Cabling and Platform Solution

Project 200-215

Final Report

Reporting Period 15 Feb 2022 – 31 Mar 2022

Halagonia Tidal Energy Limited

DP ENERGY

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Executive Summary

Halagonia Tidal Energy Limited (HTEL) worked with OERA (now Net Zero Atlantic), Fundy Ocean Research Center for Energy (FORCE) and other Industry members on the Pathway Program. HTEL was responsible for designing, assembling, and delivering to OERA a fully functional, multi-sensor monitoring platform design. The fully functioning platform has now been successfully demonstrated in the tidal stream at the FORCE site in Parrsboro.

HTEL used an existing platform frame designed to be used at the FORCE site, owned by FORCE, as the starting point for the monitoring platform. Using the best information available at the time, HTEL acquired sensors to be used by the project. The layout of the sensors on the platform was designed to ensure the proper clearance, access and coverage specific to each sensor. These sensors were attached to the platform using bespoke brackets designed and manufactured by Precise Design; the brackets were specified to withstand the expected forces at the test site. The sensors were integrated through a common user interface by JASCO Applied Sciences (JASCO). The data management plan was developed and executed by Strum Engineering. A corrosion analysis was completed by Corrosion Services to identify the optimum size of and locations for sacrificial anodes to provide cathodic protection to the platform, sensors, fixings and connectors. MacArtney Canada Ltd (MacArtney) completed the cable termination of the subsea cable and other sensor cables as required. MacArtney also designed and manufactured the multiplexor for the system. This multiplexor split the power from the power supply to each sensor and provided the fibre connection for data transfer from each sensor to the workstation ashore. The Marine Operations (deployment, recovery, etc.) were planned and managed by Halifax Offshore Consulting, supported by Huntley's Dive and Marine and Dominion Diving. Seaforth Geosurveys identified the best route for the subsea cable from the test site back to shore. Enginuity designed and manufactured bend restrictors to protect the subsea cable at the platform connection point.

The monitoring platform was deployed at HTEL's Berth E located in the FORCE Crown Lease Area (CLA) at the test site in the Minas Passage. This was the first time a monitoring platform had been deployed at the FORCE site, at this distance offshore and depth, cabled back to the FORCE Visitor's Centre. It was a successful demonstration of the ability to collect information about fish presence at the FORCE test site from a tethered platform. The tether to shore allowed the team to modify sensor settings to optimize sensor performance for any given period of time or research purpose. This was a demonstration of a critical ability for instream tidal turbines at the FORCE site; Environmental Effects Monitoring is a key requirement for the FORCE EA, bertholder Marine Licence and DFO Authorization.

The platform was successfully deployed initially on 2 August 2021, however the project was unable to establish communications and, after thorough troubleshooting, recovered the platform for investigation on 14 September 2021. Following a fault analysis, a number of components were identified to either be refurbished or replaced. The platform was redeployed on 26 November 2021. The project completed its initial testing objectives on 10 December 2021 and commenced a full data collection program. Ever since, the platform has continued to collect data, with gaps that were caused by power loss at the Visitor's Centre during winter storm outages. The project encountered a number of different events during the data collection period, all of which will be discussed in later sections of this report.

Recovery of the platform is pending due to a series of weather delays. The most recent attempt, on 24 March, was unsuccessful as the recovery buoys had released in early February, likely as a result of a failure in the flap designed to keep them spooled. The buoys detached prior to a recovery being possible. The project is intending to grapple for the platform's recovery line and recovery the platform at the next available opportunity. Currently, this is planned to occur during the 7 April neap tide cycle, with a back up planned for on or around 22 April.

Introduction & Objectives

The Cabling and Platform Solution project is one part of OERA's larger Pathway Program. The Pathway Program was established by OERA to develop and test technology to identify and validate preferred environmental monitoring solutions for marine renewable energy projects. Environment Effects Monitoring is a major risk for in stream tidal energy projects as Fisheries and Oceans Canada (DFO) requires each proponent to be able to demonstrate the ability to monitor installed devices for the effects on biological components of the marine ecosystem[1] as a part of their authorizations process concerning fish and fish habitat protection regulations.

HTEL was responsible for designing, assembling, testing and demonstrating a fully functional, multi-sensor monitoring platform. This was achieved in the tidal stream at the FORCE site in Parrsboro. The deployment demonstrated the ability to deploy the multi-sensor monitoring platform in the correct location and it continues to be operated successfully 15 weeks later, much longer than the two-week objective. "Successfully Operate" is defined as data being acquired from the platform's sensors and subsequent transfer to shore for data storage.

The reliability and robustness of the platform, sensors, cabling and connectors was verified during the deployment, with several lessons learned to improve the system.

This Final Report is a summation of the overall project. It should be read in conjunction with the Deployment Report, Submission 007, to ensure a full understanding of the platform design. Technical specifications and related referenced reports can be found in Submission 007. Those items have not been included in this report; this report includes all lessons learned, a summary of the testing conducted, and data collected while deployed up to 31 March 2022. The objective of this report is to provide a close out of The Cabling and Platform Solution in accordance with the Project Agreement.

[1] OERA "The Pathway Program" An Overview

Platform System Design

System Description

The Monitoring Platform is considered a system that is comprised of eight major components split into two sections. The "platform" section of the system includes the Platform, Sensors, Multiplexor and the "wet" connectors. The "onshore" section includes the "dry" connectors, the demultiplexer, Power Supply and UPS, Workstation, and Data Management System. The subsea cable is the bridge between the two sections. The complete system wiring diagram is captured in Figure 1 and Figure 2 below.

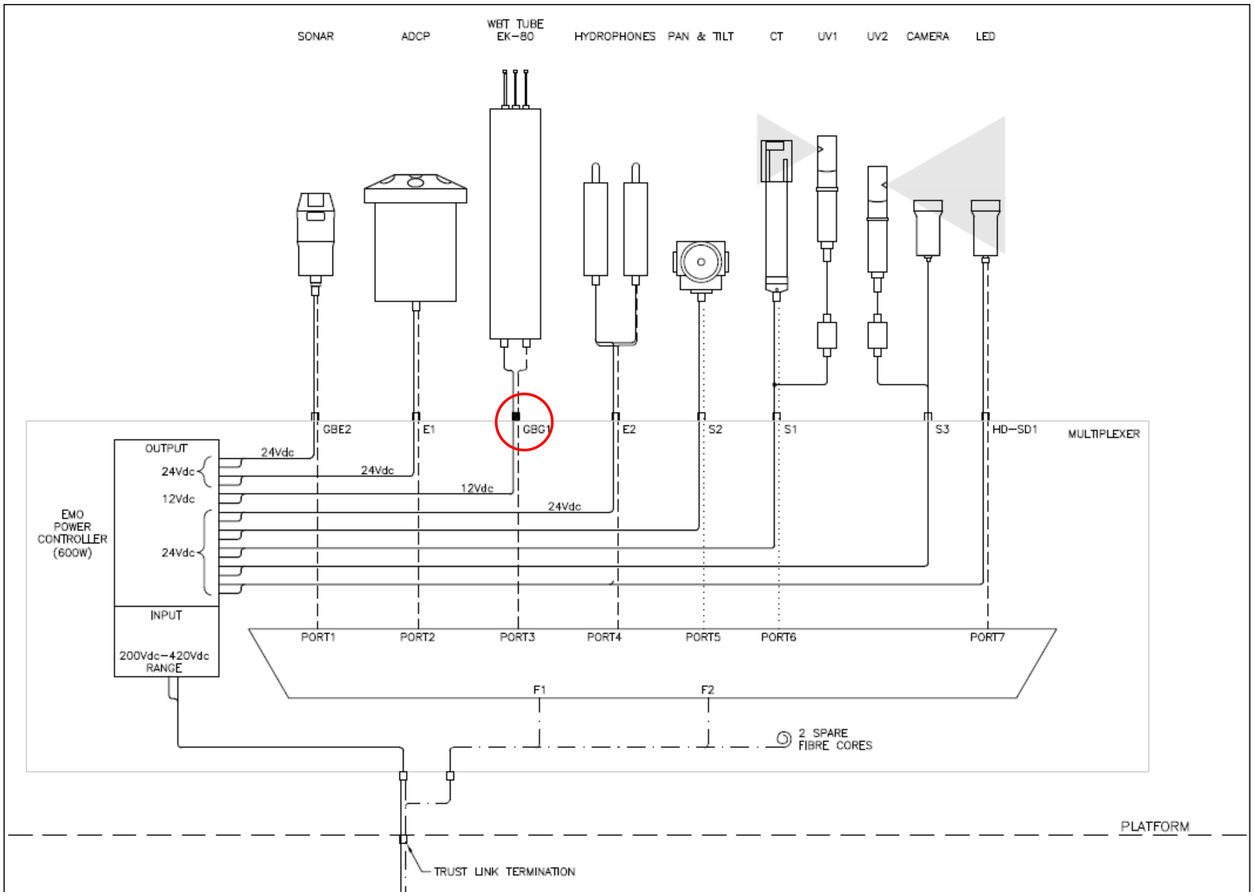


Figure 1: Platform Section

All equipment on the Platform Section was designed and/or is rated for at least 50m depth and was built to withstand a deployment of at least a year.

The Echosounder has a designated pin connection as it requires a different voltage than the other equipment. This has been distinguished by a different colour pin in the physical MUX and captured in the drawing and in the pin out table (red circle in Figure 1 above).

The Onshore Section of the Monitoring Platform system was selected to be fit for purpose and the intended environment, including those components at the beach connection and the cables through the salt marsh to the FORCE Visitor's Centre.

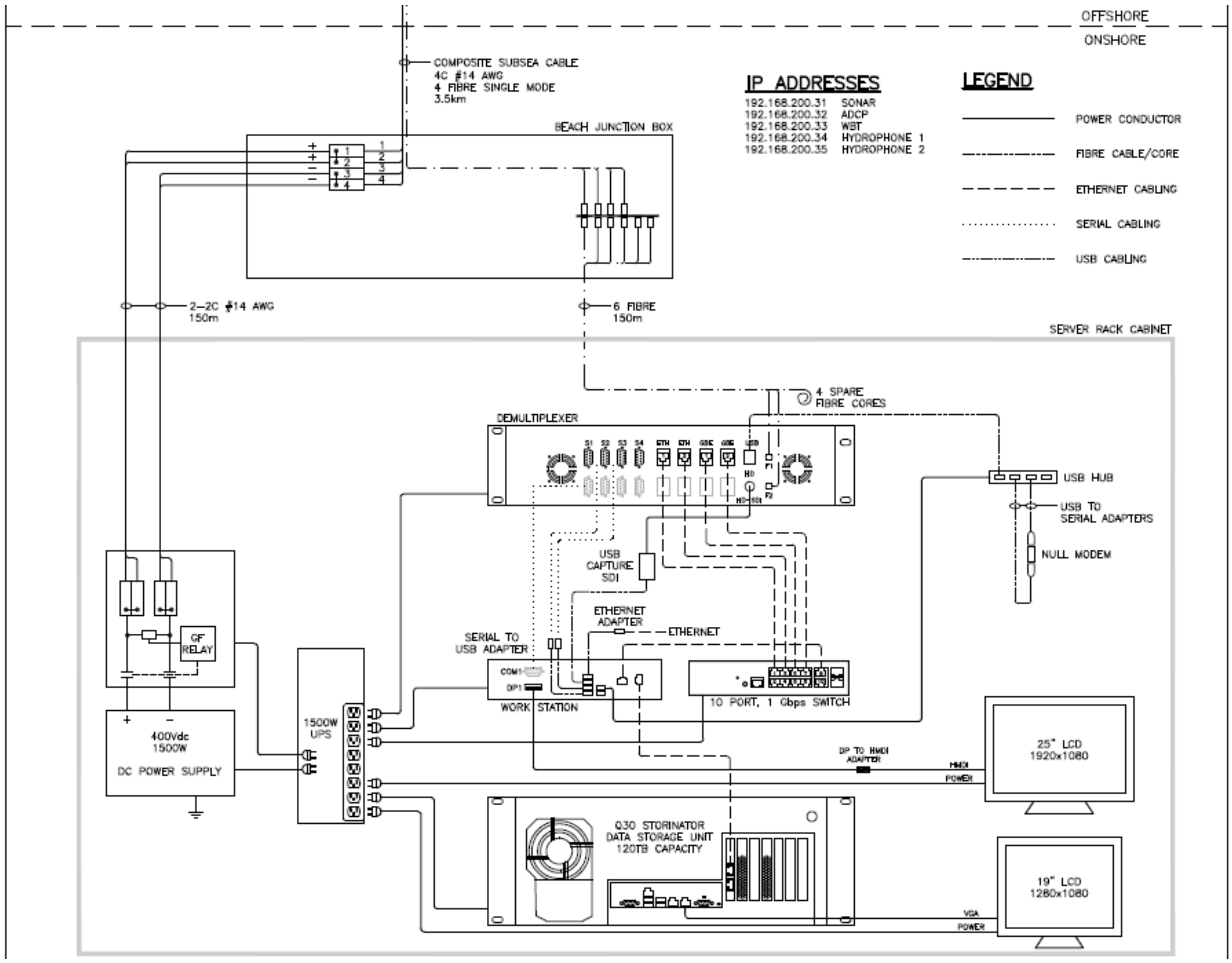


Figure 2: Onshore Section

Prior to the first deployment, the entire system was tested in a dry environment with a 30m test cable in place of the subsea cable. An in-water, harbour acceptance test, complete with the subsea cable on the reel, was successfully completed in Sept/Oct 2020. Prior to the system level test, all sensors were tested independently and then tested one-by-one with the other sensors to define interactions and possible concerns. The data management system was tested until all data flowed as expected for a 24-hour period, uninterrupted.

The system was deployed in August 2021. This is the "first deployed" referenced in this report. After communication issues, the platform was recovered in September 2021; the MUX had experienced water ingress through a corroded plug. The MUX was rebuilt by the OEM. The system did not undergo full system testing prior to redeployment due to time constraints. As discussed in the Lessons Learned section, this led to issues with spurious noise, most likely from the rebuilt MUX.

