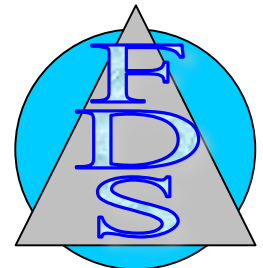
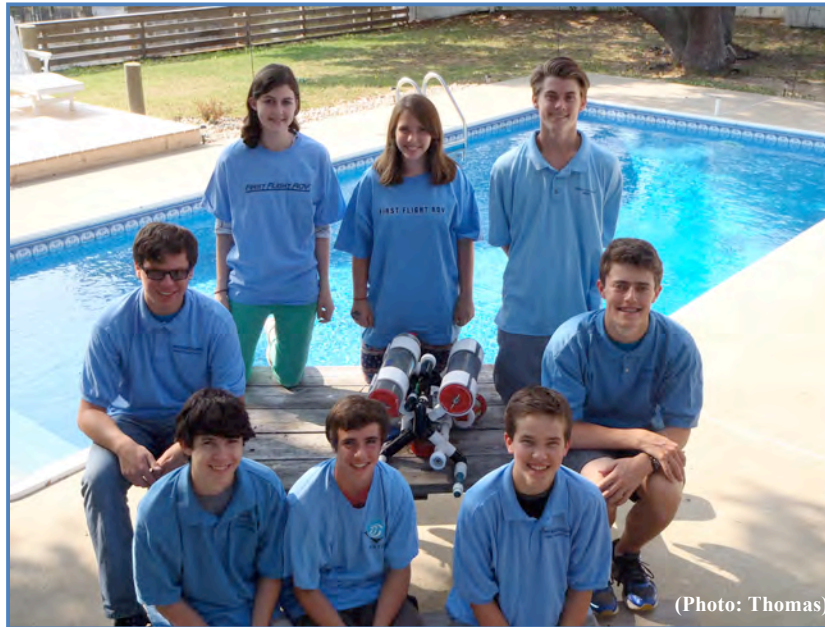


# First Descent Solutions - First Flight ROV

## 2014 MATE International Competition, Exploring The Great Lakes



Suppliers of  
Reliable and  
Affordable ROVs

## FDS 2014 Technical Report

### Our People

- Matt Thibodeau, CEO, Electrical Engineering and CAD, Junior, 3<sup>rd</sup> year
- Matt Gray, CFO, Construction, Navigator, Junior, 3<sup>rd</sup> year
- Heather Wells, OSHA Liaison, Electrical Construction, Navigator, Senior, 1<sup>st</sup> year
- Dakota Tholen, Community Relations, Construction, Tether Management, Junior, 1<sup>st</sup> year
- Sam Weybright, Regulatory Affairs, Construction, Pilot, Sophomore, 1<sup>st</sup> year
- Ricky Carroll, Animal Control, Construction, Launch and Recovery, Sophomore, 1<sup>st</sup> year
- Kenzie Potter, Fundraising, Construction, Data Analyst, Freshman, 1<sup>st</sup> year
- Luke Potter, Underwater Photography, Machinist, ROV Operations, Freshman, 1<sup>st</sup> year

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.”**

## **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 Thunder Bay National Marine Sanctuary (TBNMS) along with its affiliates through the National Oceanic and Atmospheric Administration (NOAA) have requested proposals to aid in the documentation, exploration and conservation of shipwrecks. The 2014 FDS ROV, dubbed FDS-2014, has been specifically tailored to the needs of TBNMS 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 and in perfect view of the wide angle tool camera. These include a tape measure, a core sampler for capturing biological mat samples, and a conductivity probe to test seeping fluids in sinkholes. The most significant design choice for the TBNMS was the ROV's overall dimensions since the ROV is required to access the interior hull space of shipwrecks. Six thrusters, and three cameras are standard on our base model giving FDS ROVs maximum agility, thrust, and viewing angles. FDS has incorporated an expansion cable on the ROV for an add-on camera 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.

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## 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 FDS machinists or sent out to local shops to reduce costs and maximize design flexibility. Our ROVs are designed to be large enough to fit all required tools without wasted space. FDS ROVs integrate expansion space for a variety of tools. A multifunctional manipulator and three cameras providing multiple angles are standard on all models. 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-2014* 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-2014 (Photo: L. Potter)

## Design Rationale – Task Integration

FDS has designed and constructed a ROV that meets the needs for working in the Thunder Bay National Marine Sanctuary. By using the tasks set forth in the Request for Proposal, FDS prioritized a step-by-step

design and planning process to build the current ROV. The mobility and versatility of FDS-2014 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.

### **Task 1: Shipwrecks**

In line with our company philosophy, FDS attempted to use the simplest method possible to measure the shipwreck. We tested many measurement devices, including a custom-built apparatus involving lasers, but after testing the options, a simple tape measure was deemed the most cost-effective, accurate, and reliable solution.

To determine the specific shipwreck, FDS created a table that lists all possible shipwrecks and their associated attributes. We can then easily determine the wreck with process-of-elimination as we gather information throughout the mission.

The size of the ROV was a major design consideration. With openings as small as 60 cm x 60 cm in the ships commonly found in the TBNMS, we designed FDS-2014 to easily fit into tight spaces by keeping the height and width under 50 cm x 50 cm.

The multifunctional manipulator was designed to be oriented in both the horizontal and vertical directions. To retrieve the plate, the manipulator is manually rotated to the vertical direction

while the ROV is surfaced for the swapping of tools. This allows easy grasping of the plate inside the hull of the shipwreck.

### **Task 2: Science**

To determine the conductivity of the vented water, FDS designed a small sensor with two electrodes and a pointed tip that punctures the cling wrap covering the cups. The electrical resistance between the electrodes secured inside the sensor is measured, and from that measurement we can see which sample is more conductive. A light on our control box clearly illuminates when the probe registers high conductivity.

