Post Access Report

A Tow Body Optical Camera System

Awardee: Igiugig Village Council

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EXECUTIVE SUMMARY

The Igiugig Village Council (IVC) installed and operates a marine energy device, the ORPC RivGen® Power System, in the Kvichak River in Igiugig, Alaska. As required by IVC's 2019 FERC license to operate the power system, a Fish Monitoring Plan was developed and implemented for collecting images from underwater cameras to assess the interaction of sockeye salmon with the RivGen Power System. The underwater camera system, however, has not performed reliably over the year-long deployment with multiple camera failures and issues with fiber optic communications occurring regularly.

In search of a solution to the problematic underwater camera system, IVC submitted a TEAMER application, "A Tow Body Optical Camera System (Project)," to develop an alternative and independent camera monitoring approach working with University of Washington. The proposed design would create a tow body for stabilized image acquisition that could be deployed over and adjacent to the turbine. The proposed tow body would be maintained in place by an anchored vessel, which would also record the data streamed by the camera system. The images would be used in EyeSea detection software developed by the Pacific Northwest National Laboratory (PNNL). The Project would focus on providing specifications and basic design for a system that would be able to obtain high resolution images for assessing fish interactions with a stationary and rotating turbine set. The ultimate goal, which extends beyond the scope of the application, would be to deploy the system in the Kvichak River during two critical fish migration periods—when sockeye salmon smolt move downriver and when adult sockeye salmon migrate upriver.

At Project completion, the tow body camera system was designed by University of Washington's Applied Physics Laboratory (UW-APL) design team for IVC. The design will allow for a wide range of viewing angles and deployment locations of the machine vision optical system for monitoring the RivGen turbine. This system may be deployed from a small vessel with minimal infrastructure or personnel requirements. If future funding is available to build and test the system, UW-APL will be able to perform all or part of the fabrication, assembly, and testing tasks. The cost of the system components, along with these tasks at UW-APL was included in the bill of materials. Similarly, software support for data acquisition and processing will be available through UW-APL or TEAMER network facility partner MarineSitu. Due to long lead times on some of the system components (particularly the underwater cabling and connectors) it was recommended to allow approximately four months for system delivery.

In addition to the site-specific application at Igiugig, the UW-APL design is applicable to a wide range of uses as a stand-alone and deployable from any small vessel of opportunity. It may also be applied to many other optical monitoring use cases; optical monitoring of marine turbines is the best way to address regulatory concerns around animal interactions and advance the industry's understanding of these risks.

Design of this tow body camera system was completed as proposed, except the completion date was delayed due to lack of personnel availability because of delays on prior unrelated projects.

Regarding next steps that would build off completed work, IVC is considering applying to TEAMER for testing of the design and will search for additional funding to build the device.

1 Introduction to the Project

IVC operates the ORPC RivGen® Power System, installed in the Kvichak River, under a FERC license and an approved Fish Monitoring Plan. For the device to operate during critical fish migration periods and to be in compliance with regulations from state and federal agencies, it is necessary that fish detection cameras be functional, and that data be immediately available. Although the Kvichak River is uniquely suited to camera methodologies due to water clarity, the present camera installation has proven to be difficult.

IVC has reached a juncture where it is critical to solve the fish monitoring issues for the following reasons:

- Improving system availability which directly affects an installation's levelized cost of energy
- Proving ability to continuously displace diesel generation
- Demonstrating the interactions between marine energy devices and the environment to regulatory agencies
- Retiring risk of the marine energy device technology

IVC proposed to seek technical support from experts to design an appropriate tow body that would support the deployment of an optical camera system for imaging in the vicinity of the ORPC RivGen turbine. The design team from UW-APL proposed to provide the technical specifications suitable for fabrication and deployment of the optical camera system.

Details about the requirements for such a system and the products that were provided by UW-APL are summarized in the Section 5 Test or Analysis Article Description.

