WIREWALKER™

WAVE-POWERED PROFILER

Users Guide

v4 July 2020

DEL MAR OCEANOGRAPHIC

www.delmarocean.com

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I. PREFACE

I.1. ABOUT THIS MANUAL

This manual is designed as a guide to assist users of the Wirewalker™ in becoming familiar with the profiling system and in making wise operational choices. We recognize that each deployment is unique and that resources, such as vessel size, type, and supporting equipment, are variable. While it's impossible to cover all scenarios in this manual, the information contained herein has been proven effective and is offered as a guide. If you have questions, please reach out to us for more information. Remember: safety must always be paramount when undertaking sea-going operations, and is the users responsibility.

The focus here will be on the platform/profiler itself; we recommend users refer to, and become familiar with, the appropriate instrumentation manuals for operation of the payload and/or sensors that are integrated onto the platform (see MANUAL LINKS FOR COMMONLY INTEGRATED PAYLOADS).

Del Mar Oceanographic prides itself in being sensor agnostic and in adding new dimensions to sensors you're likely already familiar with. However, not all sensors are ideal for rapid vertical profiling. As a general rule of thumb, high-quality low-powered sensors with fast sampling and response rates are ideal for collecting high resolution data. Please carefully consider the sampling parameters of any sensor, and the sampling goals, before integrating a new sensor onboard the Wirewalker.

At our website, www.delmarocean.com, you will find other supplemental information, including photographs, that users might find useful when planning a Wirewalker™ deployment.

I.2. FEEDBACK

Feedback is always appreciated. If you find errors, omissions, or sections poorly explained, please do not hesitate to contact us at inquiry@delmarocean.com. We appreciate your comments, and your colleagues will as well.

I.3. MANUAL REVISIONS

v1	Aug 2018	Initial draft
v2	Sept 2019	Minor updates to figures, text, and formatting.
v3	Feb 2020	Formatting updated.
v4	July 2020	Updates to figures, text, and formatting.

2. INTRODUCTION

Del Mar Oceanographic's Wirewalker™ profiling system uses ocean wave energy to drive an instrument platform (often referred to as the Wirewalker vehicle, or simply "the Wirewalker") vertically through the water column. A single suite of user-selected sensors can repeatedly sample over a range of depths, rather than produce time series at a single location. The Wirewalker is purely mechanical, with batteries required only to power sensors and communications. It profiles continuously, with wave energy driving the buoyant profiler downward. On reaching the deepest user specified sampling depth, it free-ascends along its suspension cable (aka profiling wire), nearly completely decoupled from mooring motion. This provides an ideal opportunity for precise ocean measurement. The Wirewalker profiling vehicle is designed to be extremely adaptable, to facilitate the mounting of a wide variety of sensors.

Key requirements for system operation include:

- Waves: Even weak wind-chop on lakes work well. The lack of wave energy is rarely a constraint at sea, but profiling repeat rates depend on sea-state.
- Free vertical motion of the buoy-wire-weight combination (Figures 1 and 2): Specifically, the downweight at the end of the profiling wire should not become grounded or the wire slackened for any other reason.
- Free vertical motion of the profiler: this means that the vehicle must be properly ballasted and cannot become fouled.

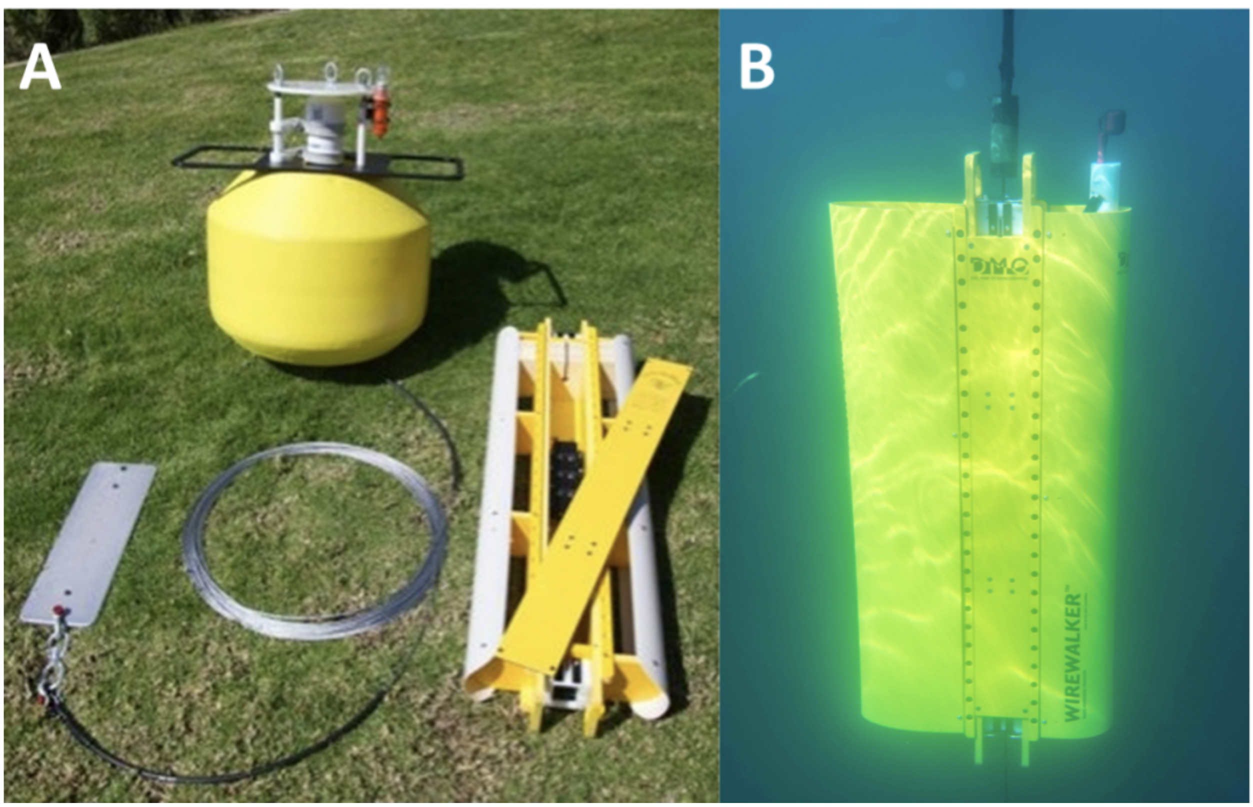


Figure 1: (A) Wirewalker surface float, profiler, cable and downweight, (B) submerged profiler.

Optimal system performance requires proper ballasting. The profiling vehicle must be positively buoyant with a target up-cast speed of roughly 40 cm/s. As a rule of thumb, the profiling round trip (i.e. surface/bottom/surface) speed is roughly 1 minute per 10 meters of profiling depth. Thus, profiling to 200 m is sampled about every 20 min.

The Wirewalker profiler has a ratcheting motion on the way down, as it uses the surface waves to propel the vehicle downwards, but smooth on the way up as shown in Figure 2. The separation of upcast and downcast is handled in post processing with just the upcast typically used for detailed analysis. However, data is/can be collected during both upcast and downcast and very useful when looking at mooring dynamics. The overall principles of operation describing the method of harnessing wave energy through the reversing cam are not presented here, but interested readers can find further information in the publications listed in the REFERENCES section.