To retrieve a sample of the microbial mat, we designed a cylindrical core sampler. The sharp rim of the cylinder, fashioned from PVC, cuts through the agar in the cup and a raised lip inside the cylinder prevents the core sample from unexpectedly falling out. Our team used a similar design in Hawaii in 2010 when they won the International Competition.

We use a 30 x 30 cm quadrat to count and extrapolate the zebra mussels. Teamwork is critical to estimate the zebra mussels, as the navigator and data analyst must work together closely with the pilot at this stage.

Our manipulator is used once again to retrieve the old sensor string and bring it to the surface. Once we surface the machine, the old sensor string is removed, and a new string is brought to the lakebed.

### **Task 3: Conservation**

For this task we found that no additional tools were required. We use the manipulator to remove and surface with the bottles as well as removing and surfacing with anchor line debris. Once again we find that by combining tasks into one well designed tool, we can streamline our ROVs and become more efficient.

## **Design Rationale - ROV Systems and Tools**

While designing the components of our 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.

### **Frame**

For the 2014 ROV, FDS began with a collaborative discussion of possible design options. Our design process involved rapid prototyping and judgment of potential frames 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 translated into a SolidWorks rendering (Figure 2). One significant design change for 2014 incorporates the pressure housing into the frame structure of the ROV. In years past, the pressure housings seemed to be more of an afterthought and were external to the frame structure. This simple design consideration further enhances the holistic design approach. This stark difference can be seen when the 2013 ROV frame is compared to the 2014 frame.



Figure 2: SolidWorks Rendering of 2014 Frame Structure  
(Render: Thibodeau)



The new, streamlined frame design of FDS-2014 resulted from discussion of the hydrodynamics of FDS 2013, last year's ROV. Through reduction of size and surface area of the ROV we were able to nearly double its water speed (~1 m/s to ~2 m/s) and greatly increase its maneuverability. This additional speed and maneuverability allows us to accomplish the mission in much less time than previous years.

With a frame composed entirely of PVC and PVC fittings, we were able to maintain a clean design by routing the wires through its hollow interior. This improvement becomes a key safety feature and also contributes to the overall hydrodynamics by reducing drag. Thruster and tool wiring is not exposed to sharp surfaces or handling during the launch and recovery process.

### **Thrusters**

In accordance with our company philosophy, FDS tested many differing designs before committing to the finalized design. 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 35 mm, 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 3" to 1½" PVC reducers to which we added large flow holes. The housings prevent prop wash and direct thrust, while improving overall safety. They are painted red to indicate a potential hazard and to prevent injuries (Figure 3). The thrusters are mounted to the ROV PVC framework with 1½" conduit hangers.

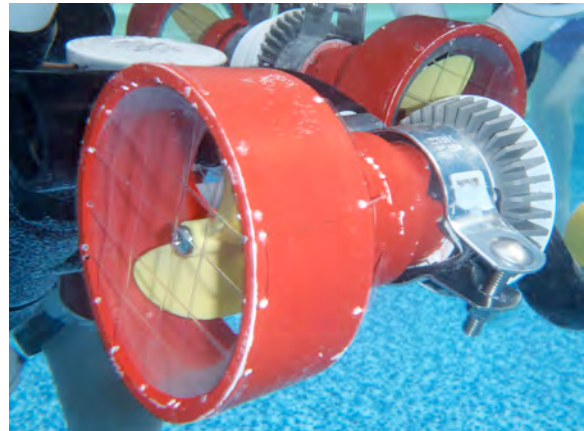


Figure 3: The red Kort nozzles with safety netting (Photo: L. Potter)

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 2013 engineering judges, we reduced the distance between the propellers and Kort nozzles by adding a ring of 3" PVC between the housing and the edge of the propeller (Figure 4).

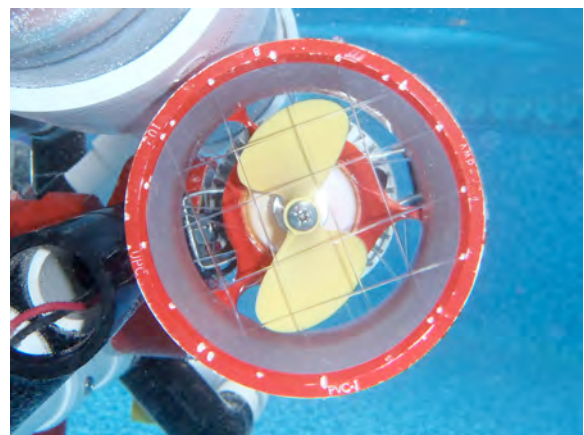


Figure 4: The Kort nozzle insert is clearly visible around the prop (Photo: L. Potter)

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  $\frac{3}{4}$ " clear PVC enclosed with rubber grommets, PVC bushings, and PVC end caps. 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 (Figure 5). The manipulator is placed on the left side of the machine, attached with a pivoting 1" PVC 90° elbow that allows the manipulator to swivel out of the way during the operation of other tools. The manipulator assembly can also rotate along the actuator's axis, allowing us to operate the hand in both the horizontal and vertical planes (Figure 6).