2 Roles and Responsibilities of Project Participants

AlexAnna Salmon – President, Igiugig Village Council
Project Lead

Jarlath McEntee – ORPC, Inc. Senior Vice President & Chief Technology Officer
Technical Advisor of RivGen Power System

Kerry Strout Grantham – ORPC, Inc. Development Services Manager
ORPC Environmental Manager & TEAMER Application Coordinator

Dr. Christopher Bassett – University of Washington, Applied Physics Laboratory
Design Team

Dr. James Joslin – University of Washington, Applied Physics Laboratory
Design Team

Paul Gibbs – University of Washington, Applied Physics Laboratory
Design Team

Cassandra Riel – University of Washington, Applied Physics Laboratory
Design Team

2.1 Applicant Responsibilities and Tasks Performed

IVC and ORPC supported UW-APL staff in providing technical information about the current camera system design, available assets in Igiugig for tow body design, and technical review of the test plan.

2.2 Network Facility Responsibilities and Tasks Performed

UW-APL provided complete design specifications and documentation for an optical camera system deployable on a small tow body platform from an anchored, small vessel for monitoring the RivGen turbine. The deployment platform was designed to ensure image stability with depth and orientation control for optimal field of view positioning. Additional considerations were made for turbine protection, ease of deployment/recovery, maintenance in the Igiugig environment, and data transfer requirements. The specifications included the optical cameras and lighting, the tow body platform, cabling, power supply, control computer, and data acquisition software. This complete specification will make the system stand-alone and deployable from any small vessel of opportunity, thus making its design applicable to a wide range of uses. UW-APL's expertise with complete marine system design from custom mechanical components to software for real-time data acquisition and processing makes them ideally suited for this task.

Further assistance, once field testing is available, may include custom component fabrication, tank or vessel testing, deployment planning, and customization of real-time data processing software.

3 Project Objectives

The Project objective was to design an appropriate tow body to support the deployment of an optical camera system for fish monitoring imaging in the vicinity of the RivGen device. The camera system installed in the Kvichak has proven unreliable. Benchtop testing has not been able to reproduce the failures, and the cameras have not been accessible since deployment.

To date IVC has worked with University of Alaska Fairbanks, Pacific Northwest National Laboratory, University of Washington, and ORPC to develop a protocol for fish monitoring:

- UAF provided insight on what constitutes meaningful data in this context
- MarineSitu, a University of Washington spinoff company, provided software for image collection from multiple cameras
- PNNL provided database and image processing tools to help identify interactions
- ORPC provided technical and permitting support in implementing these systems

The UW-APL design team provided technical specifications suitable for the fabrication and deployment of the system. Optical and acoustic sensing packages were developed by UW-APL for a variety of different deployments and applications. These results have been summarized in number of peer reviewed publications and conference abstracts on imaging capabilities and system endurance.

4 Test Facility, Equipment, Software, and Technical Expertise

The UW-APL Ocean Engineering department has considerable experience with various aspects of marine energy research and the development of instrumentation packages. Multiple researchers have been previously involved with aspects of the Project in Igiugig and were familiar with the challenges of operations at the site. UW-APL's expertise with complete marine system design made them ideally suited for this work.

For the design of this tow-body camera system, UW-APL leveraged the experience of Dr. James Joslin and Paul Gibbs working with similar marine systems such as the machine vision camera system for the Adaptable Monitoring Package and tow bodies for sonar surveys. Specification of the camera system components, control computer, and data acquisition software emphasized reliability and sought to minimize system cost and complexity while meeting the system requirements. To determine system stability during deployments, dynamic simulation software (ProteusDS) was used to assess the tow-body's hydrodynamics.

5 Test or Analysis Article Description

This Project objective was to design a tow body camera system to monitor fish interactions with the RivGen device. The design emphasized the ease of use and control of the camera field of view to capture the best image quality possible. While this system was designed for the RivGen device, the design may be applied to many other optical monitoring use cases. Optical monitoring of marine turbines is the best way to address regulatory concerns around animal interactions and advance the industry's understanding of these risks. As is the case for the RivGen device, performing this type of optical monitoring may be a requirement for operation.

The camera system design incorporated machine vision cameras and lights with a tow body platform that will be easily deployable from a small vessel. Figure 1 shows an example of Allied Vision cameras along with a custom PVC underwater camera housing that would be suitable to this design. Paired with LED lights, this camera system will be connected to the vessel by a single power and Ethernet deployment cable. Onboard the vessel, a computer and power supply will be used to operate the camera system and control the image acquisition during the deployment.