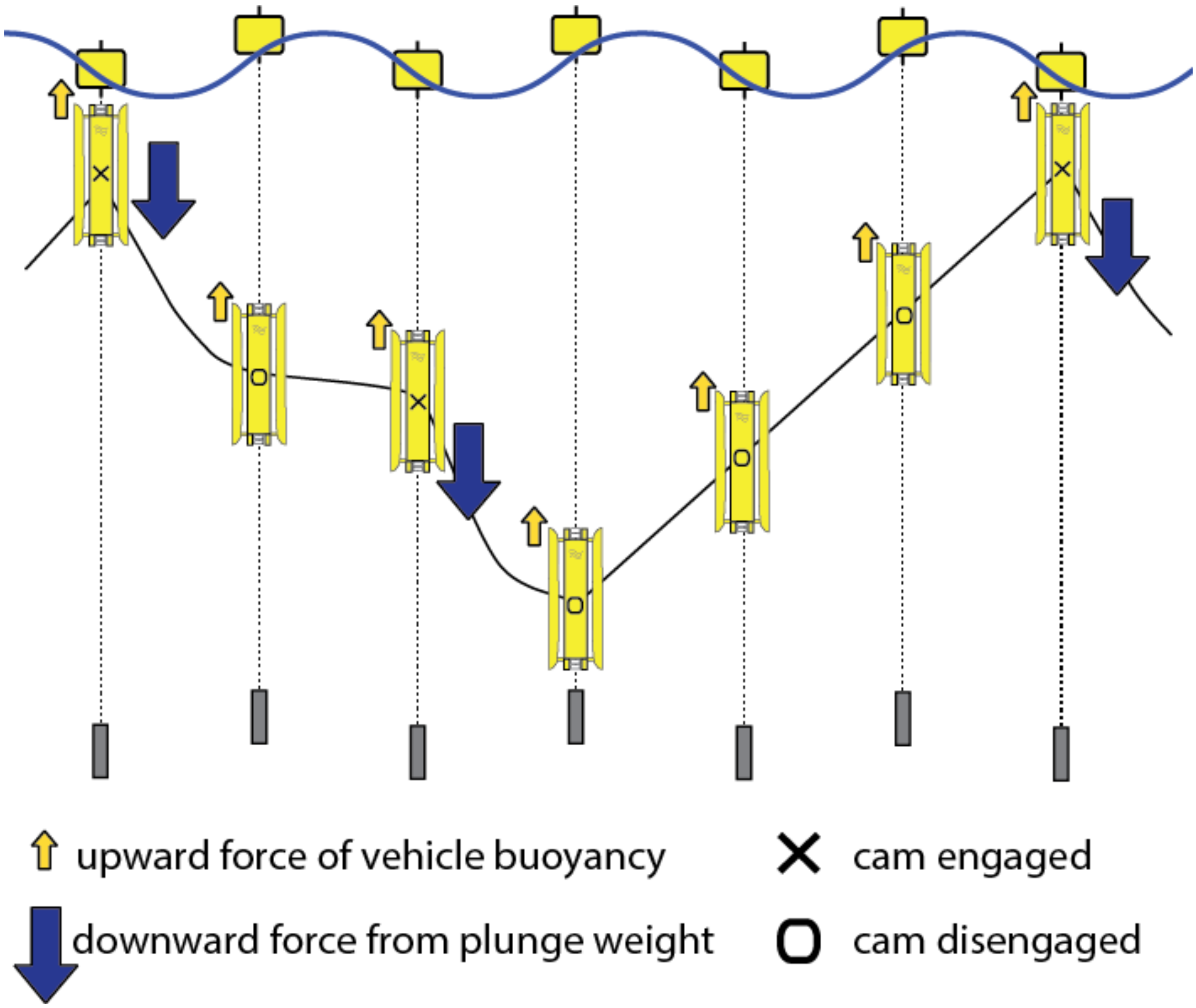


Figure 2: Profiling cycle of the Wirewalker.

3. SYSTEM COMPONENTS

The Wirewalker Profiling System consists of four primary components, each is addressed individually with a summary of detailed specifications in [Section 3.5](#). The full system is visualized in Figures 1A and Figure 3.

3.1. SURFACE BUOY

The surface buoy's primary function is to harvest the energy from the surface wave field. The surface buoy also acts as a platform for real-time satellite GPS tracking of the Wirewalker's position and can be equipped with a real-time telemetry system via Iridium or GSM. The surface buoy has been designed for optimal handling and efficient operation in a wide range of wave conditions. It comes equipped with a flasher (aka strobe) for deployment and recovery operations.

3.2. PROFILING WIRE

The Wirewalker profiler travels along a 3/16"jacketed profiling wire that links the surface buoy above, to the downweight below (see Table 3.5, below). This wire transmits surface wave energy deep into the sea through its mechanical motion. The length of the wire, along with turnaround bumpers attached near each end, define the upper and lower limits of the profiling range. In addition to providing motive power, the jacketed profiling wire also enables use of an inductive communications link between the moving profiler and the surface float.

3.3. WIREWALKER PROFILER

The profiling vehicle (the "Wirewalker") consists of the instrument platform itself, including the cam mechanism that selectively engages the profiling wire when descending. The cam mechanism drives the profiler downward, using wave action, to the end of the profiling wire, at which point the cam releases, allowing the profiler to float freely up to the surface. The profiler houses a configurable set of oceanographic sensors as well as a configurable set of depth rated foam to set the positive buoyancy. Various foam densities are available and define the depth rating of the profiler (300m-1000m). The profiler is outfitted with asymmetric cowlings that give it a leading and trailing edge as they align the profiler body into the current.

3.4. DOWNWEIGHT

The downweight is suspended at the bottom of the jacketed profiling wire, just below the profiler's lower turnaround point. Typically, two steel downweight plates totalling 90 lbs (40kg), is sufficient to ensure that the profiling wire maintains the tautness needed for proper profiling of the water column. There are four mounting holes in the plates; these allow the plates to be linked in series or the holes can be staggered and the plates bolted together. In areas of high shear and/or currents, additional weight may be required.

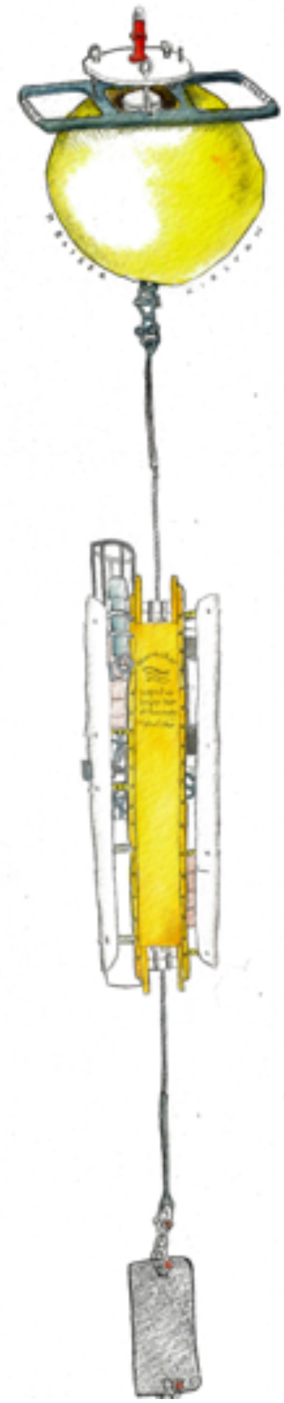


Figure 3: Artistic rendering of the Wirewalker Profiling System Components (source: Omand et. al. 2017).

3.5. SUMMARY OF SPECIFICATIONS

SURFACE BUOY		
Dimensions	36″ Ø x 40″ With 10″ Ø well	0.9 m Ø x 1.0 m With 0.25m Ø well
Buoyancy*	600 lbs	275 kg
Weight*	~135 lbs	~61 kg
Mooring Attachment	½″Shackle	
Includes	Solar powered flasher with multiple patterns	
Recommended Accessories	Iridium GPS beacon, Real time telemetry system.	
PROFILING WIRE		
Jacketed Wire Diameter	3/16″ nominal Ø 0.255″ jacketed OD ± 0.010″	5mm nominal Ø 6.5mm jacketed OD ± 0.25mm
Breaking Strength	4000 lbs	1814 kg
Weight (water)	0.052 lbs/ft	0.0772 kg/m
Terminations	Standard: ½″ shackle	Hammerhead: ⅝″ shackle
WIREWALKER PROFILER		
Dimensions	60″ x 26 x 6.5″	152.5 x 66.0 x 16.5 cm
Weight (air, no payload)	~55 lbs	~25 kg
DOWNWEIGHT (x2)		
Dimensions	24″ x 8″ x ¾″	61 x 20.3 x 2 cm
Weight	45 lbs	20 kg
Mooring Attachment	½″ shackle (on both ends)	
WIREWALKER SYSTEM		
Payload	Modular design accepts most oceanographic sensors	
Profiling Rate	10 m/min (round trip) in most wave conditions; 0.3 - 0.5m/s ascent rate is typical	
Max profiling depth	3280 ft	1000 m
Buoyant foam depth rating options	984 / 1640 / 2460 / 3280 ft	300 / 500 / 750 / 1000 m

** Fully assembled, not rated for depth*

3.6. PROJECT CUSTOMIZATION NOTE

Due to the adaptable and modular nature of the Wirewalker, each of the four primary components can be outfitted to match the needs of the project. Options could include an upward looking Acoustic Doppler Current Profiler (ADCP) positioned at the base of the profiling wire, supplementing the downweights, or the addition of auxiliary sensors on the profiler. Likewise, alternative instrumented surface buoys have also been used with good success in well designed moorings. The Wirewalker is an adaptable system that can be upgraded and outfitted to meet the unique needs of future projects; however, it's impossible to predict the impact that all customizations may have. We suggest gaining experience with the Wirewalker Profiling System with its standard components first, before beginning significant customization.

