. (see Figure 7 below).

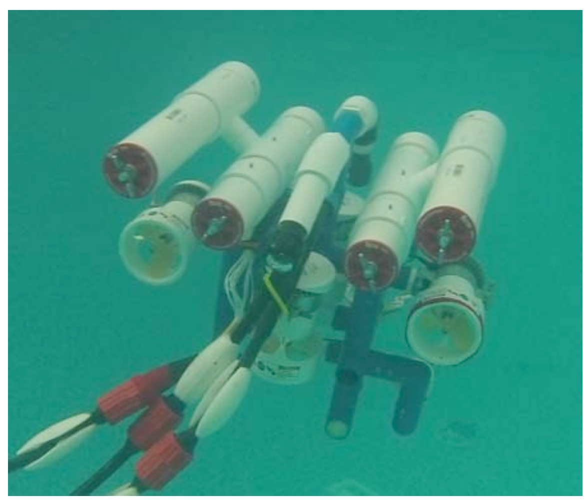


Figure 7: The backside of the FDS 2016 showing the four top ballast tubes that keep the vehicle stable underwater. (L. Potter).

Cameras

The cameras on our ROV are designed as compact outdoor surveillance cameras with an IP-67 rating. While these cameras are rated for severe weather conditions, they are certainly not designed to withstand deep-water pressure. In past competitions we have built and waterproofed our own cameras; however, inconsistent waterproofing has convinced us to buy "weatherproof" cameras to waterproof and house ourselves. Our cameras are housed inside ¾" PVC unions, sealed using an O-ring coupled with a thin piece of Plexiglas. Cable entries are epoxy-potted to prevent water intrusion. We used this process for the 92° 700 line high-resolution cameras that are used for forward driving and manipulator view. Our ROV also features two 170° 700 line wide-angle cameras which provides an overhead view of our manipulator and payload tools. Camera attributes, including type (e.g., wide-angle) and position, were integrated into the design process to maximize field of view and redundancy. The wide angle cameras are not able to be waterproofed as easily as the 92° cameras. The cable connections of the 170° cameras are reinforced with PVC and potting compound. The "camera" end of these cameras have been tested to beyond 1 ATM or 10 meters of pressure successfully. (See below Figure 8). Each camera is positioned to be multifunctional. For example, the forward drive camera is also used to judge the horizontal position of the manipulator when grasping objects. The four cameras are displayed using a standard home-security quad splitter. This allows us to view all cameras simultaneously while using only one monitor.

Figure 8: The wide-angle camera (Photo: jetviewcam.com)

Tether

FDS-2016's tether consists of two underwater-rated cables. One cable (18 conductors, 18 AWG) supplies power to motors and power and data to sensors. The other cable (shielded 12 conductor, 20 AWG) supplies power to cameras and video from the ROV to the surface. MacArtney discounted the 18.5 meter section of P4TSP20 shielded camera cable. The tether is bound at two-foot intervals with zip ties allowing the tether cables to move independently of each other. This increases flexibility and thus maneuverability. The tether also features three SubConn wet-mate multipin disconnect assemblies to connect the tether to the ROV. This provides for easy transport and carrying of the ROV. The tether is made neutrally buoyant with the addition of gill net floats. (Figure 9). Future improvements may include lightening the weight of the tether to increase its maneuverability in the water.


Figure 9: Tether consisting of two cables and gill net floats. (L. Potter)

Surface Controls

The control box was designed with simplicity and safety in mind; we wanted all of the systems to be easily accessible. Our two heavy duty arcade joysticks are mounted to a 6 mm Plexiglas cover so that all connections could be easily viewed from outside the control box. Both joysticks are used for thruster control while two triggers, one on each joystick, are used to control the manipulator. The placement of these controls insured simple routing of all wires in the box.

Both joysticks use cherry switches wired directly to the tether. The signals sent from the joysticks are amplified using relays and sent to each motor through the tether. This hardware-based approach was employed in accordance to the FDS core philosophy: efficiency through simplicity. The use of relays as opposed to software-driven H-bridges allowed for simpler troubleshooting and error correction. The hardware approach is also more resilient to jostling or other external physical influences. FDS believes the hardware approach presents a much more resilient ROV that can handle the rigors of space travel. Cost and reliability were also major factors in choosing the hardware option. Each relay is rated for 100,000 switching operations, much more than FDS would ever require year-to-year. Our relays are also an order of magnitude less expensive than H-bridges: $4.00 for a relay vs. $40.00 for an H-bridge. Our limited budget made this an easy decision.

The camera quad splitter is also located in the control box. It processes the four camera inputs and outputs to a standard 22" flat-screen TV that sits atop the control box for easy viewing. (Figure 12).