Figure 1 - Allied Vision Manta machine vision cameras with a custom PVC underwater housing.

The tow-body was designed to maintain stability and capture high quality images during deployments. Figure 2 shows an example of a tow body designed for similar deployments. The structure included control surfaces to orient the system at the desired depth and standoff from the turbine structure. Adjustable mounting points allowed for the camera system to be oriented in different configurations depending on deployment requirements. A variety of tow points were integrated in the tow-body to allow various tow configurations to match specific situations.

Figure 2 - Example tow body designed for video camera systems.

6 Work Plan

The Project goal was to provide a complete design package for a tow body camera system that would be deployable from a small vessel for monitoring fish interactions with a marine energy device. This effort was computer based and did not involve any fabrication or testing of the designed equipment. The final deliverables included design specifications and materials to enable rapid fabrication and use of the system given availability of funding. The design process started with the development of a specifications document for the system requirements. Components were then selected for the available commercial off-the-shelf (COTS) products, and the mechanical design of the custom components began. After the preliminary design was completed, it was modelled in ProteusDS to ensure that the requirements were achieved. Finally, the completed design will be used to develop the fabrication and assembly documents.

6.1 Experimental Setup, Data Acquisition System, and Instrumentation

For the purposes of this test plan, the experimental setup described below outlines how the designed system is intended for use; however, testing was not completed as part of this effort.

During periods where optical monitoring of the RivGen device is required for critical fish migrations and the onboard cameras are not available, this camera system may act as a substitute. For deployment, a small vessel will anchor upstream of the turbine at a pre-determined location to allow the camera system to be properly positioned. Figure 3 illustrates the proposed deployment configuration. The camera system will be powered from a small generator or battery bank on board the vessel and controlled by a computer on board. The tow body will be lowered into the water by the user with a deployment cable to the desired depth and position relative to the turbine. Once in position, with the desired field of view confirmed by the operator, the acquisition software will be set to run for the duration of the deployment. Recovery of the system will involve hauling the tow body back aboard the vessel before returning to shore. Post processing of the acquired imagery may be performed to identify any fish/turbine interactions of interest.

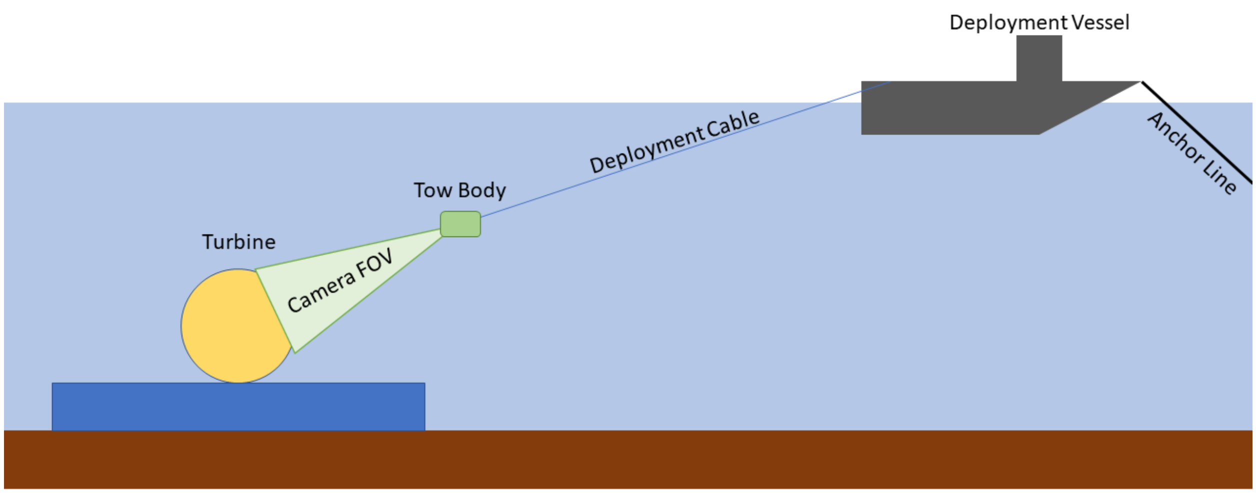

Figure 3 - Deployment diagram showing turbine structure, tow body camera system, and deployment vessel.