Figure 5: The Manipulator's fingers, with red tips (Photo: K. Potter)

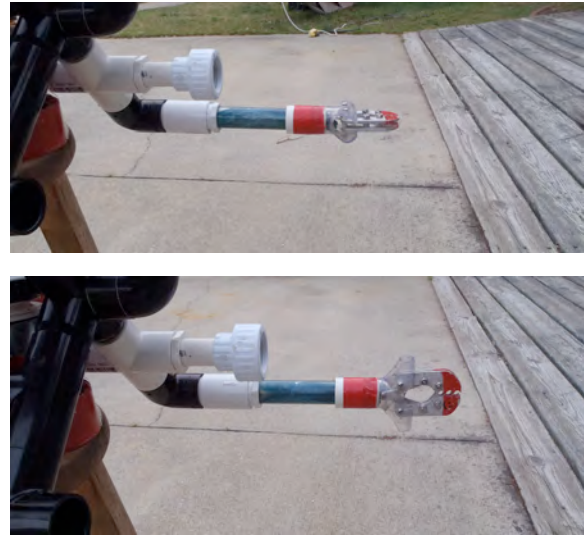


Figure 6: The Manipulator in horizontal and vertical configurations, respectively (Photo: K. Potter)

### **Payload Tools**

FDS uses a tape measure to measure the shipwreck. The tape measure's case was removed and the inside was packed with marine grease to prevent corrosion of the metal tape. To take advantage of the screws embedded in the corners of the shipwreck a 2" stainless steel ring was attached to the end of the tape measure. The entire assembly was screwed to a 1" PVC 90° elbow, which is compatible with the ROV's interchangeable tool system. To operate the measurement device, the driver of the ROV loops the ring around a screw on the shipwreck and the reverses the ROV along the length or width of the wreck, or descends along the side of the wreck to measure height. The device is well within view of the wide-angle tool camera, which is used to read the measurement off the tape.

The tape measure is mounted on the front of the ROV, in full view of the cameras for easy reading (Figure 7). The tape measure is one of our add-on tools that fit into the expansion port on the front of the ROV. The tape measure is fitted with a 5.1 cm stainless steel ring that can be hooked on the corners of the shipwreck. With simple



post mission maintenance, the tape measure has proven to be safe and reliable at less than 10% of the cost of a dual laser system that was not very effective.

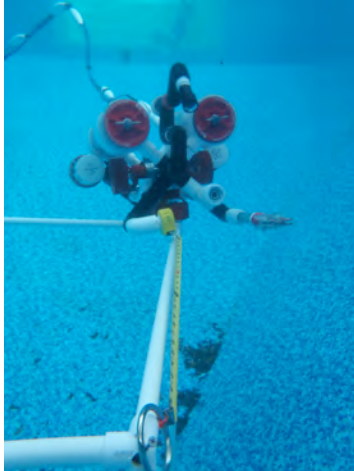


Figure 7: The tape measure in action (Photo: L. Potter)

A core sampler is used to collect the microbial mat sample. The sampler is constructed from a length of 1½” clear PVC that has an internal volume greater than 150ml. Like the tape measure, the sampler is mated to the ROV via the expansion port under the tool camera. The pilot uses the ROV’s vertical thrusters to plunge the sampler’s serrated tip into the mat. Clear PVC is used so that the pilot can see the sample in the tube through the tool camera (see Figure 8 below).

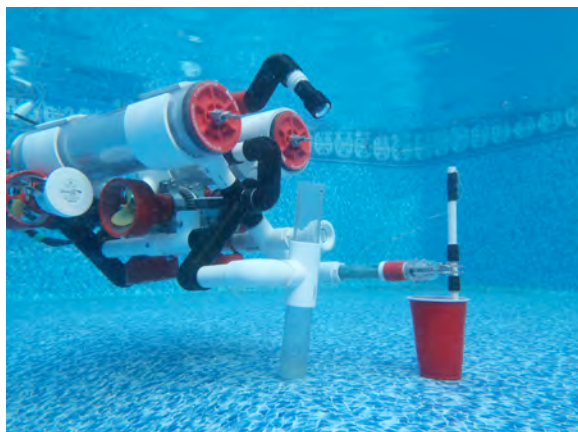


Figure 8: Conductivity probe inserted into the red cup and firmly grasped by the manipulator. Core sampler for the microbial mat attached to the expansion port on the ROV (Photo: L. Potter)

A conductivity probe (pictured in Figure 8) is employed to identify the groundwater venting fluid. The probe is constructed of 3/8” PEX piping, with one end machined to a sharp tip that penetrates the plastic cling wrap. Inside the pipe, two water-blocked electrodes are epoxied next to each other at a distance of 2mm. The electrodes are connected to the main power source and a car dashboard light. Through testing we determined that standard pool water is too resistive for the light to activate. However, when the sensor is placed in high salinity water, the conductivity is sufficiently high to provide the current to illuminate the light.

### **Pressure Housings**

FDS always incorporates two pressure housings into its ROV designs. Besides providing a housing for electronics, they also provide buoyancy and, this year, structural support. Constructed of 4” PVC tubing, each housing is capped with a 4” removable test plug on one end and a removable aluminum end-cap on the other.

In previous years, our pressure housings were designed with one end permanently sealed with a flat piece of acrylic that allowed us to thread in water-blocked penetrators and connectors. The disadvantage of this method was that all electronics were permanently attached to the tube, severely hindering our troubleshooting. This year, we instead opted to design a brand new endcap that was both threadable and removable (Figure 9).

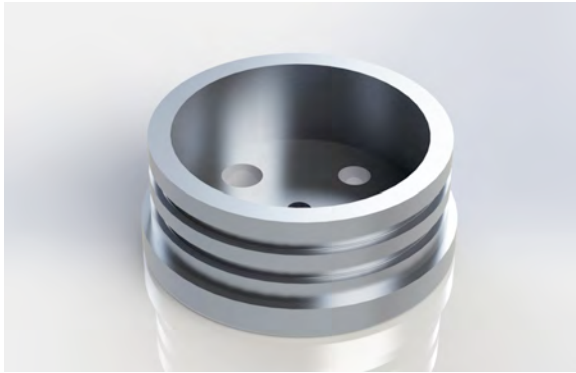


Figure 9: The aluminum endcap with o-ring grooves (Render: Thibodeau)

Our final design can be seen in our final model being tested in Figure 10. Two AS568-240 O-rings act as redundant seals (see Appendix A). Correct dimensions for the plug and its o-rings were obtained from the Parker O-ring Handbook. (see Appendix B for relevant excerpts). The aluminum plug was designed in-house using SolidWorks and then sent to a machine shop for manufacturing. Two were ordered: one with four threaded holes for the drive electronics tube, and one with two threaded holes for the camera electronics tube.