4. PRE-DEPLOYMENT SET-UP

The Wirewalker Profiler is a purely mechanical device. Its simplicity is a strength, but the profiler must be properly set up (ballasted, affixed to the profiling wire, deployed in the proper orientation, i.e. with the correct side facing up) or there is a risk of compromised profiling performance. Therefore, it is important to become familiar with what is necessary to prepare and access for a deployment. DMO has made this intuitive by using a variety of hardware. While you may utilize additional tools during integration and ballasting procedures, typically on deck you only need a #3 Phillips screwdriver to remove the Phillips flat head 1/4-20 screws on the cowlings, center lid, and on the cam cover to load the wire into a Wirewalker.

4.1. ANATOMY OF THE WIREWALKER PROFILER

At the heart of the Wirewalker Profiler is the profiling cam mechanism, which engages with the wire to propel the platform down through the water column. Since the payload is customizable, so are the clamps and mounts to secure them to the platform. Buoyant foam is used to ballast the system for the desired ascent rate and to balance the weight of adding various payloads. Refer to PAYLOAD BALLASTING CONSIDERATIONS for a more in depth view of ideal locations to mount particular types of sensors and for where to add/remove foam. Additionally, there are two cowlings that help to protect the integrated payload. The leading edge cowling is the shorter of the two, while the longer is the trailing edge. Sensors that benefit from maximum unobstructed water flow should be mounted on the leading edge. More Wirewalker anatomical terms are defined in the GLOSSARY.

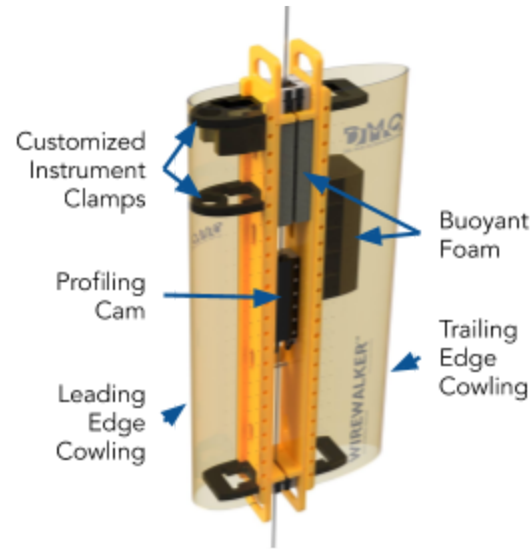


Figure 4: Illustration of the basic anatomy of a Wirewalker Profiler

4.2. REMOVING THE COWLINGS

In order to integrate a payload, change batteries, add/remove foam, or often to access the data and/or program a sensor, the cowlings must be removed. This is done by simply removing the cowling screws (pairs of Phillips flat head 1/4-20 screws on the inner edge of the cowling) with a #3 Phillips screwdriver. No other tools are necessary. There are cowling screws on both sides of the Wirewalker that will need to be removed. Refer to Figure 5A for visualization.

To replace the cowlings, align the cowling screw holes with their mounting brackets and replace the screws. However, if instrument clamps or cowling mounts were moved, the pre-drilled cowling holes may not align. The cowling can easily be modified for the new configuration as each possible attachment location has pre-drilled pilot holes. Enlarge the hole to be used and carefully countersink the cowling.

NOTE: To avoid cowling deformation, cowlings should be affixed to the WW for long term storage as this helps them keep their shape. For short term storage, such as while prepping for a cruise, cowlings are best stored upright (on short top/bottom edge) rather than on their long edge or long side. Cowlings may widen (i.e. open up) if stored improperly, making it challenging to attach them. If widening does occur, lay the cowling on it's long side (as if it were going to be affixed to the WW), and add some weight (the WW downweight works well) distributed along the long edge. This will compress the cowling and help return it to its intended shape. This works best in a warm environment and should be occasionally inspected. An overly compressed cowling is equally as challenging as a widened one. One or two hours of compression is all that is typically needed. DMO does NOT advise the use of direct or applied heat.

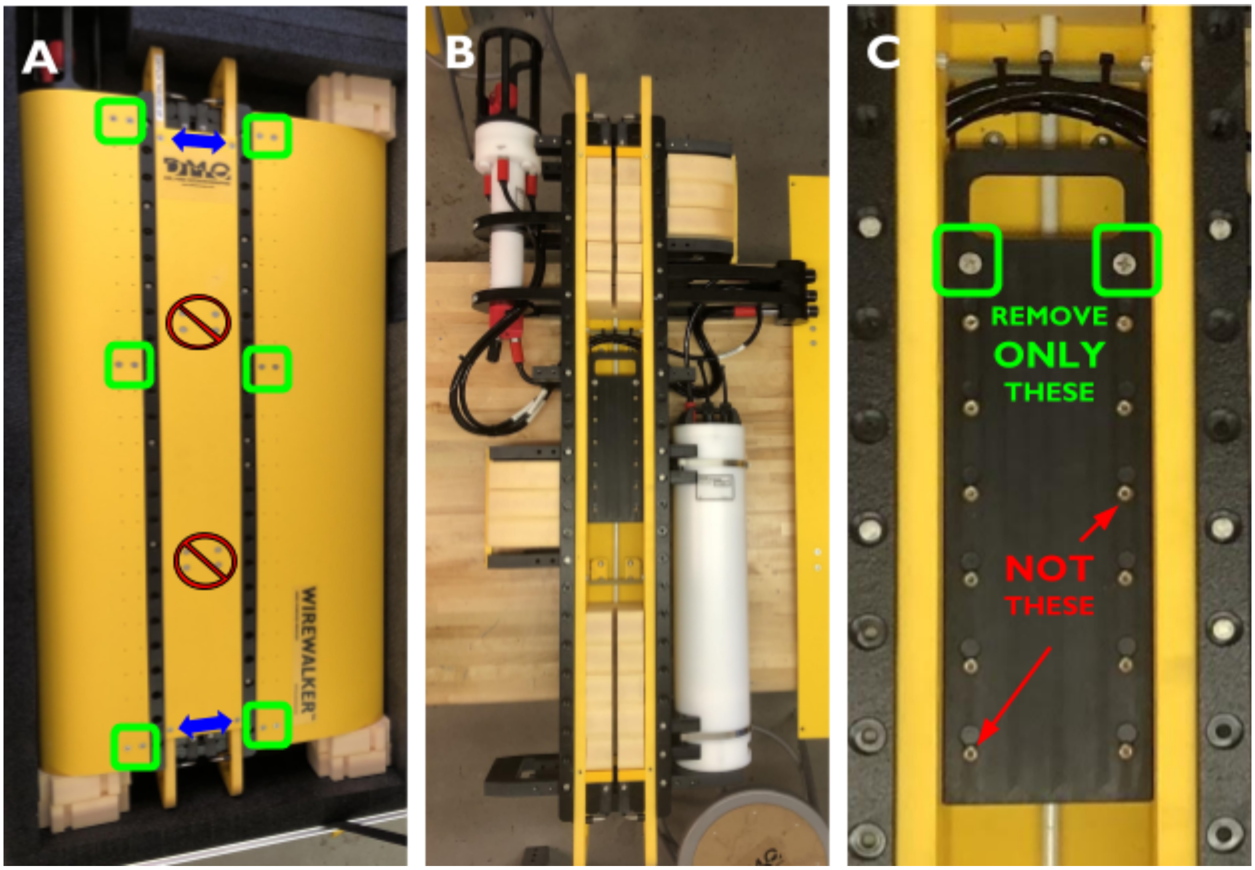


Figure 5: The cowlings, center lid, and cam can all be opened using a common #3 Phillips Screwdriver. Other types of hardware (hex drive) need NOT be removed. A) A WW with cowling and center lid installed. Green Squares identify the cowling screws and Blue Arrows are used to identify the central lid screws. B) With lid removed, the cam is visible (black box in center). C) Close up of the cam box. Green Squares identify the large Philips screws used to open the cam. The smaller hex head screws in the keyholes should NOT be adjusted.

4.3. AFFIX PROFILER TO THE WIRE ROPE

In order to connect the profiler to the profiling wire, there are a few steps to follow. These are shown in the sequence of Figure 6 and described below. Similar to removing the cowling, the only tool required is a #3 Phillips screwdriver.

A. Remove the Phillips head screws holding the center panel, or "lid" in place. The screws are located in the 4 corners of the lid (Figure 6A) and clearly marked in Figure 5A with Blue Arrows.

B. After the screws are removed, slide the center cover slightly toward the top of the profiler and remove it. The panel is held in place by two guides as shown in panel B.