Platform

The base platform frame is the DK42 FAST 2 Frame, owned by and leased from FORCE. This FAST 2 platform has previously been used as a remote monitoring platform and for other subsea testing at FORCE but with different sensors and not cabled back to shore from the proposed test site.

The DK42 frame was designed and built by Open Seas using 316 Stainless Steel.

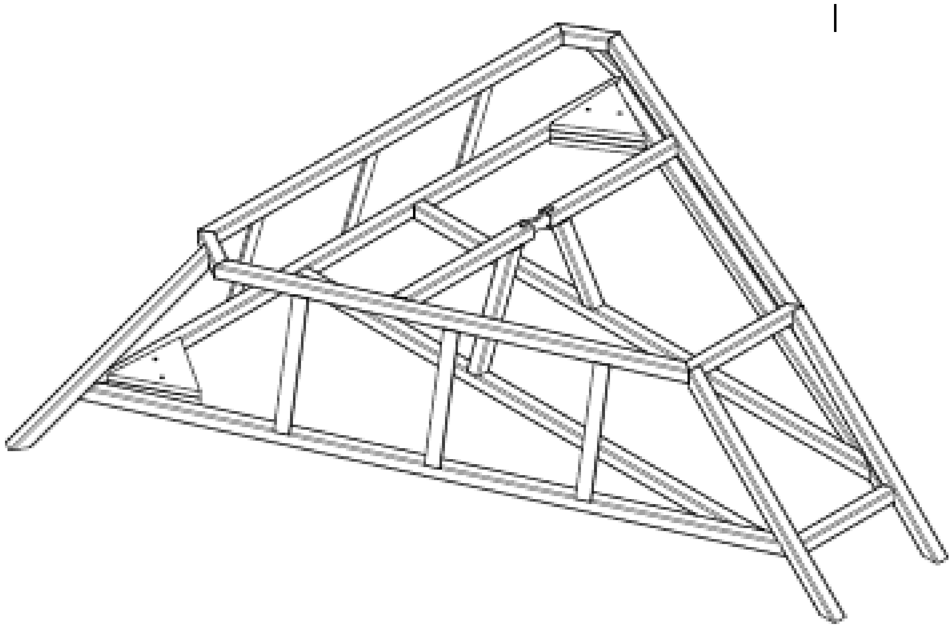


Figure 3: DK42 Frame, Open Seas

Stability and Ballast

FORCE had previously completed a stability analysis of the frame at the test site. From the review of this report, it was determined that at least 800 kgs of total weight was required to ensure the platform did not move from its installed position on the seabed after deployment. Due to spacing constraints, sizing of the ballast and the Center of Gravity of the platform, 440 kg of ballast was added. The ballast and anodes brought the total platform weight to 1039 kg.

Corrosion Analysis

HTEL contracted Corrosion Services in Dartmouth to complete an analysis of the platform design, including sensors and sensor location, to identify the cathodic protection requirements for the platform. The report recommended that nine (9) anodes be used to provide proper protection for the platform for a year-long deployment.

The anode wastage will be measured upon recovery to determine if it is within the anticipated limits.

The anodes are fabricated with a mild carbon steel tab on either end to facilitate attachment to the platform. These tabs were used to weld the anodes in appropriate locations on the platform. There is 33.5% safety factor in the anode quantity. The analysis allowed for a conservative increase in current density of 400%.

Table 1: Material Type Table

Item	Vendor	Selected Equipment	Material
Passive Acoustic	Oceansonics	2x icListen SC2 HF Smart Hydrophones endcap	POM Titanium
Echosounder	Kongsberg	EK 80 Simrad WBT Tube	Aluminum
3D Sonar	Tritech	Gemini 720is 4000m	Titanium
ADCP	Nortek	5 beam head Signature 500 Connectors	POM Titanium
CT device	RBR	Duo CT device RS-232 & Gen 3	POM
UV antibiofouling	AML	PDC-CUV-V-05 Vertical biofouling lamp PDFC-CUV-H-05 Horizontal biofouling lamp	
Camera	LUX	HD Camera	Titanium
Light	LUX	LED	Titanium
Pan/tilt	Kongsberg	OE10-104 medium duty pan/tilt unit	316L stainless
Multiplexor	MacArtney Canada	EMO Mini-T MkII	Titanium Housing
Trustlink connector	MacArtney Canada	Type III-S	316 stainless
Trustlink shackle pin	MacArtney Canada		Galvanized steel
Connectors	Various		Bronze

Recovery Method

JASCO, leaning on knowledge gained from their other projects, designed a streamlined, redundant recovery system for the platform.

The frame recovery mechanism features two Edgetech Port-LF-SD acoustic releases with aluminium housings attached rigidly to the frame. The releases provide redundancy in the case of one failing to trigger. A short length of ¼" Dyneema connects each release to the Dacron spool cover and keeps the spool in tension. The spool provides buoyancy with two 14" trawl floats and is constructed of 316 stainless steel. The spool carries 120 m of 3/8" Dyneema that is attached to the frame with a 316 stainless steel 5/8" shackle. When a release is triggered, the spool carries the 3/8" Dyneema to the surface for recovery by the service vessel.

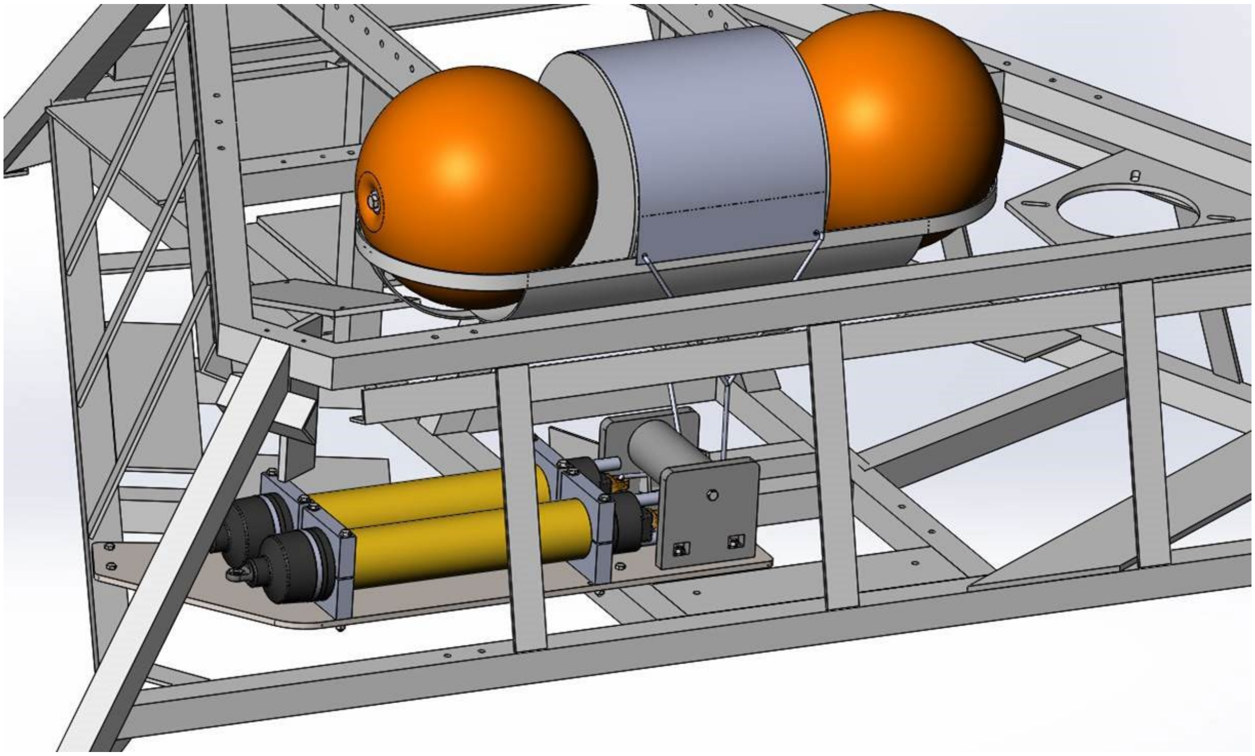


Figure 4: Acoustic Release system

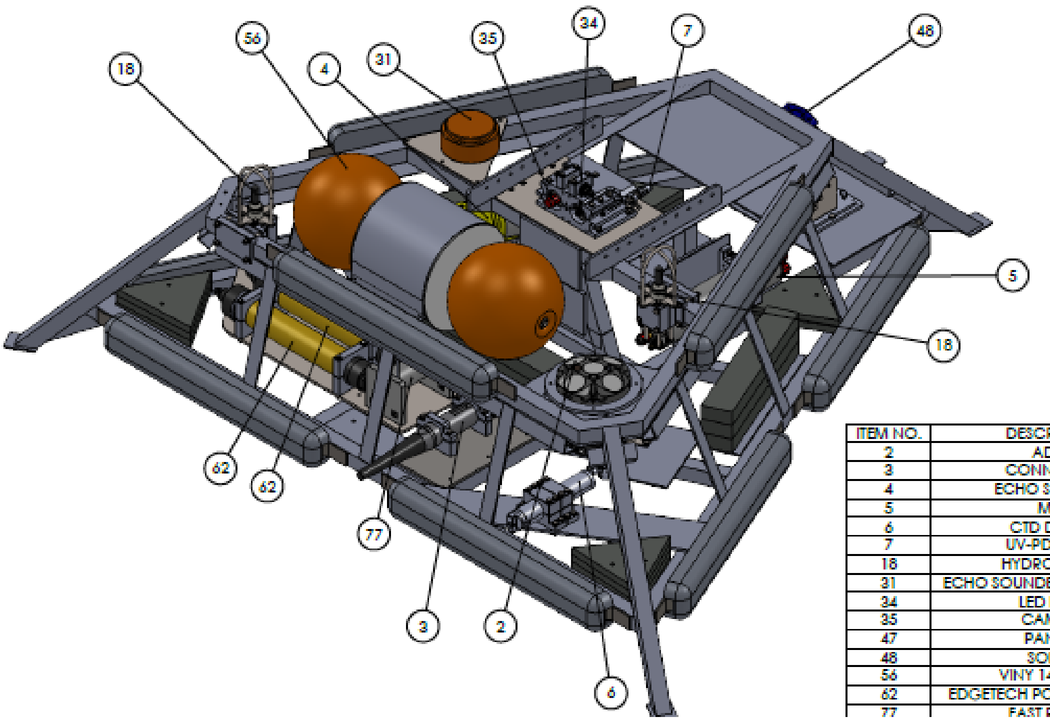
This recovery system incorporates lessons learned from a 2019 HTEL ADCP deployment and other lessons learned.

In the event of system failure, a ground line was attached and can be grappled for to recover the platform.

As discussed in the Lessons Learned section, this system failed twice, with the floats surfacing prior to the acoustic release being tripped. This system requires robust redesign for long term (> 8 week) deployments. The initial failure was investigated upon the first recovery. That report has been provided in Appendix 1 for review. It appears the rope holding the canvas spool cover chafed to the point of failure where it meets the grommet. This rope was replaced with dyneema for the second operation. Upon recovery, the failure mode will be further investigated.

Configuration

Below is a model screenshot of the monitoring platform to show the positioning of the sensors. A number of constraints from the sensors and desired performance of each informed sensor placement.



ITEM NO.	DESCRIPTION	QTY.
2	ADCP	1
3	CONNECTOR	1
4	ECHO SOUNDER	1
5	MUX	1
6	CTD DEVICE	1
7	UV-PDC-CUV	2
18	HYDROPHONE	2
31	ECHO SOUNDER TRANSDUCER	1
34	LED LIGHT	1
35	CAMERA	1
47	PAN TILT	1
48	SONAR	1
56	VINY 14" FLOAT	2
62	EDGETECH PORT LF-SD BODY	2
77	FAST ROLLER	1

Figure 5: Platform with Sensors & Equipment

The ballast was placed to keep the overall Center of Gravity (CoG) as close to the lifting point as possible. The anodes were placed at the recommended positions to ensure cathodic protection over the full platform.

Figure 6 and Figure 7 below show the beam profiles of the sensors. Beamwidths are quoted as 3 dB beamwidth, i.e., half the energy is within this beamwidth. The WBT and ADCP have axisymmetric beams in the xy plane.