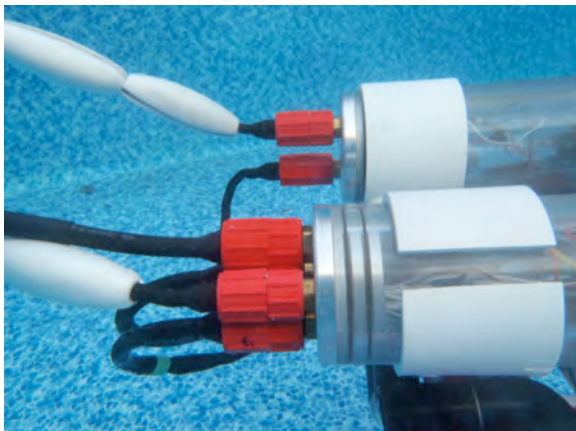


Figure 10: The aluminum endcaps in use, showing penetrators and o-ring seals (Photo: L. Potter)

## 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  $\frac{3}{4}$ ” 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 two 92° 700 line high-resolution cameras that are used for forward and reverse driving. Our ROV also features a 170° 550 line wide-angle camera (Figure 11) 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. Each camera is positioned to be multifunctional. For example, the “Sonar Scanning” camera is also used to judge the horizontal position of the manipulator when grasping objects.

The three cameras are displayed using a standard home-security quad splitter. This allows us to view all cameras simultaneously while using only one monitor.



Figure 11: The wide-angle camera (Photo: jetviewcam.com)

## On-Board Electronics

To maximize the maneuverability of this year’s ROV, FDS placed the motor control relays in a pressure housing on the



ROV. This allows us to reduce our overall tether diameter and also increase the size of the main power wires. Another pressure housing contains our camera routing electronics. All electrical connections to the pressure housings use water-blocked SubConn connectors.

The choice of relays as opposed to H-bridges was mainly due to the past experience of the electrical design team. In previous years, relays have consistently proven themselves much more reliable and robust than H-bridges. We have found that this far outweighs the associated performance loss of our ROV, which can be mitigated by a competent pilot. In the future we hope to conquer the challenge that H-bridges pose.

### ***Tether***

The tether is the lifeline to our ROV because it supplies power to our motors, cameras, and sensors. To maximize maneuverability, high tether flexibility was considered paramount. The tether is composed of two 8-AWG ultra-flexible main power wires and three standard CAT5E cables, each with eight solid-core 24-AWG conductors. Our most substantial tether improvement was the discovery of ultra flexible 8-AWG power wire. The increased size of the power wires reduces voltage drop over the length of the tether; through testing we determined that the voltage drop decreased by twenty percentage points, or 2.4 volts, when compared to last year's design. The simple discovery of reasonably priced 8-AWG wire led us to our next upgrade of housing the motor relays on the ROV; in past years we have had to keep the relays on the surface to keep the tether flexible. The 8-AWG wire is designed to be used in the extremely low temperatures of the Arctic Tundra. The supplier we found was based in Anchorage. Since the wire is designed to still be flexible at low temperatures, it is even more flexible

in our temperature range. The tether is bound at two-foot intervals with waterproof tape allowing most of the tether wires to move independently of each other. This again increases flexibility and thus maneuverability.

### ***Surface Controls***

The control box was designed with simplicity in mind; we wanted all of the systems to be easily accessible. We mounted two joysticks 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 (Figure 12). The placement of these controls insured simple routing of all wires in the box.



Figure 12: The control box with joysticks in use (Photo: K. Potter)

Both joysticks use cherry switches wired directly to the tether. On the ROV, the signals sent from the joysticks are amplified using relays and sent to each motor. 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.

The camera quad splitter is also

located in the box. It processes the three camera inputs and outputs to a standard 22” flat-screen TV that sits atop the control box for easy viewing (Figure 12).

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.

### ***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 Kort nozzles and tube caps; and safety netting around the Kort nozzles to prevent foreign objects from entering the propellers.

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**

Our initial fundraising total was \$2100.00. We established that this would be our limit for new parts. 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-2013, we had to make some big choices on where to spend our money.

Our single largest investment this year was the machined aluminum end-caps for our electronics housings. We designed the end-caps ourselves using SolidWorks and then asked a local machinist at the boatyard to cut them for us. He graciously offered to do it during his free time at a reduced rate; a luxury item for our team, but well worth the investment.

We also invested a large portion of our budget to on-hand replacement parts for the ROV. Shipping delays are one thing that have always plagued our team so we are planning ahead and stocking our shop with spare parts.

**FIRST DESCENT SOLUTIONS – ROV FDS 2014  
FIRST FLIGHT ROV**

The total value of the ROV, control station, and tether is \$4147. FDS is currently raising funds for our travel expenses to Alpena, Michigan.