Figure 12: The control box with joysticks (Photo: L. Potter)

Safety and Design Considerations

Throughout the design and build process, safety feature integration was continually discussed and implemented. Our team developed our own safety checklist (see Appendix) and designated an OSHA Officer to be responsible for monitoring workshop and poolside safety. Key safety elements of this year's design include: Kort nozzles around all of the thrusters, which not only add hydrodynamic flow but also protect wiring and body parts from the propellers; bright red paint around safety hazards, such as the manipulator fingers and tube caps; and safety netting around the Kort nozzles to prevent foreign objects from entering the propellers. FDS also designed safety labels for all of the kort nozzle thruster housings.

There are several safety features on the surface within the control box. A 25 amp fuse located on the positive cable prevents any potential fires in the off chance we exceed safe current limits. The Plexiglas is securely held in place with high-strength Velcro to prevent accidental dislodgement.

All members must wear safety goggles at all times while operating shop machinery, soldering irons, or other potentially hazardous equipment. FDS has isolated equipment to prevent members from entering a power tool's working zone. Specified areas for soldering, engineering, and manufacturing are consistently monitored by the OSHA Officer to ensure the safety of the company's employees.

Safety also remains our top concern while on the poolside. To protect the safety of each poolside employee FDS assigned specific jobs to each person. This reduces confusion and creates an efficient operating environment. The ROV has specified handle points to prevent damage or entanglement when mobilizing or demobilizing. Furthermore, we have secured all poolside wires and electronics to avoid possible issues with water compromising the security of the wires, the ROV, and, most importantly, our poolside workers. Before and after every mission, our safety officer uses the FDS Safety Checklist to ensure a safe and secure working environment (see Appendix C).

Budget and Expense Sheet

As a successful competition company, FDS has had a fair share of machines that have been successful in the MATE competition. Cost is always an important aspect of our design and planning. This year we set a strict budget due to cutbacks and layoffs within the company. For 2016, FDS set a spending cap for all new parts and extraneous expenses of $1250. FDS carefully selected which parts could be recycled from previous ROVs in our workshop and took advantage of parts discounts and donations from SubConn and local parts stores. With limited cash and big plans for improvement on *FDS-2015*, we had to make some hard choices on where to spend our money. This included purchasing used parts (reusing old parts) at fair market value. The total value of the ROV, control station, and tether is $1746. New parts came in just under budget at $1229 which required the company to really tighten the purse strings and scrap old machines.

Our detailed budget is below.

2016 Budget	**$1,250.00**			
ROV Supplies				
Reused	**qty**	**original price**	**Original Total**	**Current Value**
Tsunami Bilge Pump Cartridges	4	$32.00	$128.00	$64.00
Supercircuits Wide Angle Cameras	3	$110.00	$330.00	$165.00
Supercircuits Bullet Camera	1	$80.00	$80.00	$40.00
Suzo-Happ Joysticks	2	$140.00	$280.00	$140.00
Tether - 18AWG x 18 Conductors	1	$100.00	$100.00	$50.00

Manipulator Fingers	1	$12.00	$12.00	$6.00
Ballast	1	$20.00	$20.00	$10.00
Relays	14	$6.00	$84.00	$42.00
			$1,034.00	**$517.00**
New	**qty**	**Price**	**Total**	
Kort Nozzles	6	$4.20	$25.20	
PVC - 3/4" Blue	6	$14.73	$88.38	
12V Planetary Gear Motor	1	$27.99	$27.99	
Camera Tether - MacArtney	1	$282.60	$282.60	
Firgelli Linear Actuator	1	$60.00	$60.00	
SparkFun Depth Sensor	1	$59.95	$59.95	
Powerpole Connectors	1	$12.00	$12.00	
2" PVC (10 ft.)	1	$4.20	$4.20	
PVC Fittings	26	$2.00	$52.00	
GE Clear Silicone	1	$7.96	$7.96	
Flat Aluminum Bar	1	$0.20	$0.20	
Assorted Fasteners	1	$41.00	$41.00	
Shop Supplies	1	$20.00	$20.00	
Hook-up Wire	1	$30.00	$30.00	
			$0.00	
New parts			**$1,228.48**	
			Total retail value of FDS-2016	
New parts + current value of reused parts			**$1,745.48**	
Donations				
FFHS PTSO			$500.00	
Various Donations and Cash on Hand from 2015			$750.00	

			$1,250.00	

FDS-2016 started with some limited funds remaining from the 2015 fiscal year as well as some small donations. Our focus now is to get the international competition in Houston so that we can demonstrate the company's most recent technological advances. Our proposed budget for the international competition and additional funds for "spare parts" is included below.