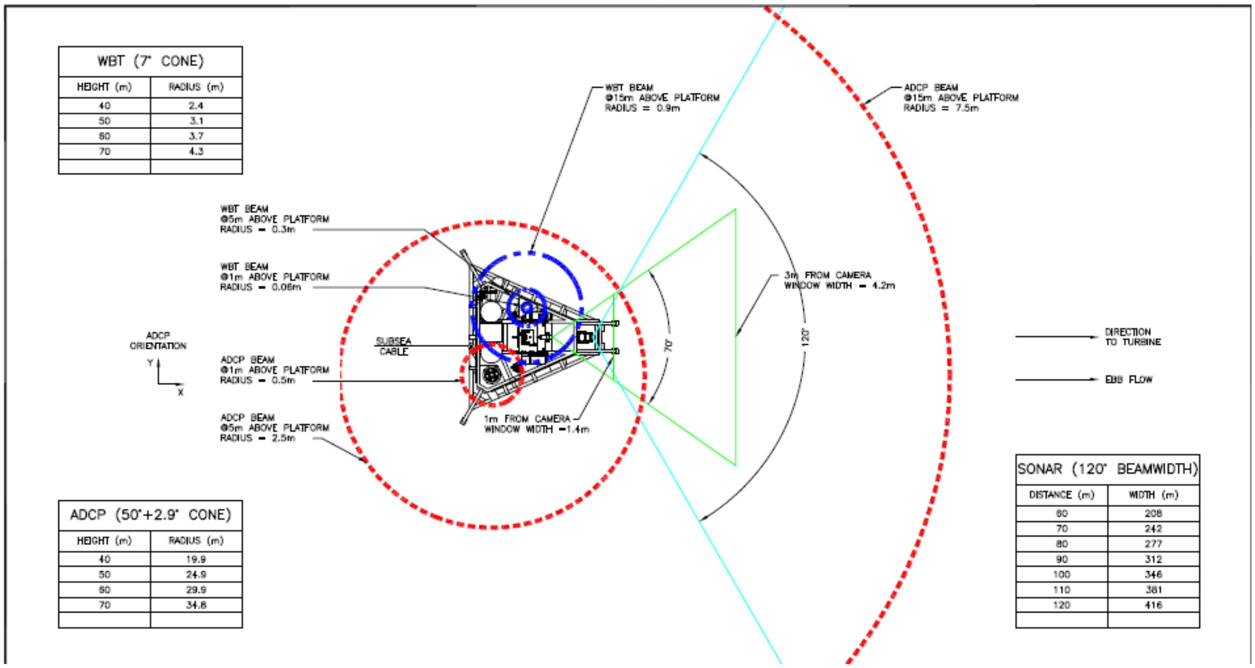
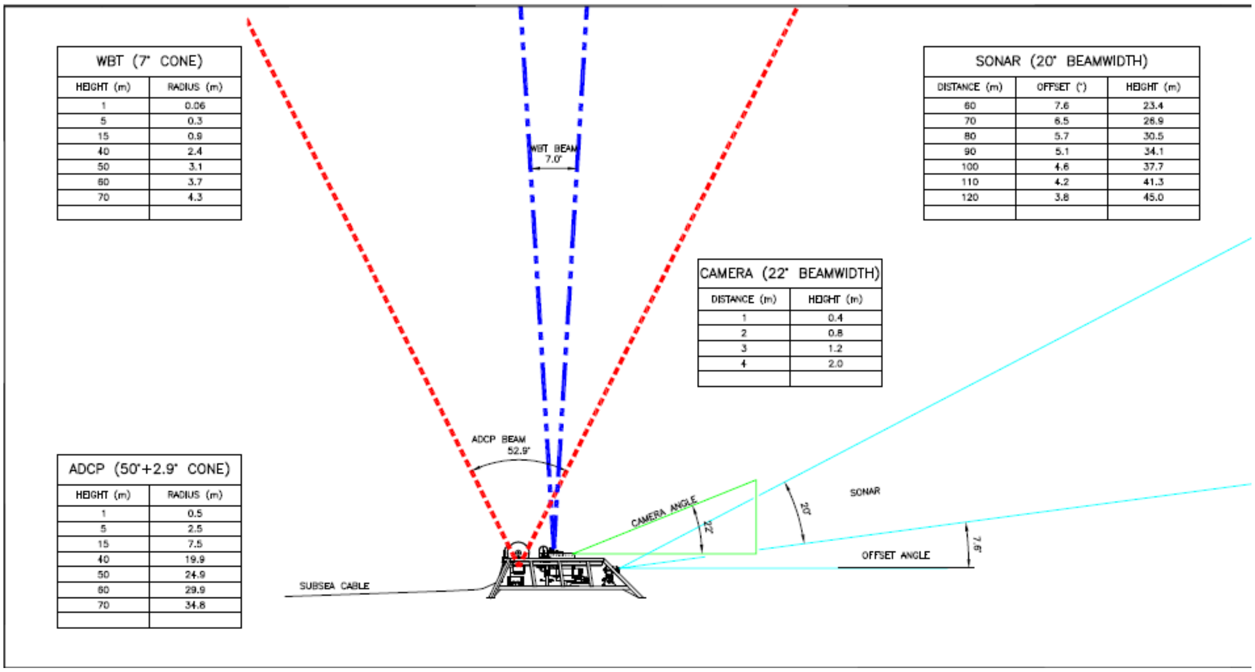


Figure 6: Plan View, Sensor Beam Width Profiles

However, to ensure the ADCP data can be used in any flow analyses, it must have a defined orientation and coordinate system. For this system, the ADCP coordinate system was defined such that the x axis is along the long axis of the platform, parallel to the multiplexor. The WBT transducer is oriented along this axis as well, with the directional arrow facing the back of the platform, away from the Gemini.

The WBT transducer was only positioned in that direction because of the existing bolt holes. Future positioning should be adjusted to match the sonar and ADCP orientation.



WBT (7° CONE)	
HEIGHT (m)	RADIUS (m)
1	0.06
5	0.3
15	0.9
40	2.4
50	3.1
60	3.7
70	4.3

SONAR (20° BEAMWIDTH)		
DISTANCE (m)	OFFSET (°)	HEIGHT (m)
60	7.6	23.4
70	6.5	26.9
80	5.7	30.5
90	5.1	34.1
100	4.6	37.7
110	4.2	41.3
120	3.8	45.0

CAMERA (22° BEAMWIDTH)	
DISTANCE (m)	HEIGHT (m)
1	0.4
2	0.8
3	1.2
4	2.0

ADCP (50°+2.9° CONE)	
HEIGHT (m)	RADIUS (m)
1	0.5
5	2.5
15	7.5
40	19.9
50	24.9
60	29.9
70	34.8

Figure 7: Left side view, Sensor Beam Widths

The hydrophone OEM, Oceansonics, suggested to position the hydrophones as far away from each other as practical to minimize feedback. Additionally, it was important to ensure the hydrophones are not located within the beam of the Echosounder. Due to the frequency and signal strength of the echosounder, there is the potential for damage to internal components of the hydrophone if located inside the beam.

The horizontal beam of the sonar covers a 120° swath. The Gemini is mounted on a Kongsberg Pan/Tilt device, which should allow fine tuning of the Gemini position after the platform is deployed. This device was expected to be an early failure point; the pan/tilt remained able to pan up to the point of this report writing but the tilt function failed early in the deployment. The position of Gemini will be confirmed upon recovery.

To ensure the swept area of the turbine is in view, and not obstructed by returns from the platform or other sensors, the Gemini was placed at the front of the platform. Originally the subsea cable was also connected to the platform near the front. This led to some concerns with the Marine Operations as it would put the subsea cable at risk of entanglement with the turbine. Therefore, the decision was made to shift the cable connection point to the back of the platform. During deployment, the vessel was able to position the platform and then move away from the hypothetical turbine (and monitoring platform) until sufficient cable has paid out to safely maneuver around the turbine to bring the cable ashore for connection at the beach junction box.

Sensors

Based on the best information available at the time, the below sensors were selected for the monitoring platform. Sensors were ordered in Oct-Dec 2019 to support the original deployment schedule, prior to COVID impacting the schedule. This sensor list was reviewed by the Pathway SME team prior to finalization. Each sensor, except the camera and LED, were provided with their own cable to connect the sensor to the multiplexor. MacArtney Canada provided the cables and bracket for the camera and LED.

Table 2: Monitoring Platform Sensor List

Item	**Vendor**	**Selected Equipment**
Passive Acoustic	Oceansonics	2x icListen SC2 HF Smart Hydrophones
Echosounder	Kongsberg	EK 80 Simrad WBT Tube with ES120-7CD transducer
3D Sonar	Tritech	Gemini 720is 4000m
ADCP	Nortek	5 beam head Signature 500
CT device	RBR	Duo CT device RS-232 & Gen 3
UV antibiofouling	AML	PDC-CUV-V-05 Vertical biofouling lampPDFC-CUV-H-05 Horizontal biofouling lamp
Camera	LUX	HD Camera
Light	LUX	LED
Pan/tilt	Kongsberg	OE10-104 medium duty pan/tilt unit
Multiplexor	MacArtney Canada	EMO Mini-T MkII
Trustlink connector	MacArtney Canada	Type III-S

Each sensor has a custom bracket designed to attach it to the platform. The brackets were made of black acetal. Bolts, nuts, and washers for each bracket assembly are made from 316 Stainless Steel.

After the second deployment, the CT device was not functioning. The cause for this is not known; upon recovery, the device will be sent back to the OEM for investigation. Any feedback on the cause of the failure will be shared with FORCE as it may have relevance to CT device selection at the FORCE site.

Additionally, one of the UV lamps was damaged during the first deployment period. As the project was not able to monitor equipment during this period of time due to communications issues, the time of damage cannot be confirmed. Damage could have occurred during the deployment itself or via a strike by submerged debris. Further system design will consider better protection for the UV bulbs themselves.

HD Camera & LED

Previous experience at the test site has shown that a camera is not overly effective at monitoring, especially on a bottom-mounted platform. This is due to the turbidity in the water limiting the sunlight, which reduces the visibility. A Camera and LED were included on the monitoring platform with the intention to demonstrate the limits of its ability. The LED was only powered on periodically so as not to bias any data collection by drawing fish and marine mammals to the platform.

The Lessons Learned section discusses the utility of the HD Camera.

Hydrophone Guards

As the hydrophones are quite sensitive to noise and susceptible to damage given their positioning on the platform, hydrophone guards were used to protect the sensors during the deployment.

A durable external-grade polyether foam inside a custom frame was used to protect the Hydrophones from the environment while the platform is deployed. The foam used was tested in the Bay of Fundy successfully on other projects and should provide the necessary protection without significantly affecting their function. The foam and the hydrophones themselves will be inspected upon recovery to determine if modifications are required for future deployments.

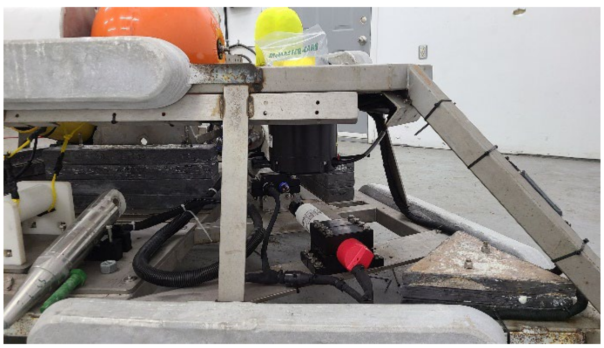


Figure 8: Platform with hydrophone guard installed

Figure 9: close-up of hydrophone guard (yellow plastic)

The Lessons Learned section discusses the Hydrophone Guards.

Gemini Positioning & Protection

Positioning

The Gemini sonar was positioned with the intention for it to "look at" a turbine swept area, meaning that a turbine swept area would be within the arc of the Gemini beams. Knowing that the Gemini inherently "looks down" toward the seabed (see Figure 10 below), some analysis was done to identify the best position for the Gemini.

The intention from the deployment was to have the Gemini facing into the direction of flow on flood tide; this was mostly to aid in cable management during the deployment itself. Steps should be taken in future deployments to more accurately verify the Gemini direction after deployment.

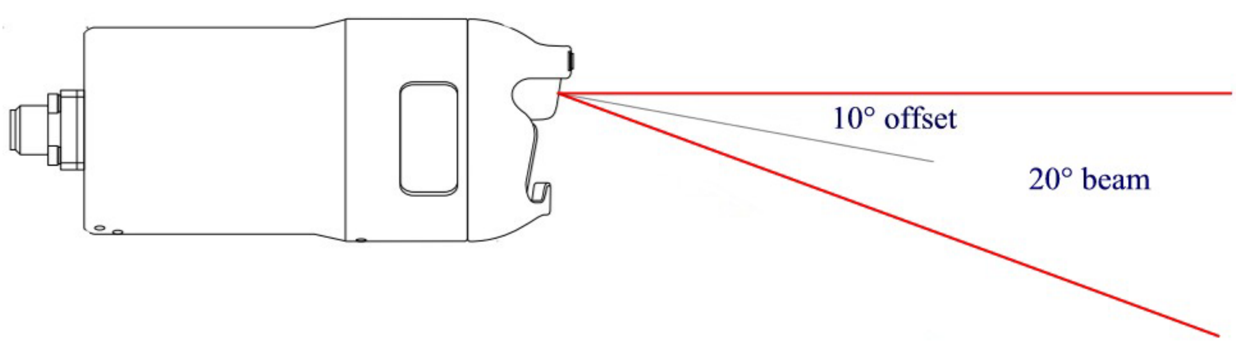


Figure 10: Original Gemini vertical beam angle

In order to have the Gemini simply look horizontal, it must be tilted up 20° to overcome the original offset and beam angle. However, the proposed turbine technologies at FORCE typically have a swept area 10m – 30m off the bottom. Finally, it was important that the monitoring platform not be positioned closer than 50 meters from a turbine, for safety of operation during the deployment and recovery.

These constraints led to a minimum target location approximately 60 meters from the hypothetical turbine, with the Gemini oriented no less than 24° up from the horizontal. The monitoring platform could be placed between 100m and 60m of the turbine in future deployments to provide coverage of a majority of the turbine swept area. The target location and Gemini orientation should be assessed for each proposed turbine to ensure the desired coverage is obtained.