C. Remove the cover of the cam mechanism and insert the jacketed wire rope. Again, only remove the large Phillips flat head 1/4-20 screws (do not alter the screws that go into the keyholes). See Figure 5C. Slide the cam cover toward the bottom of the profiler to remove the cover off the keyholed screws. NOTE: Check that the cam mechanism can be actuated by snapping the cam into the "up" and "down" positions using the triggers on either end of the profiler. The cam race (component with wheels) will be open, or held in the upward position when the bottom trigger is pressed firmly upwards. The cam race will be engaged, or free to move vertically up and down when the top trigger is pressed firmly downwards.

D. If applicable, insert the jacketed wire rope into the inductive modem's ferrite holder and close.

E. Remove the retaining roller at the end of the profiler. No tools required, just slightly lift the retaining clips.

F. Run the cable through the instrument and out the end; work the retaining roller back into place. This is done easiest by working an excess loop of wire after it has passed through the end.

G. Ensure that the retaining roller is latched into place.

H. Repeat steps E-G for the other end of the profiler.

I. Replace the cam mechanism cover, center panel, and respective screws.

* SAFETY NOTE: When lifting the profiler by the wire, it is safest for the cam to be in the open position (aka up position/bottom trigger pushed in), with the profiler resting on the bottom turnaround bumper.

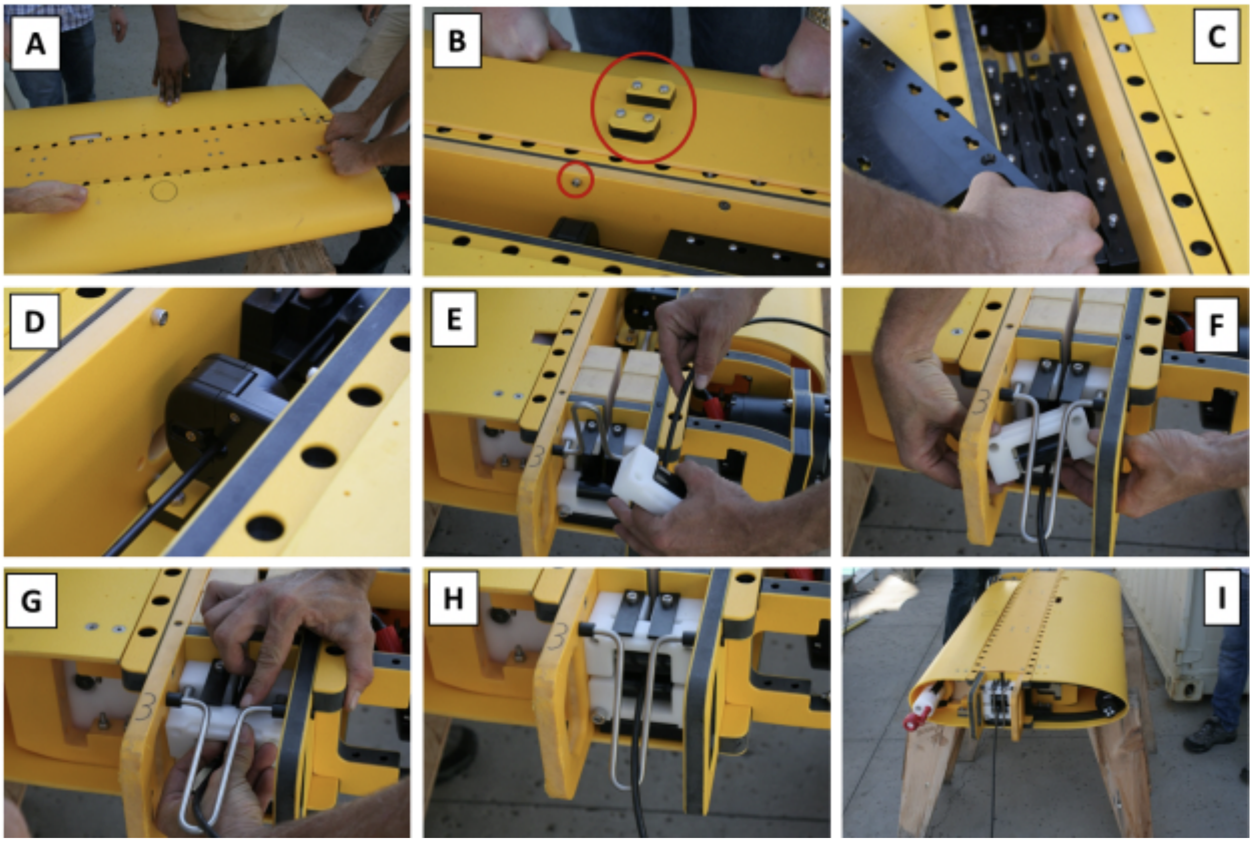


Figure 6: Step-by-step connection of the vertical profiler to the jacketed profiling wire.

5. BALLASTING

5.1. GOALS

While the ballasting procedure is quite forgiving, overall Wirewalker performance does depend on proper ballasting. The following goals should be achieved during the ballasting procedure:

- The profiler must be positively buoyant
- Target upcast speed is ~40 cm/s
- Minimum upcast speed is >30 cm/s; cam mechanism may not engage at low speeds
- Maximum upcast speed is <100 cm/s; but you rarely want to go faster than 60 cm/s
- With proper ballasting, a balance is achieved between the forces driving the downward ratcheting, and the upward buoyancy of the profiler. i.e. Too much buoyancy will make it harder/take-longer for the profiler to descend. Too little buoyancy, and the cam may not re-engage near the surface.

5.2. CONSIDERATIONS

We recommend that the ballasting procedure for the Wirewalker is done through the use of a test tank, pool, or dock/pier side (Figure 8B). New Wirewalkers should be user ballasted to ensure the setup will work as expected in your environment. Ballasting should be attempted before heading to sea with all of the instrumentation installed. Changes in instrumentation is likely to require a re-ballasting of the Wirewalker.

Floatation material (Figure 7) is inserted into the profiler centerline top and bottom as well as outside of centerline, ideally near the top of the instrument as can be seen in Figure 5B and 8A. Floatation material should be distributed equally about the centerline. When removing floatation material, foam blocks located near the bottom of the profiler should be removed before removing those located at the top of the profiler. Refer to PAYLOAD BALLASTING CONSIDERATIONS for additional considerations, including addressing various sensor technologies.

Ballasting at sea may be possible, but is not recommended. With natural variabilities at sea, it's very challenging to avoid "dragging" the WW behind the vessel; therefore, introducing external forces that bias the accent rate calculation. The ballasting procedure is best carried out where currents, wind, and particularly vessel drift are at a minimum; hence, the recommendation to utilize a test tank, pool, dock, or pier.

Figure 7: Wirewalker buoyancy foam.

5.3. RECOMMENDED EQUIPMENT

Recommended equipment for the ballasting procedure includes:

- Test tank, pool, pond, or dock/pier-side location with a deep enough water depth to allow the Wirewalker to reach a terminal rise speed for a sustained duration. For reference, Scripps Institution of Oceanography uses a 10 m deep test tank.
- Wirewalker with extra floatation foam and field tool kit
- 3/16" jacketed profiling wire with downweight attached (in a controlled environment, a single plate, or less weight, makes simulating waves by hand easier).
- Winch or chainfall to suspend the Wirewalker cable from overhead