International Competition Costs	
Plane Tickets - 8 Roundtrip Norfolk, VA to Houston Hobby	$5,200.00
Hotel - 3 Rooms x 4 nights	$1,600.00
Ground Transport - to and from Houston Hobby/Hotel	$250.00
ROV Shipping	$200.00
Meals	$1,000.00
Future Improvements - Poster - T-Shirts - Supplies	$1,000.00
Total for International Competition	**$9,250.00**
Continued	
Dare County Schools Donation	(2,500.00)
Remaining to fundraise	$7,000.00

We have purchased plane tickets, booked hotel accommodation, reserved ground transport, and started to stock up on supplies for a rebuild and future improvements before the international competition. We are currently still raising an additional $7000 to travel and compete in Houston. Several companies have made tentative commitments, but we are still working on securing most of the funds.

Challenges

Technical

After testing the machine and competing at regionals, the team decided the biggest technical problem is the tendency for the machine to get caught in ropes and cables. While practicing with the machine, the cable attached to the ESP slipped through the wiring on our Kort nozzles and became tangled with the propellers. The machine promptly became immobile and had to be brought to the surface by a team member in the pool. To resolve this issue, the team is currently designing an entirely new frame structure that locates the motors further inward on the machine, reducing the chances of getting wrapped up in the cable. The team is also remachining the Kort nozzles to better protect them. A closer knit mesh is being attached to the top of the Kort nozzles to completely stop all cable that might have previously gotten tangled in the propeller.

At the regional competition, the team also experienced issues when the ropes attached the collection basket for the CubeSats wrapped around the ballast tubes on top of the ROV. While trying to escape the ropes, one of the tubes on top became entangled and was ripped off by the mission prop. The team has come up with various solutions to this problem. Properly attaching the tubes to the ROV was overlooked while preparing for the mission, so the team plans on resolving this in the coming weeks. A completely redesigned frame will also feature a complete encirclement of PVC on top of the ROV that will block ropes from going inside of the frame during the mission.

From this lesson the team learned to always have a back-up plan. Time has become our biggest foe as we prepare for the international competition. With deadlines approaching for the international competition, we had to shift our focus from design and testing to documentation. As soon as our documentation is complete, we will begin the process of restructuring the frame to eliminate the associated problems we encountered at the regional event.

Interpersonal

FDS has also faced several non-technical problems involving this year's budget. Being a school organization with limited funds, we have been hard pressed to meet this year's monetary requirements. Traditionally we have sought out donations from local businesses and in return provided advertisement and positive public relations. However, as a result of the success of our local elementary schools in Odyssey of the Mind, dual fundraising on the Outer Banks has led to less plentiful donations for both parties. By taking unconventional methods, such as in-house contributions and merchandise auctioning coupled with a more aggressive advertising and public relations campaign, we were able to overcome this issue to complete the ROV construction. Now as the next deadline approaches, the international competition, fundraising has to begin all over.

Future Improvements

This year, FDS continued with the three-year plan on electronics associated with the machine. This plan, starting years back, grew from on-machine electronics, to relays, located in the control box on the surface. For next year's machine, FDS will have developed an entirely computer-based control system, which will improve the already substantial maneuverability of the ROV.

After looking back at previous technical reports, we have realized that we have solved one of our future improvements. This relates to our manipulator and its limited range of motion. Our 2010 international team that won the Ranger class in Hawaii designed a manipulator with three axis of motion. The subsequent team that competed in Houston in 2011 had a major failure due to human error using a similar manipulator. FDS strayed away from the complex manipulator to seek simplicity until we could redesign a manipulator that was functional and durable. This year's manipulator has achieved what none of the company's previous designs have been able to achieve: 360º of rotation and durable. Next we will incorporate this design into a manipulator that can "fold" back inside the ROV frame.

Lessons Learned

Technical

As in years past, we focused on fabricating our own parts. All of the custom PVC parts, such as the kort nozzles, manipulator housings, the S.P.A.T.U.L.A., and all of the custom metal parts, such as the fingers on the manipulator, were designed and manufactured by FDS. This tested our power tool skills and gave us an appreciation for precision and accuracy. FDS incorporated a "think-tank" brainstorming philosophy which developed our creativity and problem solving skills.

The greatest challenge from NASA and Oceaneering's RFP was the size and weight restrictions. Valuable experience was gained while designing, and redesigning the ROV to competition specs. Compromises on design were necessary to achieve our goals. As this process continues, we still have several design obstacles to refine.