6.2 Numerical Model Description

A computer aided design (CAD) model of the tow body camera system was completed in SolidWorks, and hydrodynamic stability of the system was modelled in ProteusDS. SolidWorks models included the cameras, lenses, lights, housings, camera fields of view, cabling, and tow body structure. Control surfaces on the tow body system will provide stability and may be adjusted to control the camera's field of view of the turbine. Camera mounting points will also include options for changing the orientation on the tow body structure. These CAD models may be used for structural analysis of critical components if necessary, using finite element analysis. Custom component drawings, as well as assembly drawings, were made from the CAD models.

Dynamic simulations of the tow body in the river flow were performed in ProteusDS to determine system stability and placement of control surfaces. The modeling captures the range of river currents and includes the deployment cable and tow body structure as a rigid body.

6.3 Test and Analysis Matrix and Schedule

The schedule in Table 1 assumed that the design process would start in early January. There were, however, delays in the schedule due to lack of personnel caused by delays on previous unrelated projects.

Table 1. *TEAMER Schedule*

Design Task	Month	January				February				March			
	Week	1	2	3	4	1	2	3	4	1	2	3	4
Component specification													
CAD modeling													
Dynamic simulation													
Design document preparation													

6.4 Safety

Safety protocols were not required as all Project efforts were computer based.

6.5 Contingency Plans

Contingency plans were not needed as the Project was entirely a computer-based design effort.

6.6 Data Management, Processing, and Analysis

6.6.1 Data Management

Project data products included the following documents, which UW-APL provided as deliverables to IVC at the end of the Project:

- Design specifications document
- Bill of materials with component sources and costs
- Custom component machine drawings for fabrication
- Assembly instructions

6.6.2 Data Processing

Data processing was not required for this Project.

6.6.3 Data Analysis

Data analysis was not required for this Project.

7 PROJECT OUTCOMES

7.1 RESULTS

The tow body camera system designed for this Project is shown in Figures 4 and 5. The system included the stereo optical camera system with two lights and control bottle (Figure 6). The tow body design will allow for mounting of the camera system in forward, rear, sideways, or angled orientations with adjustable tilt of the fields of view. This adjustability will allow this design to be used from any viewing location that is above the target. As indicated in Figure 4, the design included adjustable elevators and multiple tow connection points to control the bodies' orientation at different current speeds. The overall form of the tow body was designed to protect the camera system while leaving the field of view unobstructed. Flat panels connected by angle brackets made up the majority of the design to minimize production time and cost. In addition, the hydrodynamic profile does not change with different camera configurations, allowing the same body to be used for all mounting options. As a backup depth limiting option, a float may be attached to the tow rail on a short line that would guarantee that the system does not drop into the rotor swept area of the turbine.

The design package for the tow body included the CAD model, mechanical drawings for fabrication of custom parts (as *.PDFs), and line drawings for laser cut or waterjet parts (as *.DXFs).