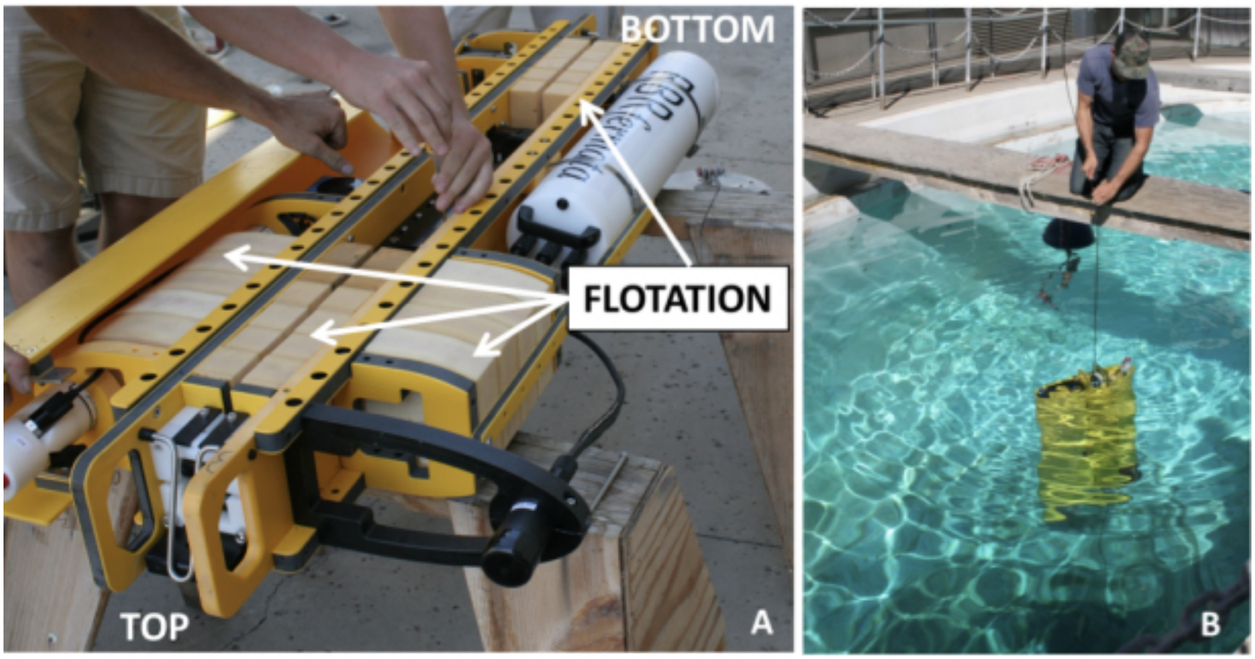


Figure 8: (A) Location of Wirewalker buoyancy foam; (B) Hands-on ballasting of the Wirewalker at Scripps Institution of Oceanography using their 10 m test tank.

5.4. PROCEDURE

- Find a suitable location to perform the ballasting procedure. Requirements are enough water depth beneath the surface to allow for the Wirewalker to reach terminal rise for a sustained period of time. A starting recommendation of depth is about 5-8 m.
- Suspend the jacketed wire rope from either a winch or chainfall. Leave enough slack in the line to easily attach the Wirewalker to the line and a weight to the wire's termination.
- Program the CTD to record with as fast a sampling rate as possible. This will allow the user to check the ascent rate via the pressure record of the CTD (optional).
- Install all equipment to be deployed on the Wirewalker. The Wirewalker must be ballasted with it's deployment configuration.
- Attach the profiler to the profiling wire as described in the section [AFFIX PROFILER TO THE WIRE ROPE].
- Ensure the cam cover and center lid are secured. Ideally, the cowlings should also be installed; however, they can be left off for the initial ballasting as you add/remove foam.

- At this point, there should be enough foam for the profiler to be positively buoyant (i.e. it won't ascend if it's negative). The cam trigger should always be in the up position (bottom trigger pushed in) when lifting overhead. Being in the up position also allows you to check that the Wirewalker is buoyant enough to float.
- Attach a downweight (using a lighter weight than when deployed makes simulating waves easier) to the end of the wire to keep the wire upright and taunt while ballasting.
- Pick the profiler and downweight up via the wire (profiling should be resting on the bottom turnaround bumper) and lower into the testing area.
- Lower the weight as low as allowable into the water to check ascent rates. Scripps uses a 10m test tank and lowers the downweight to slightly above the bottom.
- Once the unit is in the water and the weight is deployed to the proper depth, push down on the top cam trigger on the WW to set the unit into descend mode.
- Manually pull up and down on the wire to simulate wave interaction with the surface buoy. The unit should start to work its way down the wire.
- Continue simulating waves until the cam is shifted into the open position (you should feel the trigger mechanism open the cam) and the profiler ascends. NOTE: If the profiler stays at the bottom, you need to pull it up and add more foam. The Wirewalker must be positively buoyant to ascend.
- Each time the profiler is at the surface, push down on the top cam trigger to descend again.
- Continue simulating waves to achieve a couple profiles. This familiarizes you with opening and closing the cam and will help dislodge any bubbles that could bias the ballasting.
- After a few test profiles, engage the cam and gently work the profiler down the wire to just above the downweight (cam is still closed).
- Get a stopwatch ready to record the rate of ascent.
- Gently pull the wire up and down until the profiler hits the bottom turnaround bumper and the cam is shifted to the open position. This can be felt on the wire and the profiler should start to ascend.
- Start the stopwatch as soon as ascent begins.
- Compute the rate of ascent for the profiler from the downweight to the surface (i.e. distance traveled/time it took).
- Re-engage the cam and repeat this several times until confident with the value. If the cowlings were removed for initial adjustments, it's recommended to attach them for these repetitive tests.
- If the unit does not meet a satisfactory target upcast speed (nominally 40 cm/s), remove the unit from the water, adjust ballast accordingly and cycle through the procedure again.
- Remove the unit from the water, remove the profiler from the wire, give the unit a fresh water rinse down and store for deployment.
- If logging data on a CTD, download data to verify your calculated ascent rate matches that observed by the CTD (optional).

7. DEPLOYMENT

The deployment process is straightforward and requires a few key pieces of equipment and personnel to accomplish the process. This section covers a deployment process similar to that covered in Wirewalker training at Scripps Institution of Oceanography, and assumes a well equipped research vessel is utilized. We recognize that each deployment is unique and that resources, such as vessel size, type, and supporting equipment, are variable. Other methods of deployment are certainly possible, but it's impossible to cover all scenarios in this manual. The information contained herein is offered as a guide based on proven methods.

7.1. EQUIPMENT

- ❏ Winch capable of handling the necessary amount of force
- ❏ Air Tugger
- ❏ Hydraulic A-Frame
- ❏ Block wide enough to pass the profiling wire with turnaround bumpers unimpeded
- ❏ Taglines/Securing lines
- ❏ Rope line to spool on winch drum
- ❏ Quick release
- ❏ Deck cleats
- ❏ Wirewalker including all components, tools and replacement parts

7.2. POSITIONS TENDED

- ❏ Winch Operator
- ❏ Air Tugger Operator
- ❏ A-Frame Operator
- ❏ Block Tagline handler (2) also acting as Quick Release Operator/Auxiliary person
- ❏ Deck Lead
- ❏ Safety Observer (if required)

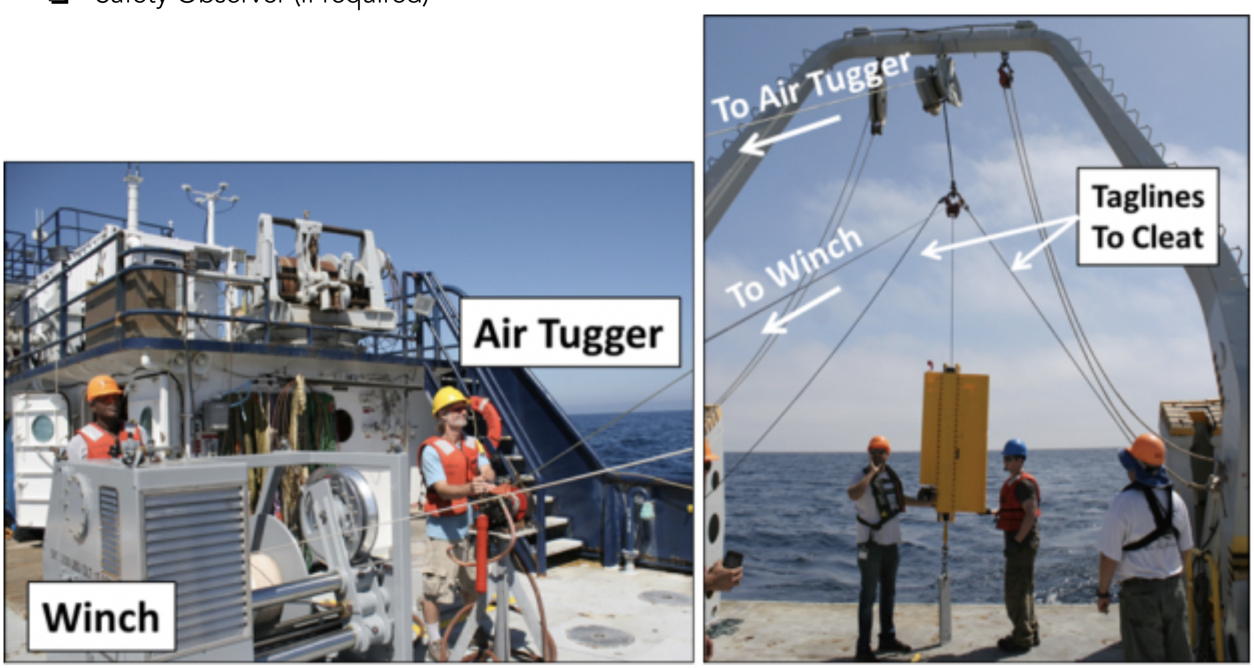


Figure 9: Positions and Equipment - (A) Winch and air tugger operators; (B) Deck lead, tagline operator/auxiliary person and safety observer.