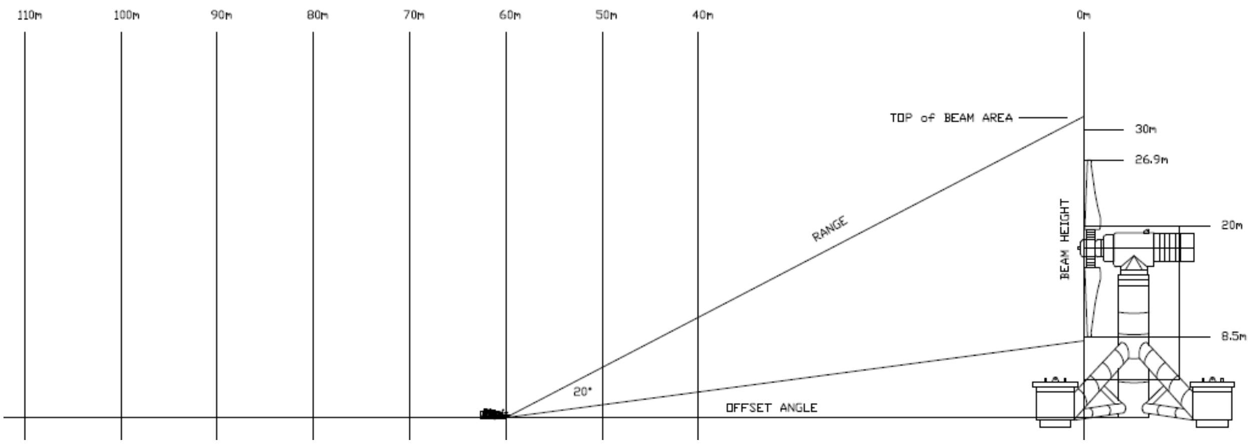


Figure 11: Monitoring Platform positioning. Representative bottom mounted turbine configuration

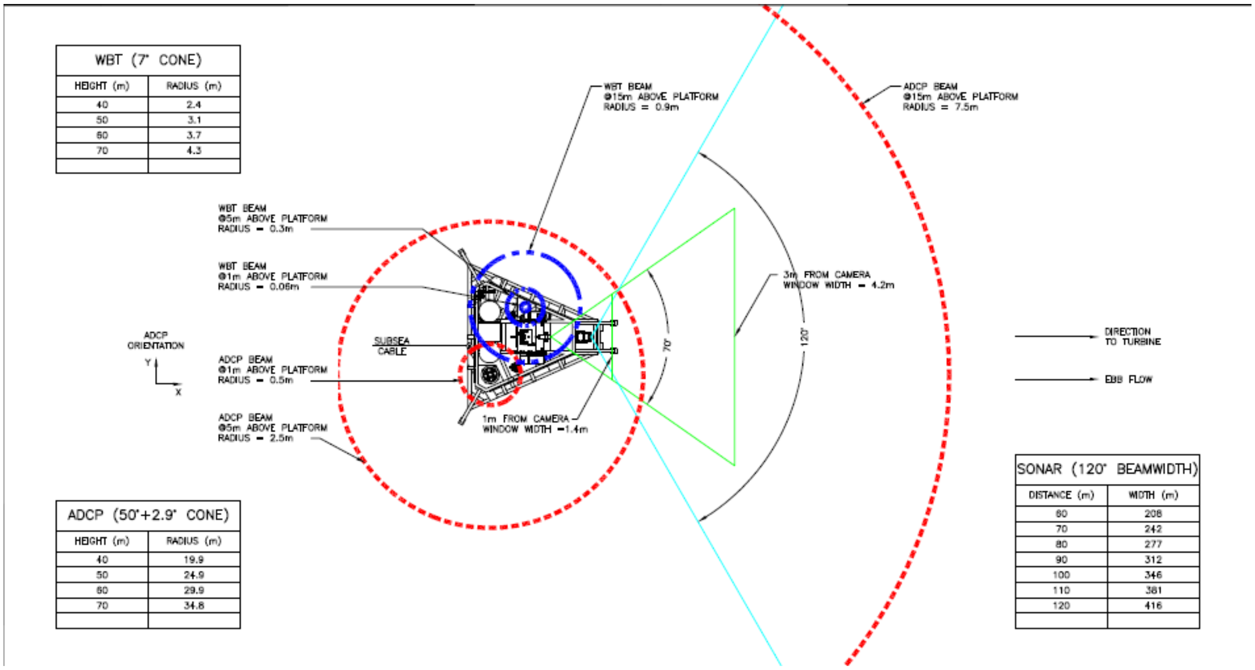


Figure 12: Plan View, Sensor Beam Width Profiles (repeated for reference)

A mechanical block was designed for the pan/tilt device, which the Gemini sits on.

The sonar data collected should be evaluated to determine if the Gemini positioning was useful or if there is a better mounting method/direction for the Gemini. In particular, future work should quantify the effective range of the Gemini sonar given tilt angle, local bathymetry, flow speed and target type to quantify efficacy of tracking targets in the nearfield or approach/departure from the hypothetical turbine.

Protection
The Gemini sonar is a critical piece of equipment to the success of the deployment. As discussed above, it is positioned on the platform in a way that exposes it to any debris in the water and the turbulent currents. To protect the sonar, a protective shroud was made to sit over the sonar. The shroud was designed with a ½" gap to ensure water flow to prevent debris build up. It has also been designed to not cut off the beam.

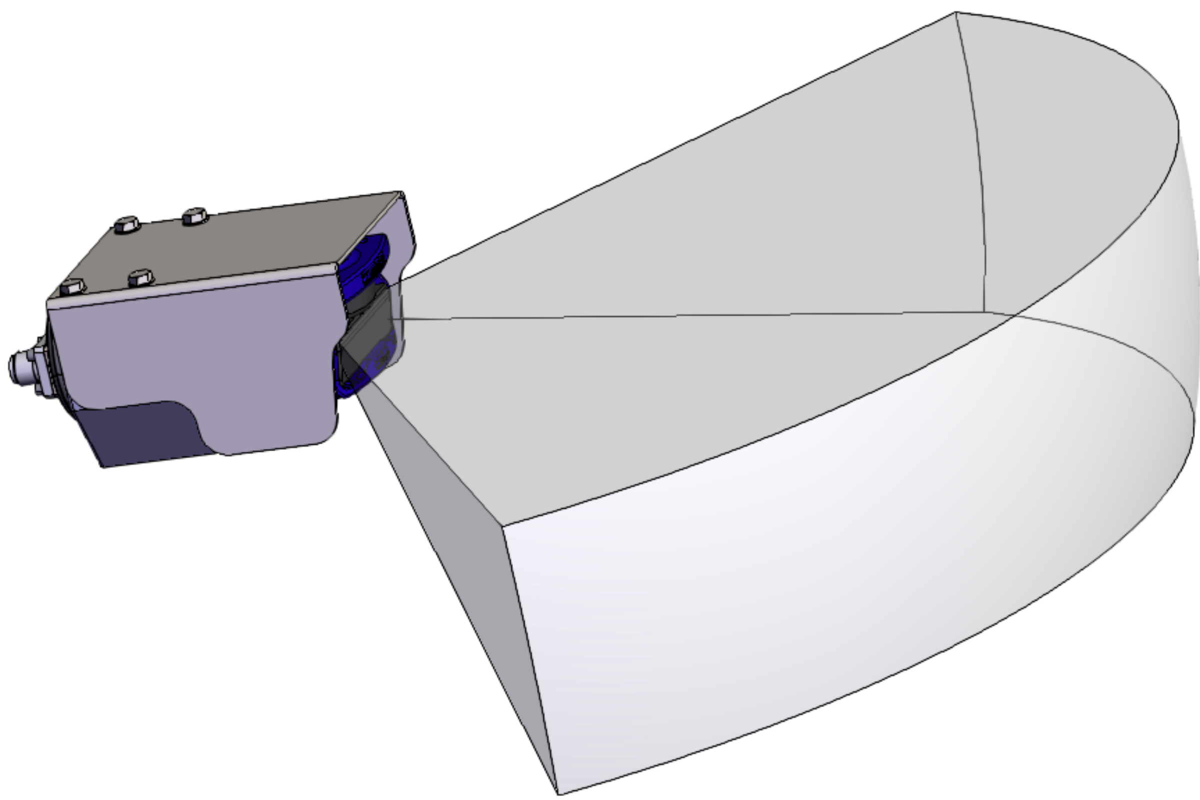


Figure 13: Gemini Protective Shroud

Sensor Clock Drift
Clock drift can be a concern with multiple sensors and would make it difficult to sync the environmental data from the CT device with the ADCP, for example. This risk was prevented as the clock on each sensor was synced with the workstation.

Multiplexor

Each sensor has a cable that connects it to the Multiplexor (MUX) on the platform. The MUX for this system is a MacArtney Canada EMO mini – T MK II System and is installed on the platform via a custom bracket made of acetal with 316 Stainless Steel fixings.

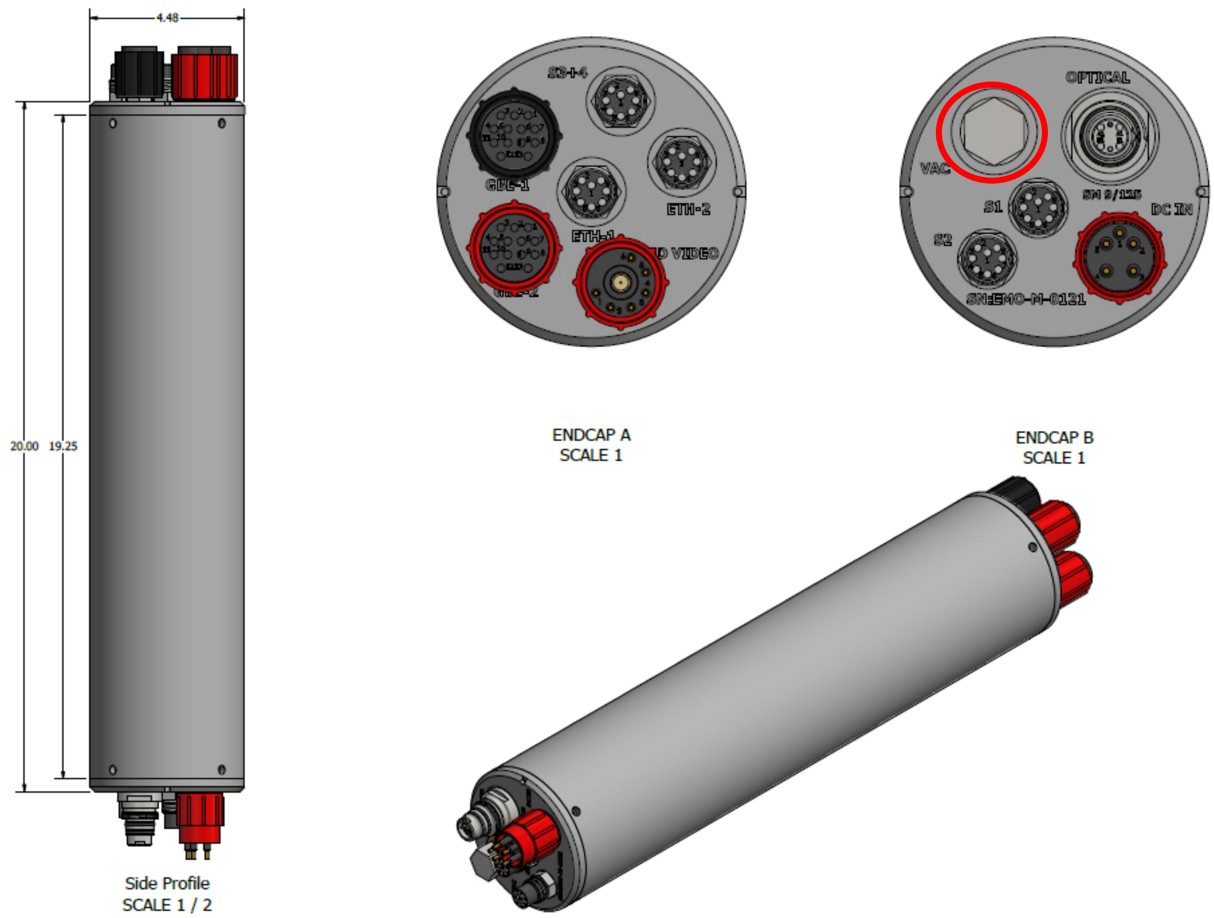


Figure 14: Multiplexor

The VAC plug (circled in Figure 14 above) is the component that showed evidence of corrosion upon recovery in September 2021. This plug is galvanically isolated from the frame through the acetal mounting bracket, so it was not protected by the sacrificial anodes installed on the frame. MacArtney Canada completed a metallurgical analysis and confirmed the component was 316 stainless steel. However, after reviewing documentation from their supplier, it was confirmed that the plug was not passivated and therefore was not protected in the saltwater environment. The component was replaced with a titanium piece in the refurbished MUX.

Figure 15: Corroded MUX Plug

Figure 16: Corroded MUX plug, threads

Inside the MUX, there is EMO Power Controller and a Fiber Core. The EMO Power Controller is a proprietary piece of equipment from MacArtney Canada which can distribute 12, 24 or 48V DC.

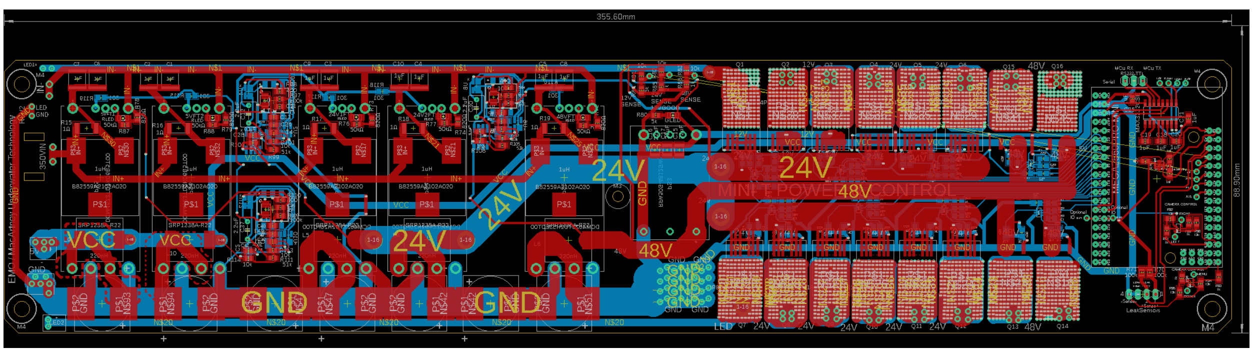


Figure 17: EMO Power Controller PCB

The Pathway Monitoring Platform only required the 24V output voltage.