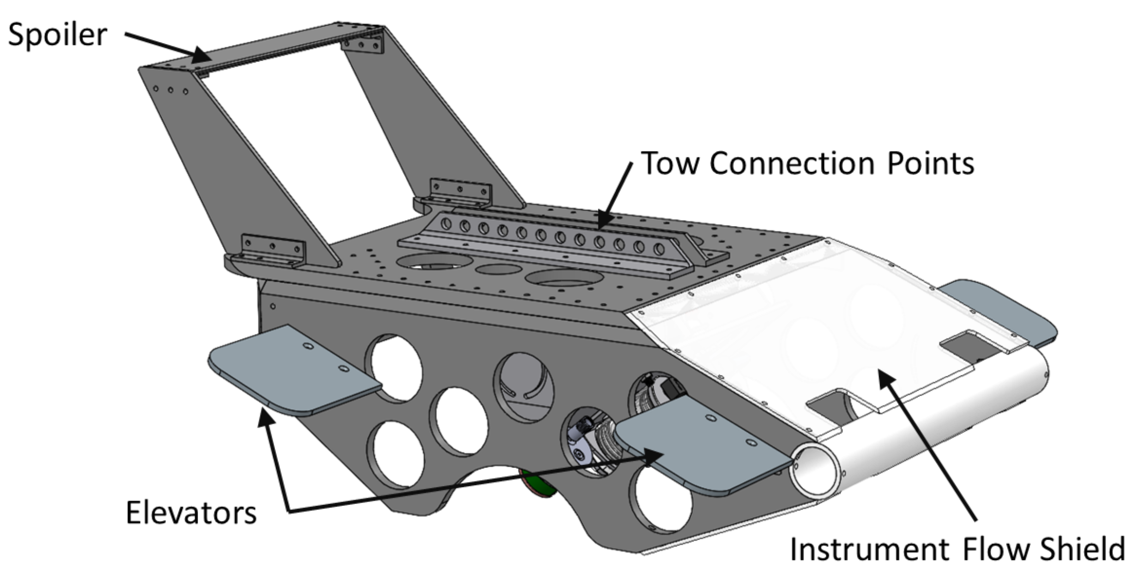

Figure 4 - Tow body design with control features.

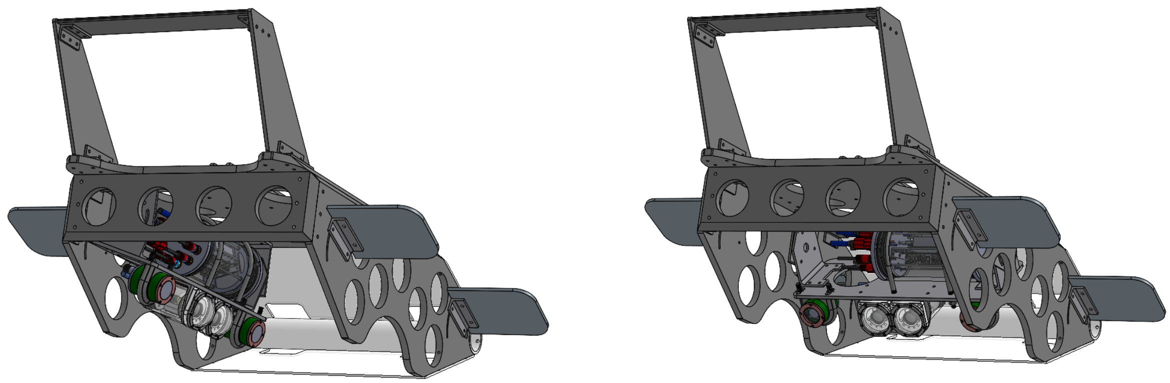

Figure 5 - Tow body with starboard side facing and back facing camera mounts.

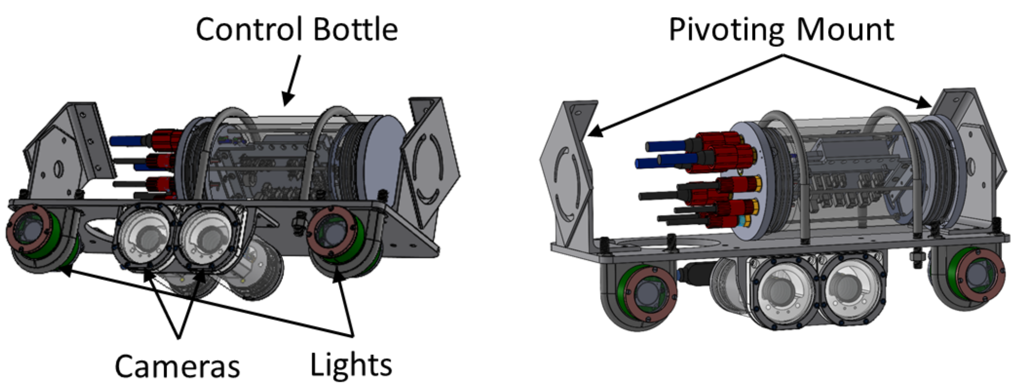

Figure 6 - Camera system on tow body mount.

The camera system included two machine vision cameras and two high power LED lights along with a control bottle. These components were specified as either an UW-APL built option or using COTS components. Details for all components were provided in the bill of materials included in the Appendix. The UW-APL option included custom housings and electronics for instrument control. Alternatively, the same structure will work with Sexton housings for the cameras, Deep Sea Power and Light LED SeaLites, and a BlueRobotics control housing with an Ethernet switch and relay control board. Custom data acquisition software (Stereo Vision) will be available either through UW-APL or TEAMER network facility partner MarineSitu if funding is available for system fabrication and testing.