7.3. DEPLOYMENT PROCESS

- Prepare mooring equipment for deployment. This may include, enabling loggers and sensors, removing protective caps from sensors (such as optodes and/or fluorometers), starting the GPS tracking beacon and flasher, arming acoustic releases, etc.
- Attach a backing line to the winch drum and spool onto the drum. The other end of the line should be terminated with a thimble (Figure 10A).
- The thimble should be connected to the top of the profiling wire via a shackle and D- Link (Figure 10B).
- Spool the Wirewalker wire onto the winch drum (Figure 10C).
- Run a line from the air tugger through the main block on the A-Frame and down (Figure 9) if using a floating block for the deployment.
- Attach a block at the end with a wide enough gape to have the turnaround bumpers and hardware (½" safety shackles and swivels) pass through easily. The distance between the cheek plates of this block should be at least 4 inches. Taglines should be connected to both sides of this block. It will be suspended above the deck and the taglines will keep it stable (Figure 9B and 11A/B).
- Run the profiling wire through the suspended block. Pay-in on the air tugger to raise the block so that it is suspended approximately 10' off the deck (Figure 9B).

Figure 10: Deployment setup - (A) Backing line to be attached to the winch terminated with thimble; (B) Connection of rope line to the top of the Wirewalker coated wire connected with a D-Ring and shackle; (C) Rope line and most of Wirewalker coated wire spooled.

- Tighten the tag lines from the suspended block and secure to available cleats on the moving part of the A-Frame. These taglines will be loosened and adjusted as necessary. They should never be allowed to become dangerously tight and available tagline operators should always be on hand to allow for quick manipulation (Figure 11A/B).
- Connect the profiler to the jacketed wire as described in the section AFFIX PROFILER TO THE WIRE ROPE.
- For safety, the cam should be shifted into the open position (bottom trigger pushed in), which allows the profiler to rest on the bottom turnaround bumper when lifted.
- Attach the downweight to the bottom of the jacketed wire. The downweight is connected via ½" safety shackles to the wire, with a swivel.
- When the ship is in position for deployment, retrieve on the winch to raise the profiler and downweight off the deck (Figure 9B). Disconnect the ship's safety lines at the stern of the ship.
- With block tagline operators in place and the profiler and weight raised off the deck, start out on the A-Frame. The air tugger operator and the block tagline operators will have to adjust as necessary to keep the block at a constant height off the deck. The deck lead should direct the A-Frame and air tugger operators as well as the tagline operators during this process to ensure positive control is always kept on the instrument, the air tugger block is not sucked into the A-frame's center block, and the taglines do not get too tight.
- Once the A-Frame is in a full outboard position, fix the block taglines.
- Pay out on the winch to start lowering the weight into the water. Continue to pay out on the winch until the top of the jacketed wire (including turnaround bumper) has passed through the block. Stop paying out on the winch when the terminated top of the jacketed wire is within reach of those on the deck (Figure 11A/B).

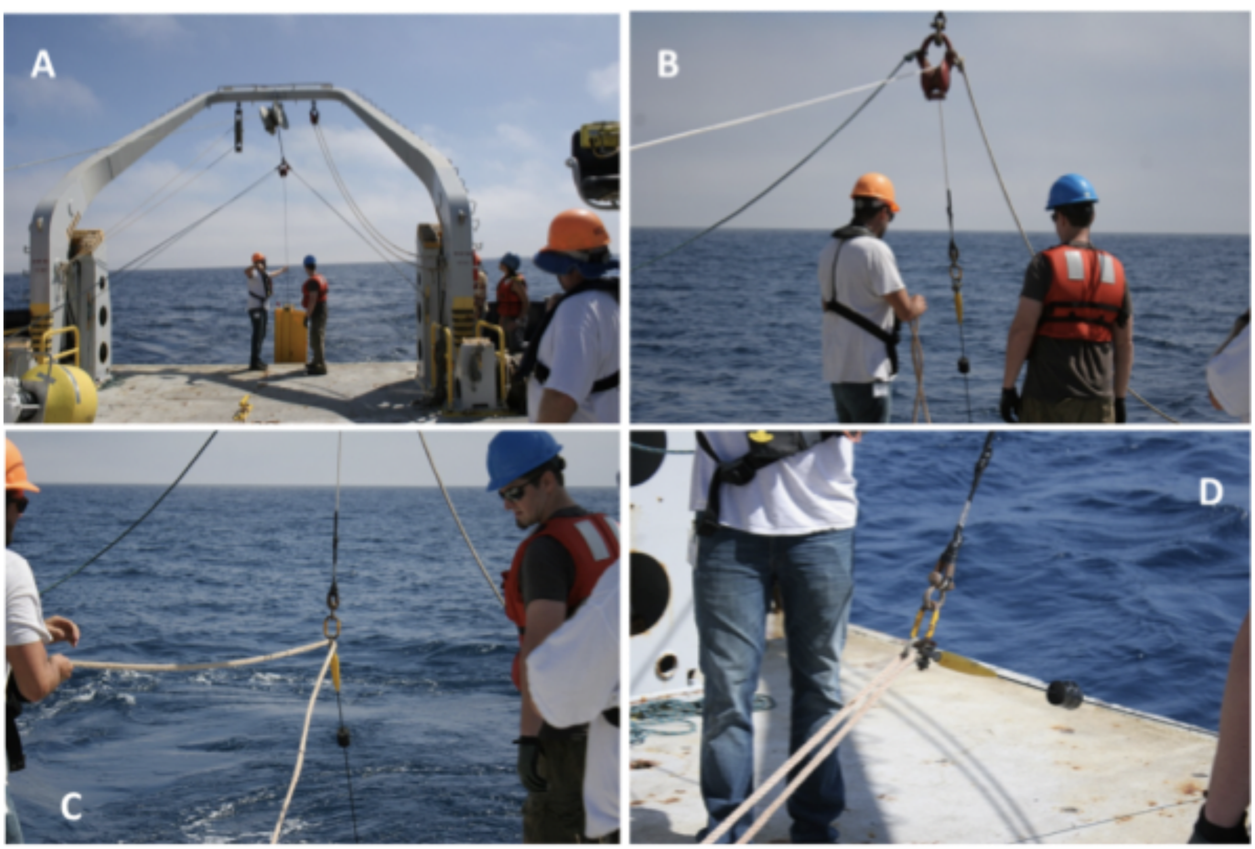


Figure 11: Deployment of the Wirewalker - (A) Lowering the Wirewalker into the water; (B) through (D) Stopping the line off to the deck to connect the surface buoy.

- Using a line stopped off to a deck cleat, run the free end through the shackle connecting the D-ring to the top of the profiling wire. Take slack out of the line and stop the free end off to the same cleat. This will ensure that the trailing Wirewalker is secured to the ship while the surface buoy is connected to the cable (Figure 11C/D).
- Disconnect the winch rope from the jacketed wire. Boom the A-frame back in while carefully tending to the air tugger's block position and taglines.
- Move the surface buoy into position on the back deck if it is not already there. If the seas are high, you may want to make sure it is still secured to the deck.
- Connect the profiling wire to the surface buoy as appropriate for one of the following scenarios,
    - Autonomous: Connect the standard jacketed wire termination to the surface buoy via a shackle/pear-link/shackle assembly.
    - Real Time: For instruction on preparing your termination type to connect with the surface buoy and modem/telemetry system, refer to the HAMMERHEAD TERMINATION ASSEMBLY GUIDE.
- Connect a Quick Release to the winch line. Connect a hoisting strap to the Quick Release with the other end run through an accessible pick point on the surface buoy as shown in Figure 12.
- Start to take some of the load from the surface buoy up via the winch line. Have positive control of the surface buoy as it is raised (Figure 12).
- When ready, slowly loosen the stopper line that is holding the load of the Wirewalker profiling wire.
- Working with the A-frame operator, air tugger operator and the block tagline operators, raise the surface buoy while booming out on the A-frame while being mindful not to jam the quick release into the block.
- When the A-frame is boomed out and the system is ready for final deployment, lower the surface buoy down by paying out on the winch.
- When ready, trigger the Quick Release to complete deployment of the Wirewalker.
- Once complete, replace the ship's safety lines and stow all gear.