The key component of the MUX is the VICOR DCM converter, which was integrated into the EMO controller PCB based on the inclusion of the following protection features:

Powertrain Protections						
Input Voltage Initialization threshold	$V_{IN-INIT}$	Threshold to start t_{INIT} delay			**75**	V
Input Voltage Reset threshold	$V_{IN-RESET}$	Latching faults will clear once V_{IN} falls below $V_{IN-RESET}$	**50**			V
Input undervoltage lockout threshold	$V_{IN-UVLO-}$		**130.00**		**155.00**	V
Input undervoltage recovery threshold	$V_{IN-UVLO+}$	See Timing diagram			**200.00**	V
Input overvoltage lockout threshold	$V_{IN-OVLO+}$				**455**	V
Input overvoltage recovery threshold	$V_{IN-OVLO-}$	See Timing diagram	**422**			V
Output overvoltage threshold	$V_{OUT-OVP}$	From 25% to 100% load. Latched shutdown	**32.10**			V
Output overvoltage threshold	$V_{OUT-OVP-LL}$	From 0% to 25% load. Latched shutdown	**32.60**			V
Minimum current limited V_{OUT}	$V_{OUT-UVP}$	Over all operating steady-state line and trim conditions			**12.00**	V
Overtemperature threshold (internal)	$T_{INT-OTP}$		**125**			°C
Power limit	P_{LIM}				**950**	W
V_{IN} overvoltage to cessation of powertrain switching	$t_{OVLO-SW}$	Independent of fault logic		1.5		µs
V_{IN} overvoltage response time	t_{OVLO}	For fault logic only			**200**	µs
V_{IN} undervoltage response time	t_{UVLO}				**100**	ms
Short circuit response time	t_{SC}	Powertrain on, operational state			**200**	µs
Short circuit, or temperature fault recovery time	t_{FAULT}	See Timing diagram		1		s

Figure 18: Powertrain Protections

The MUX housing is made of Grade 2 titanium, a relatively inert metal.

Cables to Sensors

The cables and connectors for the sensors are typically produced by Subconn, with the exception of the camera and fibre cables and connectors. The cables were spliced by MacArtney Canada, when required, to mate to different end connectors at the Multiplexor.

Cables and Connectors

Myriad cables are used on this monitoring platform and the overall data management system. The major pieces of the system are the subsea cable and its terminations.

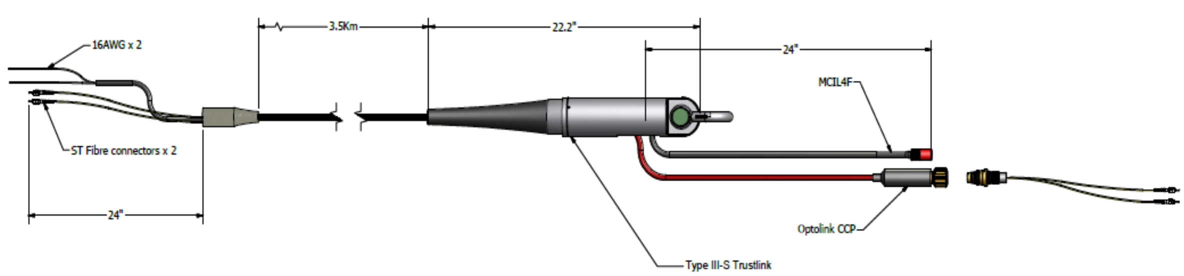


Figure 19: Subsea Cable Termination

Subsea Cable

Critical to the monitoring platform was a power and fiber optic connection with shore. This allowed for a longer deployment as monitoring is not limited to sensor battery capacity. A cabled connection also allowed for full data collection, not a reduced data file or "triggered" data collection.

The subsea cable has a fully redundant set of power cores and fibre optic cores. In the event there is an issue with one fibre core, there is an automatic switch over through the MUX. Only one fibre is required to communication with the MUX. In Automatic Mode, the MUX will automatically switch from the "A1" Fibre to the "B1" Fibre if the "A" fibre fails. There are an additional two fibres (A2 and B2) which are unconnected, which can be used as discussed further in the Lessons Learned Section of this Report.

The cable armour is Galvanized Extra Improved Plow Steel (GEIPS) and the cable has a minimum bend radius of 486mm (dynamic) and 364 mm (static).

The total expected peak load during monitoring activities is 114W.

The calculated voltage drop along the 3.5km cable is 2.3% (9.2V).

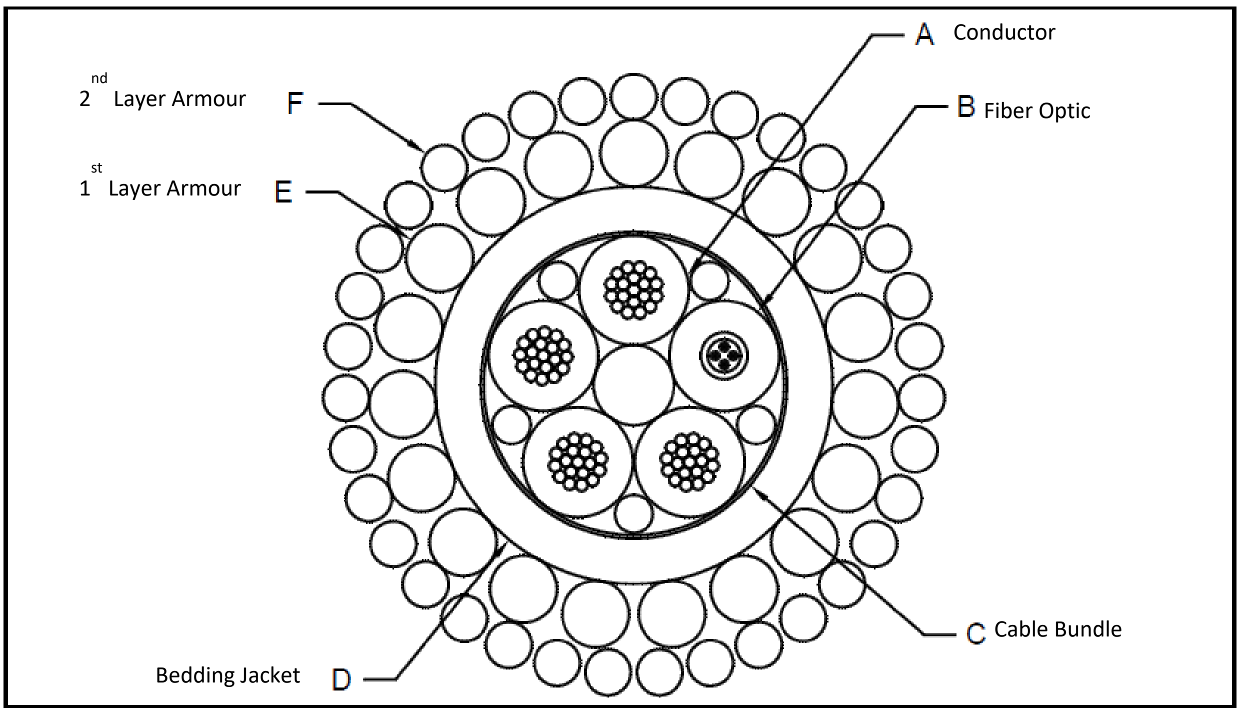


Figure 20: Subsea Cable Cross Section

The subsea cable was terminated on both ends; it connects into the platform through a Trustlink Connector to the MUX, where the power and fiber optic cables are split out and distributed for connection to the Multiplexor.

Subsea Cable Protection

Custom bend restrictors were manufactured to protect the subsea cable and ensure the cable did not exceed the minimum bend radius during the deployment and recovery. The bend restrictors were manufactured locally by Enginuity and are attached with 316SS fixings.

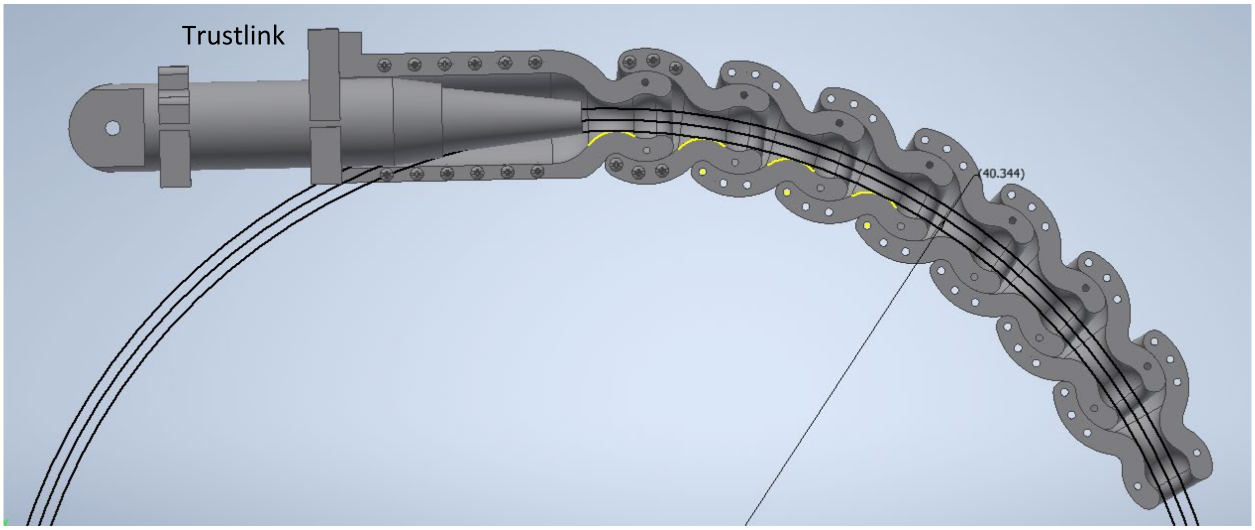


Figure 21: Bend Restrictor Cut away

The bend restrictors are discussed in the Lessons Learned Section of this report.

Subsea Cable Termination

The subsea cable is terminated on the “wet” end in a MacArtney Canada Type III-S Trust Link Termination made of 316 stainless steel and on the dry end by a glanded overmold.

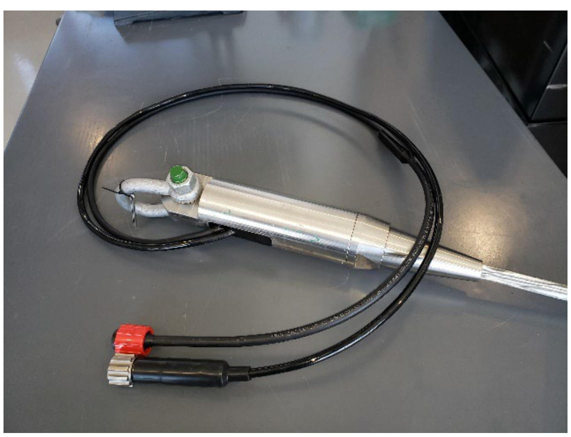


Figure 22: Wet End Termination

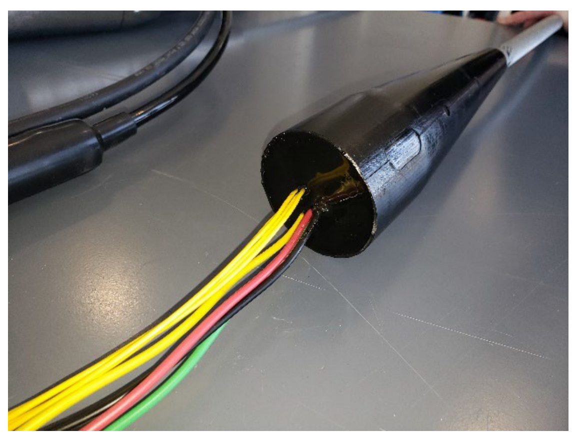


Figure 23: Dry End Overmold

If required, the wet end termination can be capped so that the cable can remain in the water without the connection into the multiplexor. This end cap for the power connection is capped with a subconn connector and the fiber connection is made of titanium.

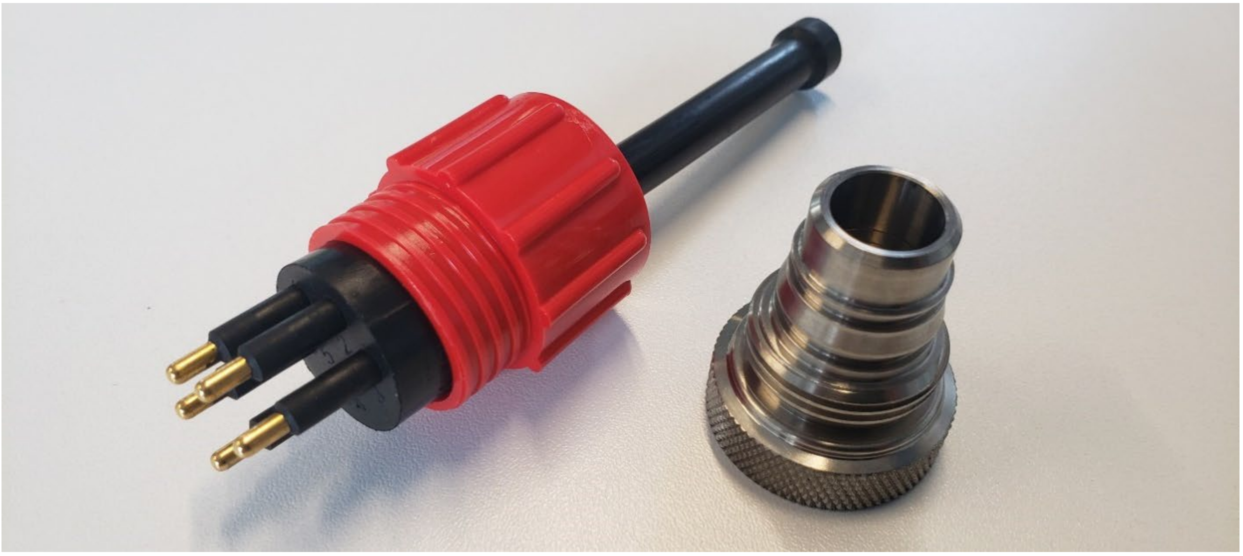


Figure 24: cable cap and plug

Trustlink Connector

The Trustlink is a MacArtney Canada connector made of 316 stainless steel. The shackle pin (green item in Figure 22) is a G-4163 WLL 4.75 T part made of galvanized steel. The dissimilar metals were included in the Corrosion Analysis and will be inspected upon recovery for unexpected wear.