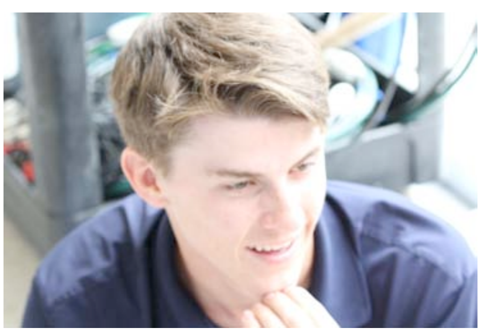
Interpersonal

One of the first lessons we learned concerns time management. Returning members and our mentor warned us of procrastination, but you truly can't understand until deadlines approach. We have wrestled with accommodating schedules of our busy team and personal time that seems significant until the deadline hasn't been met. "If we had only started our planning earlier, we would have known what parts to order based on our design." It doesn't matter how many times we say it, we never truly can tackle this obstacle. However, this would have allowed us to assemble our ROV and begin testing at an earlier date. A more flexible time frame would have made it easier to work around our conflicting schedules when planning time for extracurricular activities and rigorous coursework.

Our design and construction budget comes entirely from fundraising events like our car wash we have done in the past. We know it is better to fundraise before the project and have surplus funds than to be short of money. This year, we raised funds out of necessity for purchasing parts as we went through the construction process. Consequently, we continually found ourselves having to halt construction while we waited for parts to arrive. Having money up front is so much easier than playing catch-up. Again, procrastination and individual personalities continue to haunt our team. As we begin to fundraise for the international competition, we can already see that some team members are naturally more committed to finishing what we start.

Reflections

Ricky Carroll



ROV has taught me a lot in terms of technical knowledge, but it has also furthered my development as a person. I learned so much about teamwork during my time in this company because there are so many more challenges for a team while creating a working vehicle than you can find on a field with a sports team because it's nearly impossible to determine what kind of adversity you will face the night before a regional competition or the night before the technical report is done. The ROV team was instrumental to creating my STEM oriented mindset that will be carrying me through college and hopefully through my adult life.

Sam Weybright

My third year with the ROV team has been a memorable one. Over the years, this club has taught me to overcome failure and only grow from it. After our loss at the regional competition last year, I came back with a more positive attitude and lead the team in the best way I could. While I am the captain, however, I don't see myself as more important than any other member of this team. We have grown and learned together over these past few months and I feel they were key members in preparing me for next year as a freshman in college. I have learned a considerable amount of things both in terms of the theoretical engineering and hands on machining. These years with the ROV team have been one of the biggest parts of my high school years and affected me positively just as much as anything else I have done. I have gained friendships that will last a lifetime and will forever be grateful for this opportunity.

Left: Back in the winner's circle. Mid-Atlantic Regional Ranger Champs. From Left: Luke Potter, Jon Lawson, Sam Weybright, Ricky Carroll, Mac McClary. Photo: Thomas

Right: Mid-Atlantic Regional Scout Champs. From Left: Jack Voight, Drew Whithead, Will Roepke, Jacob Thomas. Photo: Thomas

As an added bonus this year, we were able to mentor the 7th grade Scout team, a first for the middle school and First Flight ROV. First Flight ROV – Next Generation also won the Mid-Atlantic Regional by sweeping all categories including; best mission score, top engineering presentation, best marketing display and the overall 1st place.

References

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Construction Resources

Electrical Wiring: http://www.homebuiltrovs.com/
Underwater Cable Connectors: http://www.subconn.com/
Pressure Sensor: https://www.sparkfun.com/products/12909
Linear Actuators: http://www.firgelli.com/
Cameras: http://www.supercircuits.com/
General construction Supplies http://www.mcmaster.com/
Online PVC Fittings: http://www.pvcfittingsonline.com/
Servo City: https://www.servocity.com/
Robot Shop: http://www.robotshop.com/

Local shops are always our first choice, but we live on an island.

Hometown Ace Hardware
CarQuest of Kill Devil Hills and Grandy
Mr. Thomas' Garage and Pool
Our Home Depot
Our Lowe's

Acknowledgements

MATE
MARINE
ADVANCED
TECHNOLOGY
EDUCATION
CENTER

NAUTICUS

MacArtney
UNDERWATER TECHNOLOGY

Local Donations

Dare County Board Of Education - $2500
First Flight High School PTSO - $500
Nauticus – Regional Competition Coordinator - $500
Old Dominion University – Regional Competition Venue
MacArtney – SubConn – Discount on Tether

Appendices

Appendix A – FDS Safety Checklist

First Descent Solutions/First Flight HS 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.
- ☐ Standard male Banana plugs to connect to MATE power source. (International)
- ☐ 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

- ☐ Cones are out and mission deck is cordoned off to keep passer byers safe
- ☐ 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

OSHA Officer Signature ____ Date __________

Print Name ______________________________________ ID badge # ________________

Appendix B – FDS 2016 Systems Integration Diagram (SID)