Deck controls for this system included a portable computer, power supply, umbilical cable, and the deployment line on a DC winch. Potential low-cost options for these components were provided in the bill of materials although the selection will depend on the deployment vessel and parts that may already be available.

Table 2 shows a summary of the bill of materials for the cost of the major components of the system and the remaining tasks performed by UW-APL. For more details, please see the full bill of materials in the Appendix or in the design package. The majority of the system cost was in the camera system, which could be reduced by limiting the system to one camera or switching the housings for lower cost BlueRobotics options. The tasks for fabrication and assembly, tank testing, and field testing as performed by UW-APL included use of a saltwater test tank for camera calibration and a small vessel for towing and stability performance testing.

Table 2 - *Summary bill of materials.*

TEAMER IVC/ORPC Camera Tow Body: Summary			
	Cost		
	Option 1	Option 2	Notes
Camera System	$19,196	$18,153	
Tow Body	$2,805		
Deck Controls	$1,927		Does not include generator
Fabrication and Assembly	$14,426		Support for ordering parts, fabrication of custom parts, and system assembly
Tank Testing	$10,991		In water testing to confirm operations and camera calibration
Field Testing	$7,246		Vessel testing to confirm tow orientation
Totals:	**$56,591**	**$55,548**	

7.2 Lesson Learned and Test Plan Deviation

Design of this tow body camera system was completed as proposed, except the completion date was delayed due to lack of personnel availability because of delays on prior unrelated projects.

8 Conclusions and Recommendations

The tow body camera system designed for IVC will allow for a wide range of viewing angles and deployment locations of the machine vision optical system for monitoring fish interaction with the RivGen device. This system can be deployed from a small vessel with minimal infrastructure or personnel requirements.

When funding is available to build and test the system, UW-APL will be able to perform all or part of the fabrication, assembly, and testing tasks. The cost of the system components, along with these tasks at UW-APL, was included in the bill of materials. Similarly, software support for data acquisition and processing will be available through UW-APL or TEAMER network facility partner MarineSitu. Due to long lead times on some of the system components (particularly the underwater cabling and connectors), it is recommended to allow approximately four months for system delivery.

Testing & Expertise for Marine Energy

9 Appendix

- Bill of Materials:

TEAMER IVC/ORPC Camera Tow Body: Summary			
	Cost		
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Camera System	$19,196	$18,153	
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Field Testing	$7,246		Vessel testing to confirm tow orientation
Totals:	**$56,591**	**$55,548**	

Camera System for Option 1: COTS Electronics Assembly							
						Total:	$19,196.00
Category	**Part**	**Part Number**	**Manufacturer**	**Description**	**Cost**	**Quantity**	**Total Cost**
Cameras	Machine Vision Camera	BFS-PGE-50S5M-C	FLIR	Blackfly S GigE 5.0 MP, 22 FPS, Sony IMX264, Mono	$835.00	2	$1,670.00
Cameras	Lens	KOW-LM5JCM	Kowa	Model: BFS-PGE-50S5M-C: 5.0 MP, 22 FPS, Sony IMX264, Mono	$464.00	2	$928.00
Cameras	Camera I/O Cable	ACC-01-3009	FLIR	Hirose HR10 (6 Pin) GPIO cable	$25.00	2	$50.00
Cameras	Camera Housing		APL Custom	PVC 4.5" housing with dome view port	$2,500.00	2	$5,000.00
Lights	Light		APL Custom	High Power LED Array in Custom Housing	$2,000.00	2	$4,000.00
Controller	Camera Control Housing		APL Custom	PVC 6" housing	$1,500.00	1	$1,500.00
Controller	Camera Controller		APL Custom	Custom Controller	$500.00	1	$500.00