Shoreside Cable and Termination

Two cables run from the beach back to the FORCE Visitor's Center, a control cable and a fibre optic cable. The control cable is a 1-4C #14AWG Teck90 cable that is 0.75 inches in diameter. The Fiber Optic cable is a 6-core fibre-optic cable that is 0.4 inches in diameter. These control cables are rated for 600V and aluminum armoured; they are not expected to experience wear during the year that they are installed.

Figure 25: Control Cable

Figure 26: Fiber Optic Cable

Shore Cable Installation Methodology

Installation of the cables started at the FORCE Visitor Center where the cable reel was supported. One person pulled the cables down the hill using the same routing as the previous cable used. One person remained at the cable reel to ensure the cable pays out freely.

The cables were laid on the surface of the marsh as they are hand carried through the marsh area. Over time, the cables were inevitably covered by marsh grass.

At the beach junction box, the cables were installed through glands into the existing junction box and terminated on terminal blocks.

The installation took less than one day and did not require any equipment. Minimal disturbance to the wetlands may have occurred but is unlikely as the cables are small and easily managed by one person.

At the Visitor's Center, the cables were buried 8 – 12 inches through the lawn area and then were routed through a new cable conduit into the north side of the building.

These cables were inspected prior to the deployment and no issues or concerns were noted. These cables will be removed after the platform is recovered.

Cable Protection

All cables need to be properly secured and protected to ensure they are not damaged during the deployment operations nor while deployed. On the platform, sensor cables have been cut to reduce any extra lengths. Cable trays have been fashioned out of angle bar and plates to provide a protective channel to route the cables through. Where cables are exposed, either at the connection point or due to bend radii, cable wrap has also been added. The cable wrap is Abrasion-Resistant Wrap-Around Sleeving, which has a tightly braided construction, making this sleeve abrasion resistant. It is made of polyester and has good chemical resistance.

Where the cable meets the platform, bend restrictors and additional supports were required to prevent damage during deployment, as noted above.

Professional grade cable ties were used to bunch cables together and secure them to cable trays. Cable ties were installed every 4" – 6", as allowed.

Power Supply

The Monitoring Platform System requires a 400V DC Power Supply. A 1500 XR Series supply was purchased through MacArtney Canada. The Power Supply provides 400V power to the monitoring platform through beach power cable, junction box and subsea cable power cores. To protect personnel, all voltage connections are enclosed or covered to prevent accidental contact.

Figure 27: Power Bank

Ground Fault Detection

A Ground Fault Protection (GFD) panel has also been installed so that in the event a ground is detected, the 400Vdc supply is automatically isolated from the circuit, protecting any personnel working near the field cables or monitoring platform. This panel was inspected by QPS and completed the CSA Special Inspection.

The project had a protocol in place in the event of a ground fault (see below) but this did not occur during the project.

Safety Protocol: If the 400Vdc system is shutdown on a ground fault, an inspection of the onshore equipment and cables will be conducted to determine if the problem is within the onshore equipment or offshore. If the problem is not in the onshore section of the system, there are other steps that can be taken to isolate the problem and/or ensure monitoring continues. This will be done in a risk-based approach in consultation with OERA and FORCE.

UPS

Figure 28: UPS

A 1500W BN 1500M2-CA UPS (Uninterrupted Power Supply) provides back up power for approximately 8 minutes (assuming all equipment is operating), in the event of a minor power disruption at the FORCE Visitor's Center. Any longer power disruption led to an interruption in the data management. The UPS is primarily to protect against momentary interruptions in power and possible brown-out conditions. The unit also has surge protection which will protect the equipment in the Visitor's Centre against any transient power surges that might occur during a lightning strike or power interruption.

DeMultiplexor

Once the Fibre Optic cable was brought into the Visitor's Centre through the existing conduit, it had to be deconstructed so that each sensor can be read and controlled independently. This is done through the MacArtney Canada Demultiplexor. The Demultiplexor is powered by the UPS in the Visitor's Center.

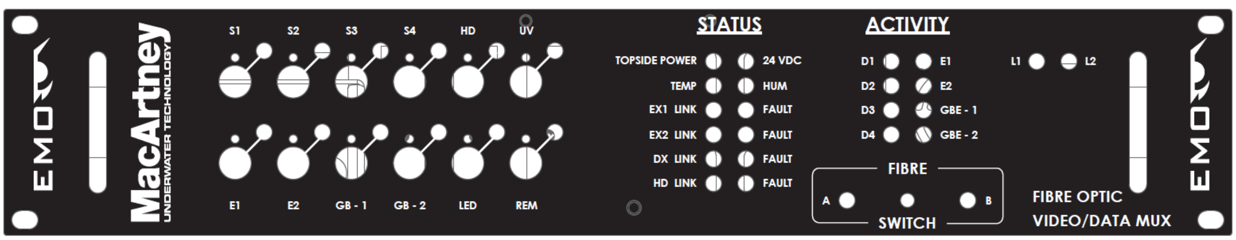


Figure 29: Front of Demultiplexor

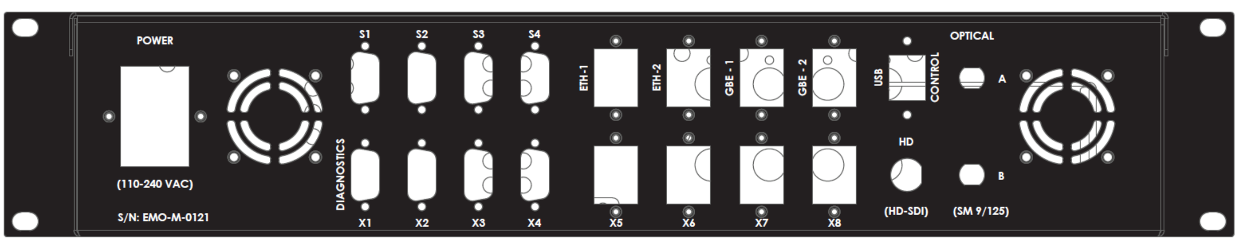


Figure 30: Back of Demultiplexor

Workstation

In order to control and access the data from the sensors, a workstation or computer was required. Given the multiple sensors, a 1Gb ethernet switch connects the Demultiplexor to the workstation. From the workstation, each sensor was accessed through the individual software programs associated with each piece of equipment.

Table 3: Sensor Access Software List

Sensor	Software Program
Sonar	Gemini SeaTec
ADCP	Signature Deployment /Midas
WBT Echo sounder	EK-80
Hydrophones	Lucy / IcListen
Camera	OBS Studio
CT	Ruskin
Pan & Tilt	Imenco OE10 GUI

After the platform was deployed and verified as working, sensor status was monitored remotely through a remote access interface, Chrome Remote Desktop. Remote access was available as long as the internet connection was active at the Visitor's Centre.

Data Management

Given that each sensor generates substantially large data files (in their unprocessed, native formats), it was important that the data management system be able to store all collected data for future use.

A Q30 120TB Storinator storage unit was purchased to support the project. This unit has sufficient capacity to store all anticipated data. Data can be transferred off this unit, either using numerous harddrives, or a direct download onto another storage system.

Data Management is discussed in the Lessons Learned Section of this report as data transfer was challenging throughout the project due to internet connection limitations.

Methodology

The scope of this project did not include analysis of the data collected. Various portions of the data have been shared with multiple interested researchers, including The North Highland College, FORCE and Sustainable Oceans Applied Research (SOAR). Parties interest in obtaining access to collected data should submit requests for consideration through Net Zero Atlantic (formerly OERA).

After the initial system check out testing, the project used three different ping schedules to collect data. Those schedules as the date they started are summarized below.

Table 4: 30 second loop w/ hydrophone always on

Date	Instrument	Ping spacing	Number of pings
20 Dec, 2021	ADCP	0.1	10 (takes longer due to driver error) ~ 5 seconds
	SONAR	0.1	20 – 2.3 seconds
	Echosounder	0.16	40 – 6.5 seconds
	Hydrophone	NA	16.2 seconds

Table 5: 30 second loop w/ hydrophone always on

Date	Instrument	Ping spacing	Number of pings
13 Jan, 2022	ADCP	0.5	10
	SONAR	0.1	20
	Echosounder	0.23	40
	Hydrophone	NA	NA

Table 6: 20 minutes loop w/ hydrophone always on

Date	Instrument	Ping spacing	Number of pings
9 Feb, 2022	ADCP	0.75 (reduced as instrument seemed to have trouble keeping up with 0.5 second ping requests)	400
	SONAR	0.1	2900
	Echosounder	0.3	890
	Hydrophone	NA	NA

During each schedule, the raw data was stored for both the SONAR and the echosounder. The ADCP beam velocity, strength and correlation data were captured per ping and the status with compass data collected every ten ping group. ADCP data was stored as csv files suitable for loading into Microsoft Excel. Hydrophones were continuously recording with the data recorded as wav files.

Results and Deliverables

As this project did not involve data analysis, the primary results are the successful demonstration of the platform, data collection and the Lessons Learned that are reported herein. Lessons Learned are presented as a description of an issue or experience, including the impact on the project and, where applicable, a recommended approach for further research for future projects.

As reported in Submission 007, The Platform Design and Deployment Report, the project successfully deployed the platform 3.52 meters from the planned location, oriented in the desired position.

Lessons Learned

Data Management

The Data Management Lessons Learned were compiled by Strum Engineering. JASCO also contributed to this section.

Power Quality

Issue: Power quality in Parrsboro is poor and the FORCE Visitor's Centre is fed from the Parrsboro distribution line. The power quality is not limited to brief power outages but can experience outages that can last several days. An off-the-shelf UPS is not adequate to cover the extended length of power outages or the low voltage levels experienced at the Visitor's Centre.

Solution: 1) Buy a commercial UPS similar to Eaton 9PX 2000RT. If such a UPS is purchased, ensure the unit is online double conversion, include an Ethernet card so that the UPS can be integrated into the Workstation and purchase extra batteries to give a 24-hour run time under normal load. 2) Have the system powered through the FORCE substation distribution line; this line has demonstrated stability over the last several years and experienced significantly fewer power outages than the Parrsboro distribution line.

Data Retrieval

Issue: Data retrieval from Storinator was slow when using the same workstation that was gathering the data from the instruments.

Solution: Purchase a second workstation for processing the data from the Storinator, zipping the files and copying to portable hard drives.

Data Download

Issue: Offloading data is a problem. Since the system produces a massive amount of data, some form of cloud storage transfer should be incorporated to allow those that are interested in viewing the data have access to it more readily. While it is possible to log on to the platform and view the data using the platform computer, the remote desktop software does not support multiple users and only supports file transfers up to 500 MB.

Solution: Once data processing plan is developed, evaluate options to determine what will work best for any future projects.

Data Transfer

Issue: Data transfer from the system was challenging and could not be completed through an FTP site, which is more standard.

Solution: An internet connection with a fixed IP address should be investigated. A fixed IP address would allow ORCAS to directly support multiple users and would allow a more robust remote desktop system than Google Chrome Remote Desktop, which is what the project was limited to.

Communications Link

Issue: After power failures, the fiber levels as measured by the MUX reduce. The reason for this could not be determined.

Solution: Investigate further upon recovery.

System Sensor Performance

The System Sensor Performance Lessons Learned were collected by Strum Engineering and JASCO.

Sensor calibration

Issue: The platform needs to have some physical system to support in situ calibration of the instruments, if required. It is virtually impossible to hold calibration targets in the field of view of the instruments from the surface in the Bay of Fundy.

Solution: Work with FORCE, SMEs and sensor OEMS to determine long term calibration needs for instruments. If instruments can be calibrated before deployment, ensure it is completed. Limit the need for in situ calibration, especially at the FORCE site.

System Notifications

Issue: ORCAS, the common user interface for sensor management, could not send notifications of a power failure so the project was only aware of a loss of power when someone tried to remote access the platform and was unable to.

Solution: Ensure the UPS has an internet connection. This would enable ORCAS to email notifications via the satellite internet system (Starlink). One would need to make sure there would be a connection available in the event of power loss (Starlink or other means) and, if multiple networks are available, ensure the system fails over to the independent network (such as Starlink) in the event of failure.

Platform Levelness

Issue: During the redeployment, upon initial data review, the platform appeared to be on a slight slope and to have shifted after the initial deployment.

Solution: Determine a method to measure "levelness" during the deployment to ensure the platform is level and not deployed on a boulder or something that could shift in the days after deployment. If possible, the site should be visually inspected through underwater pictures/video prior to deployment (other teams have used a "drop camera" approach, which will be evaluated for effectiveness at the site). Before completing the deployment activities, confirm that the platform is level. The FORCE site does not have significant concern for sediment so it is unlikely that the platform will "settle" or sink, but if not deployed in a stable location, the platform may shift, which complicates system calibrations and data analysis.

ADCP

The ADCP Lesson Learned is from JASCO.

Data Transmission

Issue: an issue was discovered during testing that the ADCP appears to stall while transmitting data when it is configured for five beam operation. As the unit functions normally when configured for four beam operation, this was used during the deployment. The cause is unknown but was reported to the vendor (Nortek) and will be investigated upon recovery.

Solution: Investigate upon recovery

Camera

The Camera Lesson Learned is from JASCO.

Utility

Issue: in the present configuration the camera did not have substantial utility for the project. The field of view is restricted to the area illuminated by the LED and could not see beyond 1 – 2 meters (with the LED). Visibility was < 1 ft without the LED.

Solution: If there is a continued desire to use a camera, configure the system design to allow for platform inspection to see sensors, cables and connectors.

CT Device

The CT Device Lesson Learned is from HTEL.

Stopped Functioning

Issue: The CT Device was not functioning after the second deployment. Efforts to troubleshoot could not resolve the issue.

Solution: Investigate upon recovery; send device to OEM to support investigation.

Echosounder (EK 80 WBT Tube)

The Echosounder Lessons Learned are from JASCO.