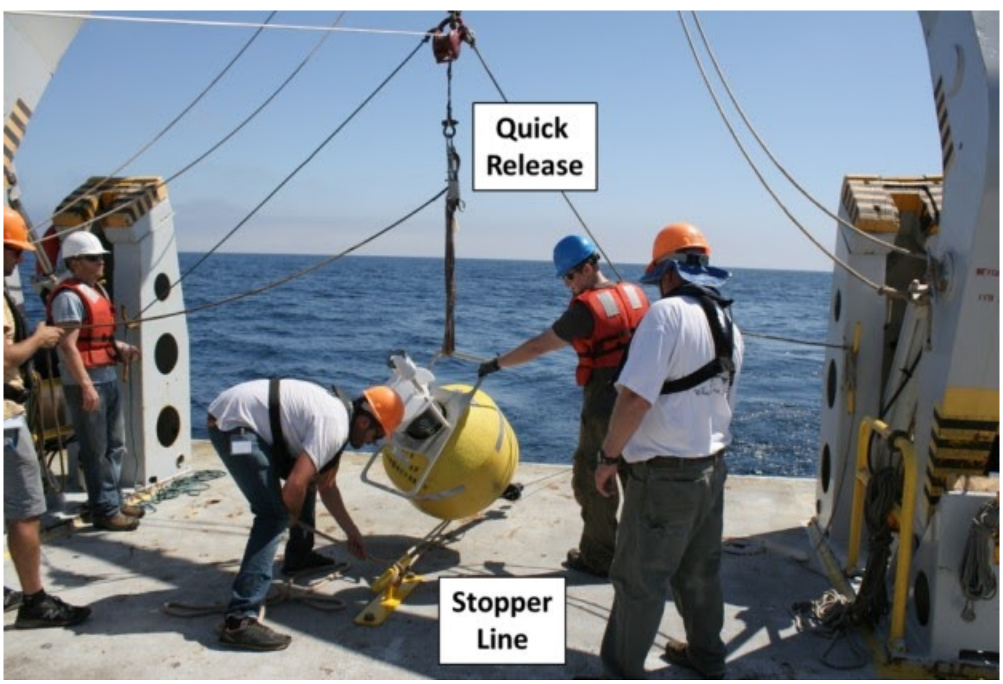


Figure 12: Quick Release, surface float and stopper line during deployment.

8. RETRIEVAL

The retrieval process is straightforward and much like the deployment process; but, accomplished in reverse. It requires a few key pieces of equipment and personnel to accomplish the process. This section covers a recovery process similar to that covered in Wirewalker training at Scripps Institution of Oceanography, and assumes a well equipped research vessel is utilized. We recognize that each recovery is unique and that resources, such as vessel size, type, and supporting equipment, are variable. Other methods of deployment are certainly possible, but it's impossible to cover all scenarios in this manual. The information contained herein is offered as a guide based on proven methods.

8.1. EQUIPMENT

- ❏ Winch capable of handling the necessary amount of force
- ❏ Air tugger
- ❏ Hydraulic A-Frame
- ❏ Block wide enough to pass the profiling wire and turnaround bumpers unimpeded
- ❏ Taglines/Securing lines
- ❏ Rope line to spool on winch drum
- ❏ Telescoping pole with releasable capture hook (like a Grab 'n Go hook)
- ❏ Deck cleats
- ❏ Wirewalker including all components, tools and replacement parts

8.2. POSITIONS TENDED

- ❏ Winch Operator
- ❏ Air tugger Operator
- ❏ A-Frame Operator
- ❏ Block Tagline handler (2) also acting as Boat Hook Operator/Auxiliary person
- ❏ Deck Lead
- ❏ Safety Observer (if required)

8.3. RETRIEVAL PROCESS

- Run the rope line from the winch drum through the air tugger's block, set up during the deployment process (Figures 9 and 13A).
- Run this line around the stern of the ship and up whichever side you will be recovering the Wirewalker from.
- Attach the end of the line to the releasable capture hook connected to the end of the boat hook or other telescoping pole. This will allow for the captured Wirewalker buoy to be connected right to the winch.
- Line the ship up for retrieval. As the Wirewalker comes down the side of the ship, capture the buoy with the releasable hook connected to the winch line (Figure 13B).
- Walk the captured surface buoy down around the stern of the ship.
- Remove the ship's safety lines at the stern of the ship.
- Boom out on the A-frame. The deck lead will lead the air tugger, A-frame, and block tagline operators to ensure that the retrieval block does not come in contact with the A-frame block and that the taglines do not get too tight.
- Retrieve on the winch line to raise the surface buoy out of the water. Boom in on the A-frame during this process to land the surface buoy on the deck (Figure 13C/D).

- As was done during the deployment process, stop the surface buoy off to a deck cleat to allow for removal of the surface buoy.
- Once stopped off and secured, disconnect the surface buoy from the winch line.
- Disconnect the profiling wire from the surface buoy as appropriate, ensuring that the jacketed wire is stopped off to the deck and that you will not lose the profiler during the process.
    - Autonomous: disconnect shackle at the base of the surface buoy.
    - Real Time: disconnect the hammerhead termination jumper wire to the seawater ground and disconnect the shackle at the base of the surface buoy.
- Stow the surface buoy and secure to the deck.
- Connect the winch line to the stopped off profiling wire.
- Slowly release the stopper line so that the winch takes all of the tension. Disconnect the stopper line from the profiling wire.
- Boom out on the A-frame. The deck lead will lead the air tugger, A-frame, and block tagline operators to ensure that the retrieval block does not come in contact with the A- frame block and that the taglines do not get too tight.

Figure 13: Retrieval Process - (A) Boat hook with capture hook. A line is run from the winch around the stern and connected to the capture hook; (B) Capturing the Wirewalker with the hook as it drifts by; (C) Winching the Wirewalker in; (D) Stopping the surface.

- Start to retrieve on the winch.
- Continue to retrieve until the profiler and end weight are out of the water (Figure 14).
- Boom in on the A-frame and land the profiler and weight on the deck.
- Pay out enough slack on the winch line to disconnect the downweights. Disconnect the profiler from the line.
- Once complete, replace the ship's safety lines and stow all gear.
- Stop data collection from the instrument and download the data.

Figure 14: Final moments of a Wirewalker being retrieved. Photo Credit: San Nguyen aboard the R/V Sikuliaq.

9. SUPPORT

9.1. CUSTOMER SERVICE

We've been there.

The DMO team consists of seagoing oceanographers, engineers, and technicians. Our goal is to provide customer service that exceeds your expectations and heads off drama before it starts. It's our hope that this guide enables you to collect exceptional data and continued use of your Wirewalker for years to come; however, we recognize that accidents happen, upgrades may be required or desired, and circumstances change. Should you need support, spare parts, assistance with a deployment, or someone to celebrate your amazing new data with, please don't hesitate to contact us.

info@delmarocean.com
(858) 524-8300

9.2. ADDITIONAL SUPPORT RESOURCES

Please refer to the SUPPORTING TECHNICAL NOTES section for additional support documents.

We also plan to provide short how-to videos on the @delmarocean YouTube channel (https://www.youtube.com/channel/UCJNav7NfkgVWQ54S1STHscQ).

9.3. REPAIRS

In the unlikely event that you require services where you believe the Wirewalker needs to be shipped back to us, please contact us for an RMA and provide details prior to shipping. We are unable to accept unexpected shipments.

9.4. CONTACT US

Del Mar Oceanographic, LLC
10457 Roselle St, Suite A
San Diego, CA 92121 USA
inquiry@delmarocean.com
(858) 524-8300

10. DISCLAIMER

The Wirewalker has a minimalistic and easy to deploy design, but all at-sea mooring deployments and retrievals can be inherently dangerous. Sufficient precautions should be accounted for to minimize risk by taking into account the vessel and its resources, operator and crew experience, as well as sea-state, weather, and other environmental aspects.

This guide has been compiled from input by experienced users; while proven a safe and effective mode of use, Del Mar Oceanographic, LLC assumes no liability for any damage or harm that may arise. See our terms and conditions at http://delmarocean.com/warranty-and-terms for full limitation of liability details.

11. REFERENCES

Pinkel, R., M. A. Goldin, J. A. Smith, O. M. Sun, A. A. Aja, M. N. Bui, and T. Hughen, 2011: The wirewalker: A vertically profiling instrument carrier powered by ocean waves. *J. Atmos. Oceanic Technol.*, 28, 426–435. Link

Rainville, L., and R. Pinkel, 2001: Wirewalker: An autonomous wave-powered vertical profiler. *J. Atmos. Oceanic Technol.*, V18, 1048–1051. Link

Smith, J. A., R. Pinkel, M. Goldin, O. Sun, S. Nguyen, T. Hughen, M. Bui, and A. Aja, 2012: Wirewalker dynamics. *J. Atmos. Oceanic Technol.*, 29, 103–115. Link

Additional Wirewalker publications may be available upon request.