Quantity	Item	Donated	Reused	2014 Cash Credit/Debits
	Carolina Designs Realty Donation			\$500.00
	Grays Department Store Donation			\$1300.00
	Miscellaneous Donations			\$300.00
	Aluminum Bar – Manipulator Fingers			(\$12.00)
2.7 kg	Ballast (lead)		\$20.50	
2	Wide Angle Camera – 1 in use, one back-up			(\$239.98)
2	90° FOV Bullet Cameras – 2 reused, 2 back-ups		\$259.98	(\$259.98)
	SubConn Connectors (MacArtney) – ½ price donation	\$228.85	\$350.00	(\$228.85)
	Clear PVC Pipe			(\$6.00)
	Tape Measure	\$6.00		
	PVC Fittings			(\$125.00)
	Electrical Connectors			(\$35.00)
	Epoxy – Potting – ScotchCast			(\$52.74)
	Fasteners			(\$79.50)
	Tether – 150 ft CAT-5 and 100 ft Ultra Flex 8	\$75.00		(\$115.00)
	Heat Shrink			(\$47.00)
2	Heavy Duty Joystick		\$311.14	
2	Clear PVC 4” electronics housings		\$60.00	
1	Molykote 44 medium Grease			(\$16.21)
2	12 V Deep Cycle Marine Batteries – Car Quest	\$230.00		
6	Kort Nozzles, 1.5” – 3” couplers		\$41.25	
1	Linear Actuators		\$80.00	
2	Mechanical Plugs 4”		\$12.00	
	Control Box wood		\$18.50	
	Miscellaneous Wire – Hook-up Wire			(\$90.00)
6	1.5" Conduit hangers for thrusters			(\$32.17)
6	Thrusters		\$210.00	
	Plexiglas for camera lenses/control box		\$45.98	
3	Power Distribution Blocks		\$30.00	(\$14.00)
6	Props and Adapters		\$60.00	
2	Quad-splitter			(\$59.99)
16	Relays		\$164.26	
	Shop Supplies – Tape, silicone, nuts, bolts, screws, marine grease, etc			(\$75.30)
	Solder			(\$15.00)
	ROV Team Television/Monitor		\$300.00	
2	Aluminum Endcaps			(\$500.00)
	<b>Totals*</b>	<b>\$539.85</b>	<b>\$1963.61</b>	<b>\$96.28</b>





### ***Interpersonal***

FDS has also faced a non-technical problem 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.

With this year's manipulator, simplicity was our main goal. As a result, this rigid tool has no axes of motion, therefore rendering itself incapable of performing meticulous tasks, putting more pressure on the pilot. In the future, FDS plans to incorporate multiple axes of motion while keeping the design compact and efficient.

### **Lessons Learned**

#### ***Technical***

As in years past we focused on machining our own parts. All of the custom PVC parts, such as the core sampler, and all custom metal parts, such as the fingers on the manipulator, were designed and manufactured by FDS. This developed important power tool skills as well as an appreciation for precision and accuracy. Brainstorming spurred competition and produced a think tank-like working environment.

Valuable experience was gained while designing the control system. Placing relays in the ROV itself gave vital experience to the design team that will be used next year to complete our three-year upgrade plan.

#### ***Interpersonal***

One of the first lessons we learned concerns time management. If we had started our planning earlier, we would have known what parts to order based on our design. 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 learned that 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.

## Reflections

### *Heather Wells*



ROV has positively affected my future as a student and an individual. With a club that requires such depth of thought and problem solving skills, ROV has taught me that no situation can go unsolved. During my one year run with the ROV team, I have gained knowledge of aquatic electronic and engineering techniques that aided in the completion of the machine. With the manufacturing of an ROV, a hands-on approach has given me immense familiarity with power tools. Working in a garage with seven other individuals has proven valuable to group problem solving as well as timely task completion. My involvement with the team has given me comfort in public speaking and presentation, which will prove a valuable asset in college and beyond. All lessons from ROV have proven invaluable to my future as a student and individual.

### *Matthew Thibodeau*



This is my third year in ROV club, and it has really been a great one. As electrical engineer, I have learned much about the concepts and applications of electrical systems. Additionally, I have become well versed in the operation of many new tools, from shop machines to CAD software. The club has also reinforced my passion for engineering and mathematics. As team captain, I have gained invaluable “people skills” and have done my best to ensure a fair distribution of jobs between all the team members. My experience with the team has been beyond what I ever could have expected, and has been a positive influence on my character. I am fortunate enough to be team captain this year, but by no means does that mean that I am the most important team member. As I see it, every single member of the team is invaluable for his or her expertise and experience. I am so lucky to have found such a great group of friends.



Photo: Thomas



## References

MATE Competition Home <http://www.marinetech.org/rov-competition-2/>  
Thunder Bay National Marine Sanctuary <http://thunderbay.noaa.gov/>

## ***Construction Resources***

Electrical Wiring: <http://www.homebuiltrovs.com/>  
Underwater Cable Connectors: <http://www.subconn.com/>  
Clear PVC: [http://www.clearpvcpipe.com/?gclid=CN\\_NhoXG8qECFRUhnAodtiGUnA](http://www.clearpvcpipe.com/?gclid=CN_NhoXG8qECFRUhnAodtiGUnA)  
Linear Actuators: <http://www.firgelli.com/>  
Black PVC Fittings: <http://www.flexpvc.com/>  
Cameras: <http://www.supercircuits.com/>  
General construction Supplies <http://www.mcmaster.com/>

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

Hometown Ace Hardware  
CarQuest of Kill Devil Hills and Grandy  
Mark Nixon – Machinist Extraordinaire – Spencer Yachts  
Mr. Thomas' Garage and Pool

## Acknowledgements



**MATE**

M A R I N E  
A D V A N C E D  
T E C H N O L O G Y  
E D U C A T I O N  
C E N T E R



### **Local Donations**

Dare County Board Of Education - \$2500

Gray's Department Store - \$1300

Monica Thibodeau, Carolina Designs Realty - \$500

Anne Hunter - \$200

Joe Lamb Realty - \$100

CarQuest of Kill Devil Hills and Grandy, NC - \$300

The Coastal Studies Institute – printing our Regional Competition Poster (soon our International)