Controller	Ethernet Switch		Netgear	5 port Gigabit Ethernet Switch	$21.00	1	$21.00
Bulkhead	Umbilical Bulkhead	DBH13M	McCartney Subconn	13 Contact Male Power and Ethernet	$207.00	1	$207.00
Bulkheads	Camera Bulkhead	DBH13F	McCartney Subconn	13 Contact Female Power and Ethernet	$250.00	2	$500.00
Bulkheads	Light Bulkhead	MCBH6F	McCartney Subconn	5 Contact Micro Circular	$110.00	2	$220.00
Cables	Camera to Controller		McCartney Subconn	DIL13F//DLSA-F//1m D/P cable//DLSA-M//DIL13M	$500.00	2	$1,000.00
Cables	Light to Controller		McCartney Subconn	MCIL6F to MCIL6M, 1 m	$300.00	2	$600.00
Cables	Surface Umbilical		McCartney Subconn	DIL13F//DLSA-F//30m D/P cable	$3,000.00	1	$3,000.00

Camera System for Option 2: COTS Electronics Assembly							
						Total:	$18,153.00
Category	**Part**	**Part Number**	**Manufacturer**	**Description**	**Cost**	**Quantity**	**Total Cost**
Cameras	Machine Vision Camera	BFS-PGE-50S5M-C	FLIR	Blackfly S GigE 5.0 MP, 22 FPS, Sony IMX264, Mono	$835.00	2	$1,670.00
Cameras	Lens	KOW-LM5JCM	Kowa	Model: BFS-PGE-50S5M-C: 5.0 MP, 22 FPS, Sony IMX264, Mono	$464.00	2	$928.00
Cameras	Camera I/O Cable	ACC-01-3009	FLIR	Hirose HR10 (6 Pin) GPIO cable	$25.00	2	$50.00
Cameras	Camera Housing		Sexton or Similar	Aluminum Enclosure with 4.5" dome port	$2,375.00	2	$4,750.00
Lights	Light	LSL-2000	Deep Sea Power and Light	LED SeaLite	$2,130.00	2	$4,260.00
Controller	Camera Control Housing		BlueRobotics	6" Acrylic Enclosure	$317.00	1	$317.00
Controller	Camera Controller		NCD-IO	4 channel solid state relay contoller	$630.00	1	$630.00
Controller	Ethernet Switch		Custom	5 port Gigabit Ethernet Switch	$21.00	1	$21.00
Bulkhead	Umbilical Bulkhead	DBH13M	McCartney Subconn	13 Contact Male Power and Ethernet	$207.00	1	$207.00

Bulkheads	Camera Bulkhead	DBH13F	McCartney Subconn	13 Contact Female Power and Ethernet	$250.00	2	$500.00
Bulkheads	Light Bulkhead	MCBH5F	McCartney Subconn	5 Contact Micro Circular	$110.00	2	$220.00
Cables	Camera to Controller		McCartney Subconn	DIL13F//DLSA-F//1m D/P cable//DLSA-M//DIL13M	$500.00	2	$1,000.00
Cables	Light to Controller		McCartney Subconn	MCILRA5F to MCIL 5M, 1 m	$300.00	2	$600.00
Cables	Surface Umbilical		McCartney Subconn	DIL13F//DLSA-F//30m D/P cable	$3,000.00	1	$3,000.00

Tow Body							
						Total:	$2,805.24
Category	**Part**	**Part Number**	**Manufacturer**	**Description**	**Cost**	**Quantity**	**Total Cost**
Frame	Top Plate		Custom	Waterjet 3/4" HDPT top plate with routed edges	$120.00	1	$120.00
Frame	Side Plate		Custom	Waterjet 3/4" HDPT side plates with routed edges, drilled and tapped edge holes	$120.00	2	$240.00
Frame	Front/top Plate		Custom	Lasercut 1/4" Plexiglass with countersunk holes	$50.00	1	$50.00
Frame	Front/bottom Plate		Custom	Lasercut 1/4" Plexiglass with countersunk holes	$50.00	1	$50.00
Frame	Front Pipe		Custom	3" PVD pipe cut to length and drilled mounting holes	$30.00	1	$30.00
Frame	Spoiler Riser		Custom	Lasercut 3/8" delrin with rounded edges	$50.00	2	$100.00
Frame	Spoiler		Custom	Lasercut 3/8" delrin with rounded edges	$50.00	1	$50.00
Frame	Elevator		Custom	Lasercut 3/8" delrin with rounded edges	$30.00	4	$120.00
Frame	Camera System		Custom	Lasercut 3/8" aluminum	$50.00	1	$50.00