System Noise

Issue: The system seemed noisy overall, as noted in the MUX section. For data collection during the deployment, the settings where changed after discussion with FORCE SME to reduce sensor bandwidth and reduce the effect of the noise on the data. The Echosounder Noise was picked up in the Hydrophones

Solution: Investigate through testing to limit overall system noise.

Data collection

Issue: The data preferences were not clear at the start of the deployment; after discussions with FORCE SME, the settings were changed to collect "real data" and not "complex data".

Solution: Ensure data plan is established before deployment. HTEL is ensuring this is complete for their own EEMP by working with contractors early to establish data processing and analysis needs.

Ping Rate

Issue: The required ping rate could not be confirmed without in situ testing; the ping rates must be low enough to allow the surface echo to die down and not interfere. The ping rates established were generally accurate overall but there is variability due to delays through the MUX and Fiber system. This delay can extend to several hundred milli-seconds occasionally.

Solution: Execute testing (see Submission 008) to set the ping rate in the scheduler to be equal to the ring down time as defined and measured in the test plan.

Hydrophones

The Hydrophone Lessons Learned are from JASCO and HTEL.

Software

Issue: The vendor supplied software, Lucy, does not allow automated restart after a power failure when more than 1 hydrophone is used. Manual configuration of the second hydrophone was required to start up the hydrophones.

Solution: Investigate with OEM

Utility

Opportunity: In addition to passive acoustic monitoring, the project found wide band hydrophones useful for troubleshooting purposes; the hydrophones assisted in detecting noise from other equipment on the platform.

Flow Noise

Issue: The hydrophones are sensitive to ambient noise. Given the turbidity and flow speeds at site, the project anticipated the need for hydrophone guards. During high flow, there was some broad band pulsing noise detected, which is likely the protective shroud fluttering in the flow.

Solution: The shroud should be made as tight as possible or removed. The project will continue to evaluate the best solutions from other testing at the site.

SONAR

The SONAR Lessons Learned are from JASCO.

Communications

Issue: The SONAR has occasional issues connecting to the communications port. This issue presented during early testing but was believed to be managed through procedures.

Solution: Investigate this issue further.

System Delay

Issue: As noted in Echosounder Ping Rate, the SONAR experienced MUX-induced delays when operating under ping control.

Solution: This requires further investigation to determine if it is best to manage this or if something needs to be changed.

System Reset

Issue: The SONAR reset intermittently and did not restart properly after the resets. This was discussed with the vendor (Tritech) who noted this was not a "common problem", the system is shipped from the OEM with "watchdog" software to reconnect and reset after a timeout. This software corrects the problem when used.

Solution: incorporate the "watchdog" software into the SONAR system from the start of future projects.

Swept Area

Issue: The monitoring platform sonar swath was oriented horizontally (to track targets moving in X/Y, horizontally, through the site. This orientation experienced seabed returns and occlusion due to the platform levelness issue.

Solution: The sonar can be installed so that it is orientated with the swath vertically upwards, with the tidal flow (tracking targets in X and in Z). This limits seabed returns. This orientation will be considered for future deployments.

UV Lamp

The UV Lamp Lesson Learned is from HTEL.

Damage

Issue: One of the two UV lamps was damaged/broken during the initial deployment timeframe.

Solution: Design protection for the lamps into future monitoring platforms.

Multiplexor System Design:

The MUX Lessons Learned are from JASCO.

System Noise from Multiplexor

Issue: The Multiplexor experienced water ingress during the initial deployed period. The issue was noticed on the day of recovery as the humidity sensor had been triggered (only available to be seen on the hard MUX itself, not remotely). Upon recovery, corrosion was identified on a plug on the MUX. The OEM (MacArtney Canada) refurbished the MUX. Noise was present in the system after this refurbishment that was not present in earlier system tests. The MUX produced several spectral lines that were picked up by various sensors on the platform.

Solution: Anytime the MUX, or any other component is refurbished/replaced, an in-water test of the complete system should be completed prior to reinstallation/redeployment at the site.

Power Status

Issue: The MUX does not set its power outputs correctly when it powers up. The MUX accurately reports its status to ORCAS and ORCAS sets all indicators to display that the power is "up" but the output is not properly reported. After a power failure, this forces a manual intervention to reset the system.

Solution: Either modify the MUX to correctly report its power outputs or update ORCAS to reset all supplies upon reboot.

Reported Fiber Connection:

Issue: The MUX reports the wrong fiber connection. When it switches to Fiber "B", it reports Fiber "A" to ORCAS.

Solution: fix the MUX to properly report the correct fiber.

Dropped Packets

Issue: When heavily loaded, the MUX occasionally drops packets of data.

Solution: Work with OEM; identify the limitation and incorporate it into the ping schedule for the system

Cable

The Cable Lessons Learned were developed by Strum Engineering, JASCO and Halifax Offshore Consulting.

Cable Connector Protection Cage Design

Issue: The locking mechanisms used to secure the two halves of the cage were too small and difficult to install quickly on deck.

Solution: Change the cage to beef up the locking mechanism or alternatively change the cage as discussed shown below in Figure 35.

Cable Connector Protection Cage Design and Fit

Issue: The was the cage was originally designed did not allow access to the shackle, which is essential in securing the cable/Trustlink on deck. This caused problems in the future retrieval of the cable, more particularly in the way we had to tie the cable off and secure it. With the cage not fitting properly, the cable was hard to manage and created a less than favourable bend near the bend restrictors. The ears on either side of the cage prevented the cages from fitting and closing properly over the truss link. The cage was modified at the next opportunity. The ears identified in the circled area in Figure 31 were removed and that allowed for the cage to fit better over the Trustlink and allow the cage to close properly without having to use zip ties. This also allowed for the shackle to be connected to the Trustlink to allow proper attachment of a ground line. An issue with the hinge also presented itself after the second retrieval of the cable and cage. Modifications were made to the cage for the redeployment that should resolve the issue.

Figure 31: Cable Connector Protection Cage

Solution: Recommend manufacturing another cage taking into consideration the modifications that were made to this one. Also, a single long pin or bolt on the hinged side of the cage with safety pins in place to avoid nuts backing off and cage coming off.

Cable Termination

Issue: The termination mould installed on the dry end of the subsea cable was nonstandard and could not be glanded to the Beach Junction Box properly. The conductor and fibres could be easily broken at the edge of the epoxy mould.

Solution: The termination should be sized to acceptable a nominal size cable gland or be formed inside a suitable sized threaded metal conduit. Additionally, the group of conductors and fibres should be covered by a PVC sleeve as it transitions from the epoxy mould to help protect the cores at the cable.

Bend Restrictors:

Issue: On first retrieval of the platform, it was noted that the bend restrictors were separated just behind the transition piece (see Figure 32).

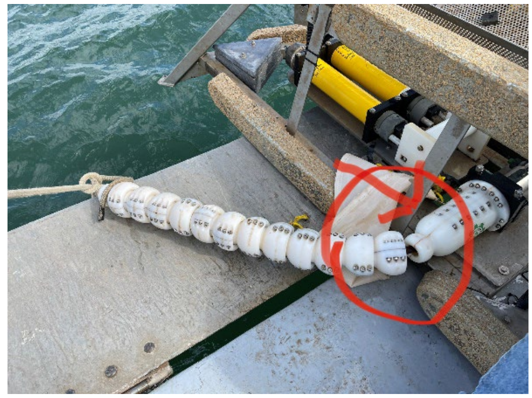


Figure 32: Bend Restrictor Separation

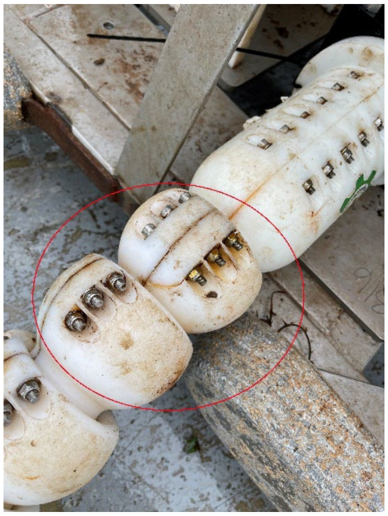


Figure 33: Crack in Bend Restrictor

There was also a small crack in the material on the first clam shell set after the transition piece (see Figure 33).

The bend restrictors were disassembled on deck and reassembled over the transition piece.

In addition, there was also a hold back line attached to the bend restrictors in the event the damage was caused during the platform set down on initial deployment (see Figure 34).

Figure 34: back line attached to Bend Restrictors

Solution: Recommend extending a metal bar out under the transition piece and past the second or even third set of clam shells on the bend restrictor assembly. This would provide support to the assembly and help prevent the possibility of the cable folding back under the platform on set down.

Cable Connection to Platform

Issue: The process to remove the subsea cable from the platform and install the Trustlink in the cage involves too many steps and requires a variety of tools to accomplish in the limited timeframe we have.

Solution: Please see Figure 35. Make the whole Trustlink assembly removable with the exception of the shackle pin. This could be done by securing it to the platform with 4 to 6 bolts with captive nuts. Design the pin to be permanent with removable cap so shackle can be slipped over pin. This would allow the Trustlink to be removed from platform by only removing 6 bolts and slipping shackle over pin. The Trustlink assembly could then be ready to submerge by installing a half cage around the Trustlink and securing with the same 6 bolts rather than having to deal with small Allen key bolts and nuts. The submerged cage would have a flat bottom and would be less likely to roll around on seabed.

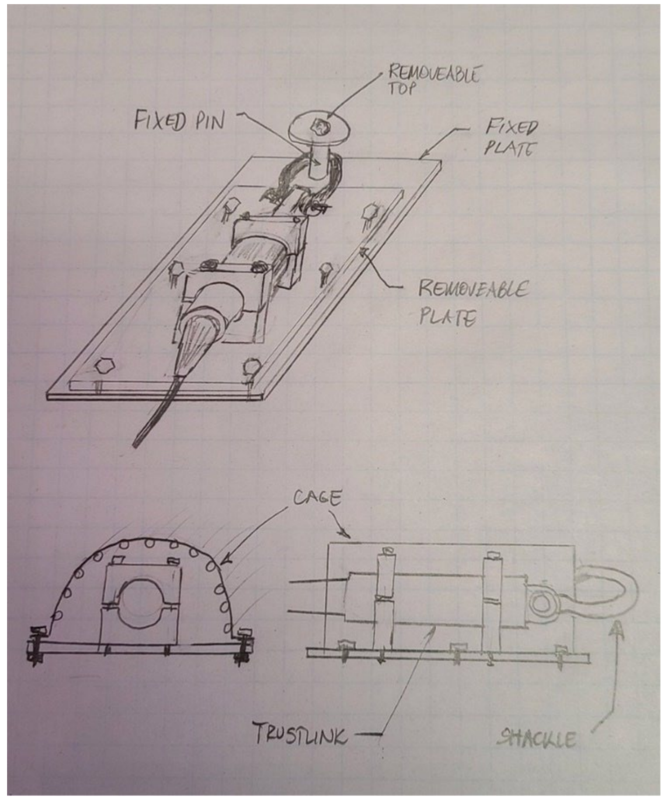


Figure 35: Sketch for Trustlink Modification

Overall System Design

The System Design Lessons Learned were developed by JASCO, Strum and Halifax Offshore Consulting.

Instrument Cable Management

Issue: The project wasted time and increased risk of failure by repeatedly installing and removing cables from the platform to use for sensor bench testing.

Solution: Purchase duplicate cables for all instruments. This is a relatively low cost compared to the risk of failure. It allows one set of cable to be permanently attached to the platform without the need to remove them to perform bench testing. Additionally, this increases reliability since cables that were working during last deployment have not been moved or reinstalled which may have inadvertently damaged cable. Finally, this would ensure that backup cables are available on hand if a platform cable fails.

Multiplexor Redundancy

Issue: Backup fibres are not utilized in offshore multiplexer.

Solution: Fibres that are not used for the primary A1 and B1 fibres should be looped together within the multiplexer so that a dB loss measurement can be taken when required to help explain issues with the primary fibres.

Acoustic Release System

Issue: On first retrieval of the platform the acoustic release had failed, and the surface floats were deployed due to faulty securing of the enclosure over the spool holding the dyneema. The surface floats were at surface when we arrived on site. The issue was rectified by using steel clips and zip ties instead of being tied down with small diameter poly rope. However, the floats were recently noticed to be on surface again, indicating another failure.

Solution: This system requires a redesign for a long platform deployment (> 8 weeks). A discussion with FORCE to determine how they secure their spool covers for the float release mechanism is a starting point however more work will be required to optimize this system.

Operations

The Operations Lessons Learned were provided by Strum Engineering and Halifax Offshore Consulting.

Unsupported Cable Lengths

Issue: Positioning of wet multiplexer on the platform caused unsupported lengths (~0.5m) of leads to be unsupported which could cause oscillation during tidal action.

Solution: Install a permanent bracket on platform to support Trustlink flexible leads.

Excess Cable

Issue: Excess cable from the cable lay operations was simply laid out on the seabed near shore. This caused the cable to move a lot within the first 150 meters of water. The crew was sent out in a small RHIB to try and spread the cable out over a larger area to help prevent the movement of the cable. That was not totally successful as some of the cable kept looping back onshore. A crew was then dispatched to retrieve all the cable possible near the shore at low tide and spill it up the beach. The cable was then coiled up near the beach termination and no further issues with cable movement have been detected.

Figure 36: Excess cable on beach after cable lay

Solution: Future installations of small cable of this type should be done with the expectation of pulling all remaining excess cable up the beach and secured to the termination area.


Figure 37: Excess Cable Spooled on the Beach

Landing Cable on Beach

Issue: During the cable lay, the cable was spooled off on the deck and transferred to Nova Endeavor. Paying out cable to the Nova Endeavor Beach point worked without issue. Offloading the cable to the beach became complicated due to the dry end of the cable becoming entangled in the wraps. The dry end had to be returned to the Nova Endeavor to untangle the cable. To resolve this, the operator returned dry end of the cable to deck of Nova Endeavor then worked the entangled wraps through the remaining cable to clear the entanglement and excess cable was fed over the deck of Nova Endeavor to avoid excess cable laying on the beach.