Appendices – CAD, Safety, SID

Appendix A – Endcap Technical Drawings  
 Overview

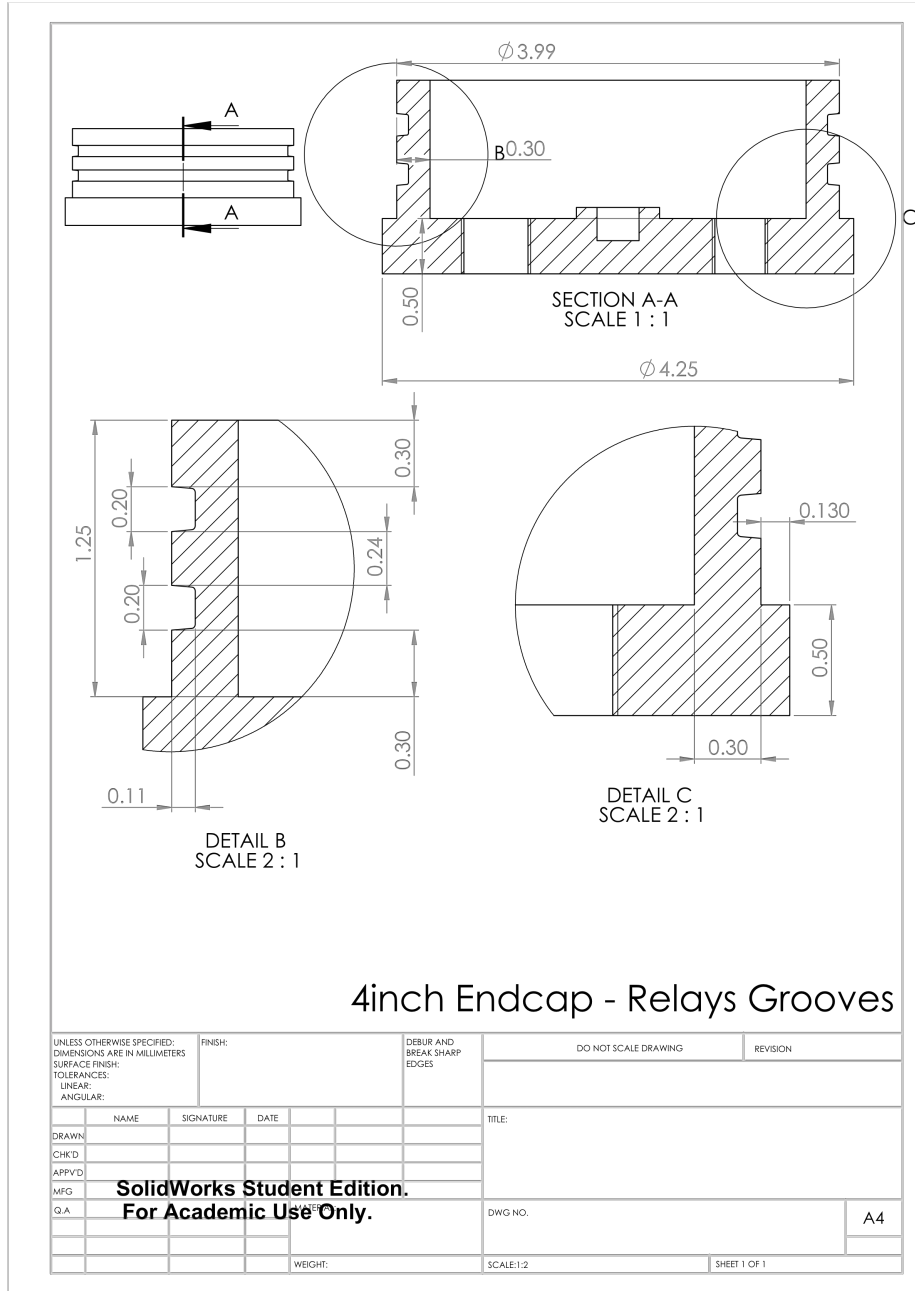
The technical drawing illustrates a 4-inch endcap through four distinct views:
 

- Front View:** Shows the endcap as a series of stacked horizontal plates with a central vertical slot.
- Top View:** A circular view showing the endcap's profile with five small circular features arranged in a cross pattern.
- Isometric View:** A 3D perspective view of the endcap, showing its cylindrical shape and the internal features.
- Bottom View:** A circular view from the reverse side, showing the same five circular features as the top view.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS		FINISH:		DEBUR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING		REVISION		
SURFACE FINISH:		TOLERANCES:		LINEAR:		ANGULAR:		TITLE:		
DRAWN	NAME	SIGNATURE	DATE							
CHK'D										
APP'VD	<b>SolidWorks Student Edition.                  For Academic Use Only.</b>									
MFG										
Q.A.									DWG NO: 4inch Endcap - Relays Overview	
				WEIGHT:		SCALE: 1:2		SHEET 1 OF 1		



Groove Detail

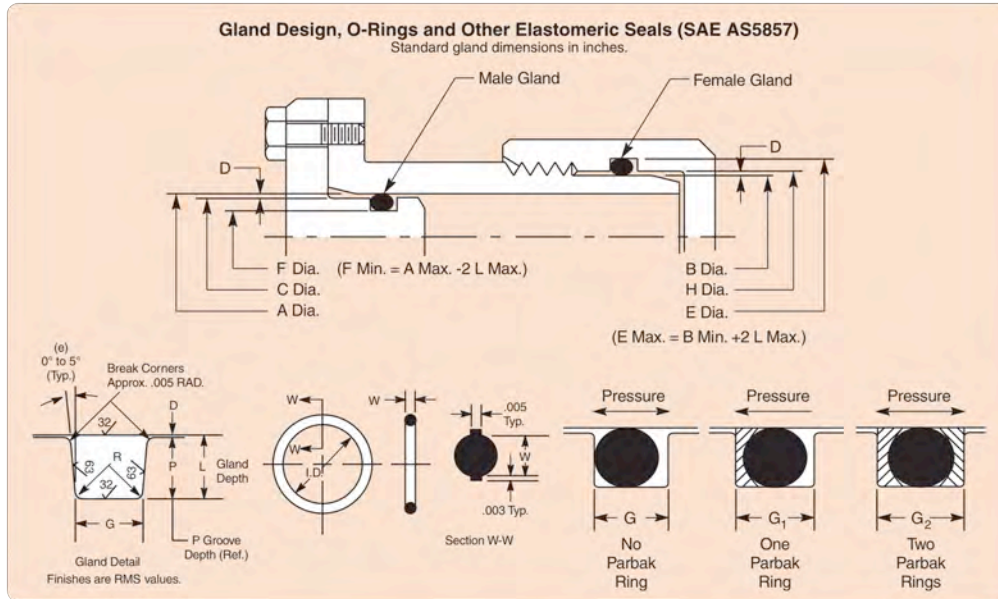


*Note- To save space, Appendix A only includes drawings of one of the two endcaps. Both are identical except for the hole pattern – the shown endcap has four threaded holes for penetrators, while the other (not shown) cap has two. The center hole is present on both, and is for a threaded rod.*