	Mounting Plate						
Frame	Camera Mount Angle 1		Custom	Machined aluminum angle bracket	$150.00	1	$150.00
Frame	Camera Mount Angle 2		Custom	Machined aluminum angle bracket	$100.00	2	$200.00
Frame	Camera Mount Angle 3		Custom	Machined aluminum angle bracket	$100.00	2	$200.00
Frame	L bracket 1		Custom	Machined aluminum L bracket	$50.00	4	$200.00
Frame	L bracket 2		Custom	Machined aluminum L bracket	$50.00	2	$100.00
Frame	L bracket 3		Custom	Machined aluminum L bracket	$50.00	2	$100.00
Frame	L bracket 4		Custom	Machined aluminum L bracket	$50.00	2	$100.00
Frame	L bracket 5		Custom	Machined aluminum L bracket	$50.00	4	$200.00
Frame	L bracket 6		Custom	Machined aluminum L bracket	$50.00	2	$100.00
Frame	L bracket 7		Custom	Machined aluminum L bracket	$50.00	2	$100.00
Hardware	U-Bolt	8896T32	McMaster	Control bottle u-bolt	$27.43	2	$54.86
Hardware	U-Bolt	3176T71	McMaster	Light u-bolt	$29.99	2	$59.98
Hardware	5-16 Bolt 1.5" Buttonhead	98164A276	McMaster	316 Stainless Steel Button Head Hex Drive Screw Super-Corrosion-Resistant, 5/16"-18 Thread Size, 1-1/2" Long	$9.17	18	$165.06
Hardware	5-16 Bolt 1" Flathead	90585A583	McMaster	316 Stainless Steel Hex Drive Flat Head Screw 82 Degree Countersink Angle, 5/16"-18 Thread Size, 1" Long	$4.10	14	$57.40

Hardware	5-16 Bolt 5" Flathead	90585A665	McMaster	316 Stainless Steel Hex Drive Flat Head Screw 5/16"-18 Thread Size, 5" Long	$3.09	2	$6.18
Hardware	5-16 Hex Nut	94804A030	McMaster	Super-Corrosion-Resistant 316 Stainless Steel Hex Nut 5/16"-18 Thread Size	$5.42	3	$16.26
Hardware	5-16 Flat Washer	90107A030	McMaster	316 Stainless Steel Washer for 5/16" Screw Size, 0.344" ID, 0.75" OD	$9.15	2	$18.30
Hardware	5-16 Lock Washer	92147A030	McMaster	316 Stainless Steel Split Lock Washer for 5/16" Screw Size, 0.322" ID, 0.583" OD	$7.06	2	$14.12
Hardware	3/4-16 Bolt	92198A388	McMaster	18-8 Stainless Steel Hex Head Screw 3/4"-16 Thread Size, 3-1/2" Long	$3.86	2	$7.72
Hardware	3/4-16 Hex Nuts	91845A175	McMaster	18-8 Stainless Steel Hex Nut 3/4"-16 Thread Size	$3.80	1	$3.80
Hardware	1/2 Shackle	3555T49	McMaster	Galvanized Steel Safety-Pin Shackle - for Lifting 7/16" Thick	$15.28	2	$30.56
Hardware	Cable strain relief grip	69675K64	McMaster	Cable Support Grip with One Loop, for 0.53" to 0.73" Cable OD, Corrosion-Resistant	$32.00	1	$32.00
Tow Line	3/8" Spectra or similar		Amazon	3/8" Amsteel blue or similar	$79.00	1	$79.00

Deck Control Box							
						Total:	$1,926.98
Category	**Part**	**Part Number**	**Manufacturer**	**Description**	**Cost**	**Quantity**	**Total Cost**
Computer	Laptop		Lenovo	ThinkPad	$1,700.00	1	$1,700.00
Power Supply	AC Generator			2 kw portable generator	Not included	1	$0.00

Power Supply	48 VDC Converter			480 w AC to DC Converter	$35.99	2	$71.98
Winch	12 VDC Deployment Winch			Portable Winch	$155.00	1	$155.00

- ## Design Package:

Please see attached PDF and DXF drawing packages along with the CAD model.