Solution: In order to prevent this for future small cable lays, it is recommended to use a different vessel; A proper landing craft, as originally selected, would work better in this situation than the Nova Endeavor. On future cable landing activities, a radius should be considered for the shore pull in.

Vessel Selection Criteria

Issue: The requirements for what is an acceptable vessel for operations in the Minas Passage and the FORCE site are unclear. FORCE had indicated that a blue decal is the preferred criteria for a vessel if it is to operate in the CLA. As a result, the landing craft intended for use during the landing was changed and the Nova Endeavor was used as the vessel has the "blue decal" certification.

Solution: FORCE should work with berth holders and marine services providers to develop a vessel standard that will clearly outline the certifications required for a vessel to operate. Vessel safety inspection program should be considered as a method of assisting operators with vessel selection.

Temporary Clump Weight Installation

Issue: An 8000LB clump weight was installed to allow the Warrior to maintain position to transfer the cable to the Nova Endeavor. FORCE had expressed concern over the anchor and its ability to properly moor the Warrior without dragging the anchor. A late request for proof of the anchor ability the night before the operation was received. HOC suggested the vessel set the anchor and perform a test to prove the ability of the clump weight. Once set at the targeted location, the Warrior moored to the clump weight for 2 hours in the peak flow conditions.

Solution: Recommend that a detailed criteria be created by FORCE outlining requirements for deploying and using clump weights and anchors in the CLA

Weather

Issue: Although two different forecast models were used to determine an acceptable weather window for the operation the weather was not as predicted. Winds forecasted from the Southwest were coming in from the East. This presented an issue for landing the cable as the wind was pushing the Nova Endeavor to the side. To manage this, the vessel master had to hold vessel in position manually to maintain position.

Solution: A proper landing craft, as originally selected, would have been helpful in this situation. Beaching the vessel completely was not an option with the Nova Endeavor.

Communications with FORCE VC

Issue: Communications with the FORCE visitor center was good. The communications between the Dominion Warrior and the visitor center on entrance into the CLA did not happen. This is due to the vessel master not waiting for the person in charge to arrive on the boat in West Bay as requested. The Dominion Warrior was told to return to West Bay and wait for the person in charge to arrive. Rules of the entrance and exiting of the CLA was reviewed with crew.

Solution: Review requirements, and remind operators of requirements, for operations in the FORCE CLA with marine operator in advance of operation.

Platform Ground Line Clump Weight

Issue: The clump weight on the ground line for the platform is just under a ton in weight. Although effective it makes the ground line hard to handle. The clump weight was left as is for this work as there was no reason to change at this point as they are working as intended.

Solution: Use half of the weight on future deployments.

Positioning for Retrieval and Testing

Issue: A clump weight was deployed about 80 meters east of the platform touch down location. This was used to assist in recovery of the platform and to extend the working time on the surface to allow for testing. The clump weight position worked great and did extend the working time at surface. Care needs to be taken to monitor the angle of the cable while working on the surface as tide flow increases, strumming on the cable and the angle of the cable off the deck will increase. If this is not monitored closely, damage to the cable could occur.

Solution: Recommend not testing on site if at all avoidable. Clump weights work well but timing should be limited to account for increased flow speeds. Recommend no more than 1.5 m/s for any operation where the cable is at surface and being worked on.

Conclusions

The project successfully demonstrated the ability to deploy a multi-sensor platform at the FORCE test site cabled back to shore for ease of sensor control and data access. The sensors were integrated through a common user interface, ORCAS. The platform successfully collected data for, at the time of this report, 15 weeks. The data collected has been shared with numerous interested parties and is available for others that may be interested. The success of and lessons learned from this project informs subsea monitoring platform projects at other tidal turbine project sites and other high-flow sites in general. The data collected from this project has been used to further progress automated data analysis programs for the Gemini SONAR. Additionally, the echosounder data collected has allowed comparisons between different duty cycles in an effort to inform researchers on how to improve data collection.

As discussed in the Lessons Learned portion of this report, the project experienced a number of challenges and learned key pieces of information that will inform future monitoring platform deployments. Most of these challenges were easily understood and can be incorporated into future monitoring programs without issue, as described in the Solution the Issue in each Lessoned Learned. However, a few items require further investigation to understand and solve.

The items that require further investigation are:

1) The degradation of the communications link, as measured by the MUX, over time. This issue seemed to be exacerbated by power failures at the FORCE VC. The underlying cause is not understood and has been discussed with the MUX OEM as well as other experts in the field. This work will continue upon platform recovery and inspection. The subsea cable will also be fitted with a loop connector that allows for continued monitoring after the platform is recovered.
2) Data retrieval and data download; the challenges experienced during the deployment make the current set up unsustainable for a long-term turbine monitoring program. HTEL will work with its contractors to devise a system that meets its tidal turbine project requirements. The system will be tested and stressed prior to turbine deployment and the start of the EEMP.
3) Sensor calibration is an area that HTEL will continue to work with FORCE on; It's not practical to calibrate sensors in situ given the site characteristics. A proper sensor calibration plan will be developed and reviewed with FORCE and/or other SMEs prior to future deployments.
4) System Noise from the MUX and sensors; more robust in water testing is recommended for future platforms to ensure all spurious noise is characterized and, if possible, eliminated from the system.
5) Subsea cable management requires further thought and work. Cable lay operations at the FORCE site are challenging and can continue to be improved upon.
6) The failure of the CT device will be investigated with the OEM once the platform is retrieved, and the sensor can be removed from the platform.
7) The platform deployment can also be improved upon; ensuring levelness on the seabed is key to sensor performance. There are various means to ensure levelness and one or more should be incorporated into future deployments.

8) The ADCP data transmission issue should be investigated with the OEM upon recovery as well. If this is a sensor limitation, processes should be developed to manage this.
9) Based on repeat failures, the acoustic release system needs to be redesigned and reinforced for long term deployments. This program is not the only failure of this type of recovery system that HTEL has encountered.

Ultimately, once the mechanical issues and CT failure are addressed, further discussion is needed with the regulatory authority and scientific community to confirm the types of data required as this informs the ping schedule. The project confirmed that these settings can be adjusted upon request to improve data quality or to target specific data in order to address changing monitoring objectives as more is learned.

Appendix 1

JASCO Acoustic Release Failure Investigation Report from initial failure

DP Energy Pathways Release Failure Investigation

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Release Mechanism Failure

The state of the release mechanism was investigated on Friday, 17 September 2021 at Dominion Diving.

It was relayed from the field team to the engineers that the recovery floats were at surface during slack tide before the releases were triggered. This would indicate a failure of some part of the mechanism; either a false release, or a mechanical failure of the parts holding the canvas cover. It is not known how long before the recovery operation this failure happened.

Figure 1. Release mechanism as rigged prior to deployment and post recovery.

After investigation, the releases did not misfire, and no parts were broken on the release itself. There was some apparent wear on the canvas cover itself. The releases remained in position. There was some biofouling and rust, but no mechanical damage.

The rope holding the canvas spool cover appears to have chafed to the point of failure where it meets the grommet on one side of the spool cover releasing the recovery floats. The opposite side of the spool cover was intact. Some of the stitching in the spool cover had come undone, but not enough to pose any threat of failure. Some of this damage may have occurred after the rope failure. Doubling up the stitching on the cover may help.

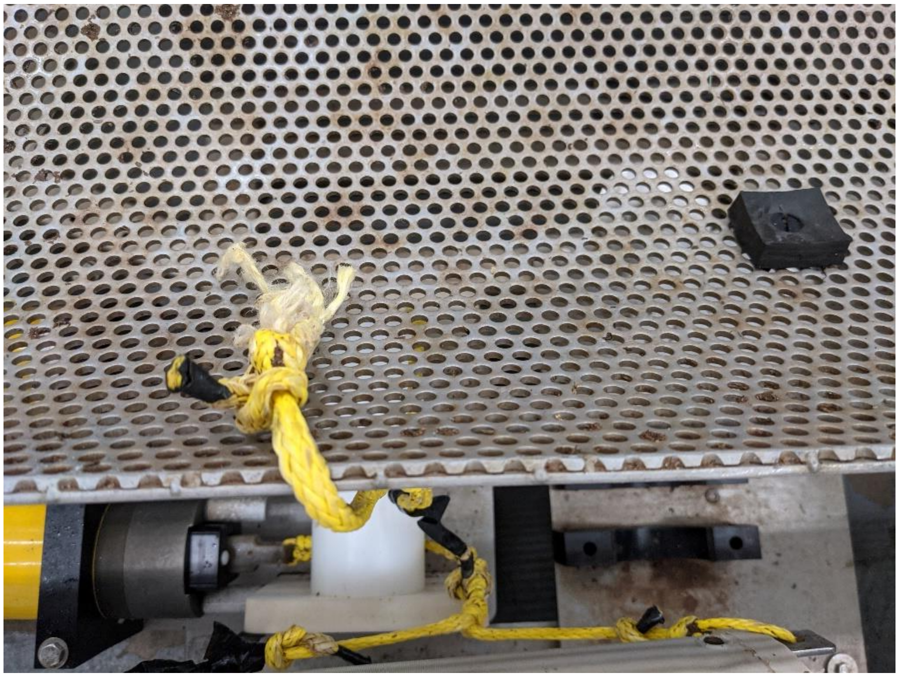

Figure 2. The chafed knot on one side of the spool cover.

All the knots in the system had been taped over, but after recovery it seems that much of the tape has worn free. Spliced connections would work better but would need to be done with high accuracy with regard to the lengths.

Figure 3. Intact side of cover now missing tape.

A shackle, or other lifting device should be placed on the grommet to reduce chafing and reduce the risk of failure in the future. A more wear-resistant rope can also be used. Jasco commonly uses Polyspec (polyester-jacketed dyneema), although the extra lead time to procure this rope will have to be considered.

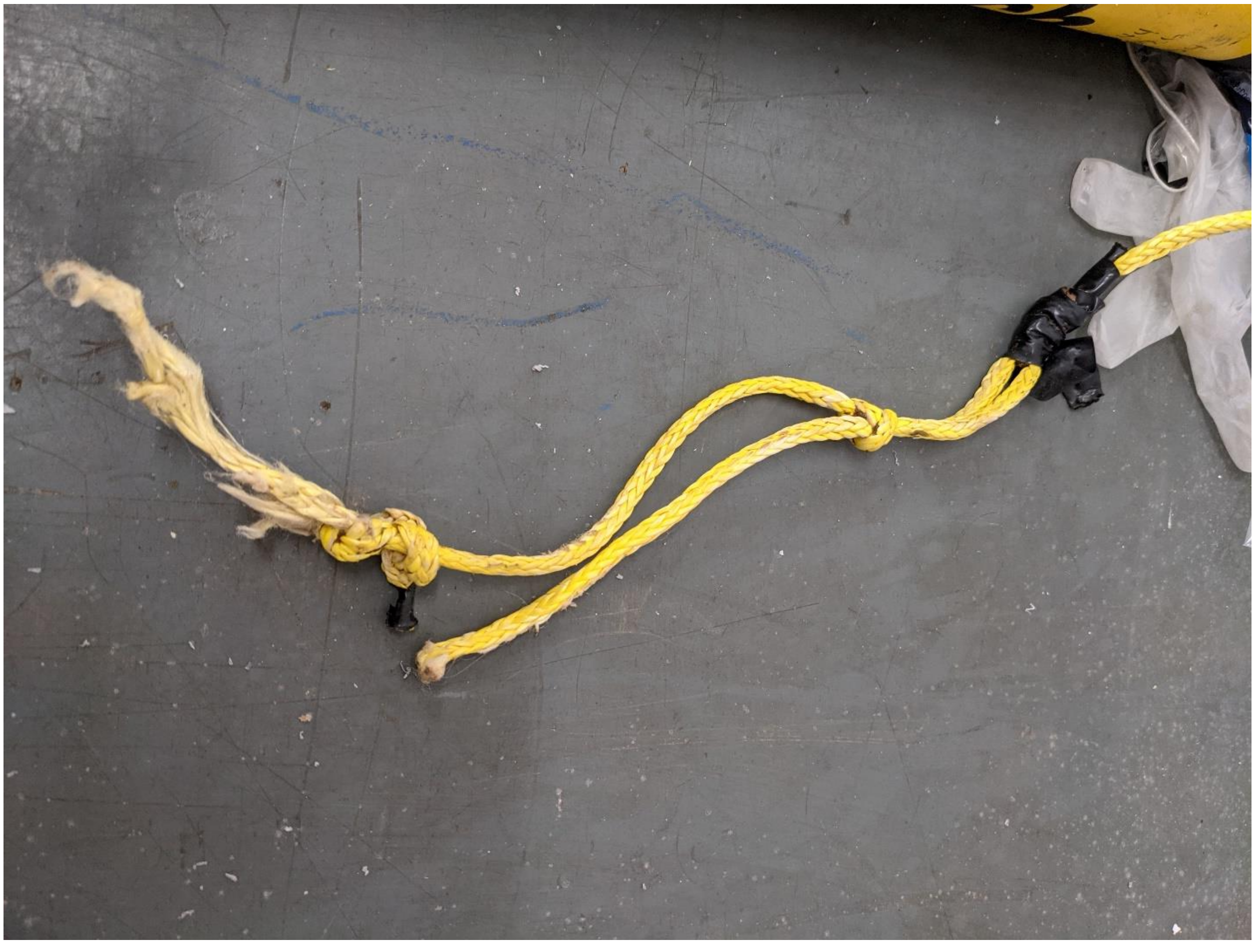

Figure 4. Full view of chafed knot.

Originally, the spool cover was kept tight with a trucker hitch. Applying more tension through a mechanical aid may also help reduce the amount of movement in the ropes, and thereby the amount of wear seen on the mechanism.