Appendix B –Parker O-Ring Handbook (Excerpt)

Parker O-Ring Handbook

Static O-Ring Sealing



**Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)**

Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E	Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E
001	0.084	0.087	0.035	0.033	0.036	0.087	014	0.611	0.615	0.506	0.498	0.501	0.608
	0.083	0.086	0.034	0.032	0.035	0.086		0.610	0.613	0.504	0.496	0.500	0.606
002	0.116	0.119	0.048	0.048	0.051	0.119	015	0.673	0.677	0.568	0.560	0.563	0.670
	0.115	0.118	0.047	0.047	0.050	0.118		0.672	0.675	0.566	0.558	0.562	0.668
003	0.149	0.152	0.063	0.063	0.066	0.152	016	0.736	0.740	0.631	0.623	0.626	0.733
	0.148	0.151	0.062	0.062	0.065	0.151		0.735	0.738	0.629	0.621	0.625	0.731
004	0.183	0.186	0.078	0.076	0.079	0.185	017	0.798	0.802	0.693	0.685	0.688	0.795
	0.182	0.185	0.077	0.075	0.078	0.184		0.797	0.800	0.691	0.683	0.687	0.793
005	0.215	0.218	0.110	0.108	0.111	0.217	018	0.861	0.865	0.756	0.748	0.751	0.858
	0.214	0.217	0.109	0.107	0.110	0.216		0.860	0.863	0.754	0.746	0.750	0.856
006	0.228	0.231	0.123	0.123	0.126	0.232	019	0.923	0.927	0.818	0.810	0.813	0.920
	0.227	0.230	0.122	0.122	0.125	0.231		0.922	0.925	0.816	0.808	0.812	0.918
007	0.259	0.262	0.154	0.154	0.157	0.263	020	0.989	0.993	0.884	0.873	0.876	0.983
	0.258	0.261	0.153	0.153	0.156	0.262		0.988	0.991	0.882	0.871	0.875	0.981
008	0.291	0.294	0.186	0.185	0.188	0.294	021	1.051	1.055	0.946	0.935	0.938	1.045
	0.290	0.293	0.185	0.184	0.187	0.293		1.050	1.053	0.944	0.933	0.937	1.043
009	0.324	0.327	0.219	0.217	0.220	0.326	022	1.114	1.118	1.009	0.998	1.001	1.108
	0.323	0.326	0.218	0.216	0.219	0.325		1.113	1.116	1.007	0.996	1.000	1.106
010	0.355	0.358	0.250	0.248	0.251	0.357	023	1.176	1.180	1.071	1.060	1.063	1.170
	0.354	0.357	0.249	0.247	0.250	0.356		1.175	1.178	1.069	1.058	1.062	1.168
011	0.418	0.421	0.313	0.310	0.313	0.419	024	1.239	1.243	1.134	1.123	1.126	1.233
	0.417	0.420	0.312	0.309	0.312	0.418		1.238	1.241	1.132	1.121	1.125	1.231
012	0.483	0.486	0.378	0.373	0.376	0.482	025	1.301	1.305	1.196	1.185	1.188	1.295
	0.482	0.485	0.377	0.372	0.375	0.481		1.300	1.303	1.194	1.183	1.187	1.293
013	0.548	0.552	0.443	0.435	0.438	0.545	026	1.364	1.368	1.259	1.248	1.251	1.358
	0.547	0.550	0.441	0.433	0.437	0.543		1.363	1.366	1.257	1.246	1.250	1.356

Design Table 4-1: Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)



Parker Hannifin Corporation • O-Ring Division  
 2360 Palumbo Drive, Lexington, KY 40509  
 Phone: (859) 269-2351 • Fax: (859) 335-5128  
 www.parkerorings.com

Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857) (Continued)													
Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E	Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E
215	1.301	1.305	1.079	1.060	1.063	1.288							
	1.300	1.303	1.077	1.058	1.062	1.286							
216	1.364	1.368	1.142	1.123	1.126	1.351							
	1.363	1.366	1.140	1.121	1.125	1.349							
217	1.426	1.430	1.204	1.185	1.188	1.413							
	1.425	1.428	1.202	1.183	1.187	1.411							
218	1.489	1.493	1.267	1.248	1.251	1.476							
	1.488	1.491	1.265	1.246	1.250	1.474							
219	1.551	1.555	1.329	1.310	1.313	1.538							
	1.550	1.553	1.327	1.308	1.312	1.536							
220	1.614	1.618	1.392	1.373	1.376	1.601							
	1.613	1.616	1.390	1.371	1.375	1.599							
221	1.676	1.680	1.454	1.435	1.438	1.663							
	1.675	1.678	1.452	1.433	1.437	1.661							
222	1.739	1.743	1.517	1.498	1.501	1.726							
	1.738	1.741	1.515	1.496	1.500	1.724							
223	1.864	1.869	1.643	1.623	1.627	1.851							
	1.863	1.867	1.641	1.621	1.625	1.849							
224	1.989	1.994	1.768	1.748	1.752	1.976							
	1.988	1.992	1.766	1.746	1.750	1.974							
225	2.115	2.120	1.894	1.873	1.878	2.101							
	2.114	2.118	1.892	1.871	1.876	2.099							
226	2.240	2.245	2.019	1.998	2.003	2.226							
	2.239	2.243	2.017	1.996	2.001	2.224							
227	2.365	2.370	2.144	2.123	2.128	2.351							
	2.364	2.368	2.142	2.121	2.126	2.349							
228	2.490	2.495	2.269	2.248	2.253	2.476							
	2.488	2.493	2.267	2.246	2.251	2.474							
229	2.615	2.620	2.394	2.373	2.378	2.601							
	2.613	2.618	2.392	2.371	2.376	2.599							
230	2.740	2.745	2.519	2.498	2.503	2.726							
	2.738	2.743	2.517	2.496	2.501	2.724							
231	2.865	2.870	2.644	2.623	2.628	2.851							
	2.863	2.868	2.642	2.621	2.626	2.849							
232	2.990	2.995	2.769	2.748	2.753	2.976							
	2.988	2.993	2.767	2.746	2.751	2.974							
233	3.115	3.120	2.894	2.873	2.878	3.101							
	3.113	3.118	2.892	2.871	2.876	3.099							
234	3.240	3.245	3.019	2.997	3.002	3.225							
	3.238	3.243	3.017	2.995	3.000	3.223							
235	3.365	3.370	3.144	3.122	3.127	3.350							
	3.363	3.368	3.142	3.120	3.125	3.348							
236	3.490	3.495	3.269	3.247	3.252	3.475							
	3.488	3.493	3.267	3.245	3.250	3.473							
237	3.615	3.620	3.394	3.372	3.377	3.600							
	3.613	3.618	3.392	3.370	3.375	3.598							
238	3.740	3.745	3.519	3.497	3.502	3.725							
	3.738	3.743	3.517	3.495	3.500	3.723							
239	3.865	3.870	3.644	3.622	3.627	3.850							
	3.863	3.868	3.642	3.620	3.625	3.848							
240	3.990	3.995	3.769	3.747	3.752	3.975							
	3.988	3.993	3.767	3.745	3.750	3.973							
241	4.115	4.120	3.894	3.872	3.877	4.100							
	4.113	4.118	3.892	3.870	3.875	4.098							
242	4.240	4.245	4.019	3.997	4.002	4.225							
	4.238	4.243	4.017	3.995	4.000	4.223							
243	4.365	4.370	4.144	4.122	4.127	4.350							
	4.363	4.368	4.142	4.120	4.125	4.348							
244	4.489	4.495	4.269	4.247	4.252	4.475							
	4.487	4.493	4.267	4.245	4.250	4.473							
245	4.614	4.620	4.394	4.372	4.377	4.600							
	4.612	4.618	4.392	4.370	4.375	4.598							
246	4.739	4.745	4.519	4.497	4.503	4.725							
	4.737	4.743	4.517	4.495	4.501	4.723							
247	4.864	4.870	4.644	4.622	4.628	4.850							
	4.862	4.868	4.642	4.620	4.626	4.848							
325	1.864	1.869	1.523	1.498	1.502	1.848							
	1.863	1.867	1.521	1.496	1.500	1.846							
326	1.989	1.994	1.648	1.623	1.627	1.973							
	1.988	1.992	1.646	1.621	1.625	1.971							
327	2.115	2.120	1.774	1.748	1.752	2.098							
	2.114	2.118	1.772	1.746	1.750	2.096							
328	2.240	2.245	1.899	1.873	1.878	2.223							
	2.239	2.243	1.897	1.871	1.876	2.221							
329	2.365	2.370	2.024	1.998	2.003	2.348							
	2.364	2.368	2.022	1.996	2.001	2.346							
330	2.490	2.495	2.149	2.123	2.128	2.473							
	2.488	2.493	2.147	2.121	2.126	2.471							
331	2.615	2.620	2.274	2.248	2.253	2.598							
	2.613	2.618	2.272	2.246	2.251	2.596							
332	2.740	2.745	2.399	2.373	2.378	2.723							
	2.738	2.743	2.397	2.371	2.376	2.721							
333	2.865	2.870	2.524	2.498	2.503	2.848							
	2.863	2.868	2.522	2.496	2.501	2.846							
334	2.990	2.995	2.649	2.623	2.628	2.973							
	2.988	2.993	2.647	2.621	2.626	2.971							
335	3.115	3.120	2.774	2.748	2.753	3.098							
	3.113	3.118	2.772	2.746	2.751	3.096							
336	3.240	3.245	2.899	2.873	2.878	3.223							
	3.238	3.243	2.897	2.871	2.876	3.221							
337	3.365	3.370	3.024	2.997	3.002	3.347							
	3.363	3.368	3.022	2.995	3.000	3.345							
338	3.490	3.495	3.149	3.122	3.127	3.472							
	3.488	3.493	3.147	3.120	3.125	3.470							
339	3.615	3.620	3.274	3.247	3.252	3.597							
	3.613	3.618	3.272	3.245	3.250	3.595							
340	3.740	3.745	3.399	3.372	3.377	3.722							
	3.738	3.743	3.397	3.370	3.375	3.720							
341	3.865	3.870	3.524	3.497	3.502	3.847							
	3.863	3.868	3.522	3.495	3.500	3.845							
342	3.990	3.995	3.649	3.622	3.627	3.972							
	3.988	3.993	3.647	3.620	3.625	3.970							
343	4.115	4.120	3.774	3.747	3.752	4.097							
	4.113	4.118	3.772	3.745	3.750	4.095							
344	4.240	4.245	3.899	3.872	3.877	4.222							
	4.238	4.243	3.897	3.870	3.875	4.220							
345	4.365	4.370	4.024	3.997	4.002	4.347							
	4.363	4.368	4.022	3.995	4.000	4.345							

Design Table 4-1: Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)

Static O-Ring Sealing





## Appendix C – 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 D – FDS 2014 Systems Integration Diagram (SID)