12. APPENDICES

12.1. GLOSSARY

Profile	A full vertical turnaround of the profiler, i.e. roundtrip. Typically comprising one downcast and one upcast, in that order.
Downcast	The portion of a profile where the Wirewalker gets deeper with time. A Wirewalker downcast is made via a series of steps during which time the cam is engaged and under influence of the surface waves. The rate of descent is affected by wave conditions.
Upcast	The portion of a profile where the Wirewalker is returning to the surface from depth. A Wirewalker upcast is made with the cam disengaged; the profiler is decoupled from the wire and floats smoothly upward under its own buoyancy.
Ascent Rate	The average speed at which the Wirewalker Profiler floats toward the surface when the cam is disengaged. The ascent rate remains consistent throughout the deployment as it's based on buoyancy.
Profiling Rate	The average speed it takes for the Wirewalker Profiler to make a full round trip along a given length of wire. The profiling rate will fluctuate depending on how wave conditions affect the downcast rate.
Wirewalker Anatomical Terms	Top: The end that faces the surface when deployed. Bottom: The end facing the ocean floor when deployed. Leading edge/cowling: The side with the short cowling. Trailing edge/cowling: The side with the long cowling. Front: The side with the removable cover, or "lid" (affixed by Phillips screws) that is removed when inserting the wire rope. The U-shaped wire guide is attached and open on the front side of the profiler. Back: The side with the cover affixed with hex head screws. The back cover does not need to be removed.
Core Foam	Buoyant foam blocks that are installed in the center cavity that the wire passes through.
Rail Foam	Buoyant foam blocks installed under the cowlings.

12.2. MANUAL LINKS FOR COMMONLY INTEGRATED PAYLOADS

Del Mar Oceanographic prides itself in being sensor agnostic, and as such, we have integrated a large variety of sensors and equipment. Here is a (non-comprehensive) list, in alphabetical order, of links to some of the integrated payload options and their respective manuals.

LINK TO MANUAL	TYPE
Carmanah M550 Marine Lantern	Buoy Flasher
Coastal Ocean Vision CPICS-1000-e	Logger + Particle Imager
JFE Advantech RINKO	Sensor
LI-COR PAR	Sensor
Nortek Signature1000	Sensor
Pacific Gyre Globeacon	GPS Beacon
RBRconcerto & RBRmaestro	Logger + Sensors
RBRcervello	Real Time Telemetry System
Rockland Microrider-1000	Logger + Sensors
SBE 19v2 SeaCAT	Logger + Sensors
SBE 49 FastCAT	Sensor
SBE 52-MP	Logger + Sensors
SBS ECO Puck (triplet)	Sensor
SBS C-Star Transmissometer	Sensor
Seapoint Turbidity	Sensor
Sequoia LISST-200X	Logger + Sensors
Turner Cyclops-7F	Sensor
Xeos Rover Beacon	GPS Beacon

12.3. SUPPORTING TECHNICAL NOTES

The following pages include technical notes to assist in getting the most from your Wirewalker Profiling System.

RECOMMENDED WIREWALKER TOOLS AND SPARES KIT

Technical Note

Below is a checklist of recommended tools and spare parts you should have on hand when servicing and/or deploying your Wirewalker. The spare parts are optional, but being field experienced oceanographers ourselves, we know accidental drops can happen; regardless of the size of your ship or experience of the crew. Please contact DMO if you'd like to obtain any of the spare parts listed.

Field/Deployment Tools

- ❏ #3 Phillips Screwdriver
- ❏ Diagonal Cutting Pliers (aka Wire Cutters, Dykes)
- ❏ 3/4" Combination Wrench and/or Adjustable Wrench, qty 2 (for mooring shackles)

Lab Tools

- ❏ 7/16" Nut Driver
- ❏ Ratchet Wrench with 7/16" Socket
- ❏ Basic Combination Wrench Set (Standard/Imperial/SAE sizes)
- ❏ Basic Hex Key set, T-handle recommended (Standard/Imperial/SAE sizes)

Suggested Spares

- ❏ WW Retaining Roller Assembly
- ❏ 316 SS Phillips Flat Head Screws, 1/4"-20, 3/4" Long (For cowlings, center lid, and cam box)
- ❏ 1/2" Galv Safety Shackles
- ❏ Cotter Pins
- ❏ Assorted Cable Ties, UV Resistant

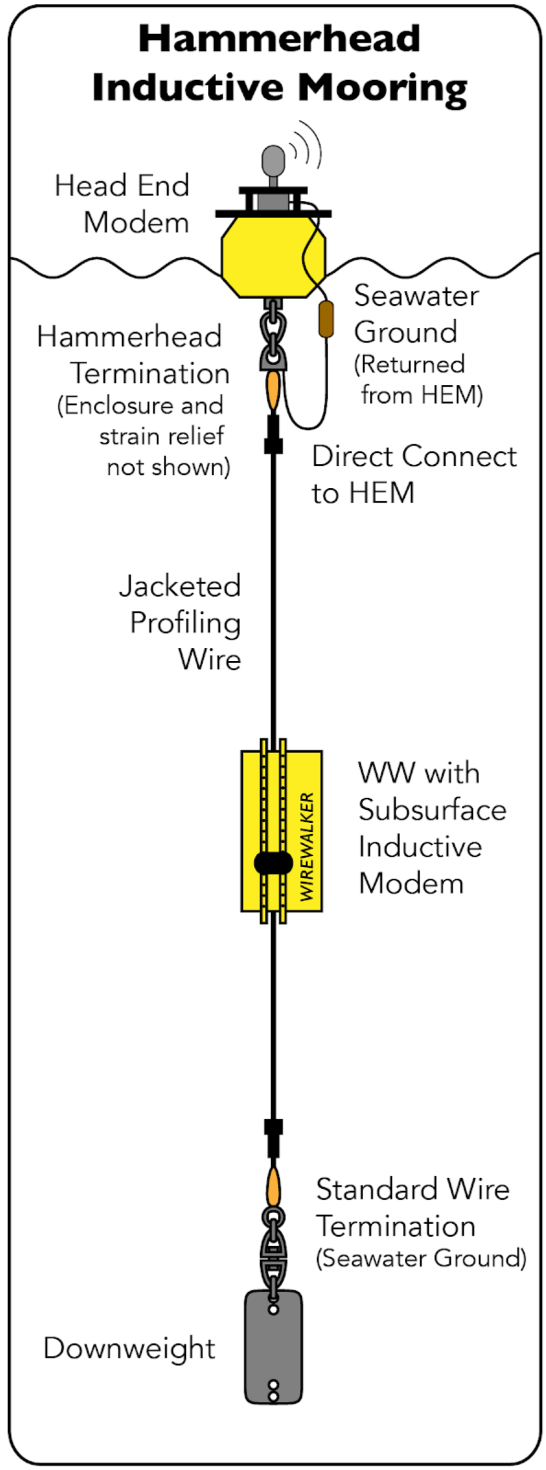
HAMMERHEAD TERMINATION ASSEMBLY GUIDE

Technical Note

A WW with autonomously logging sensor package uses the profiling wire solely for its mechanical purposes. However, if real time data is required, the conductive wire also acts like an electrical cable that sends data up to a telemetry system in the surface buoy. Here, we will address some of the nuances associated with using the jacketed wire rope with a "direct connect" inductive telemetry solution; including, how to assemble the top side inductive assemblies.

First, it is important to differentiate between the types of profiling wire terminations. There are two primary types of terminations used: standard or hammerhead. Standard terminations are used for autonomous applications where telemetered data is not required.

A hammerhead termination gets its name from it's shape, and often connects directly to a head end modem. In the case of a "direct connect" inductive coupling, the termination cannot act as a seawater ground as there is a jumper wire that, in essence, directly connects the wire into the modem itself. Since a seawater ground is still required, a seawater ground return is typically passed back into the water to an exposed anode. This method of inductive coupling is very robust and becoming standard practice on extreme weather and long term moorings. The mooring cartoon provides a visualization based on the use of a RBR*cervello*.



ASSEMBLY INSTRUCTIONS

- Locate and layout the hammerhead and cover components.
- Wrap a small piece of electrical tape at the base of the hammerhead jumper connection and insert into the hammerhead. This better seals that connection from introducing a seawater ground.
- Tighten the set screws on the hammerhead to secure the jumper pin.
- Prep the HH cover by installing the bolts on one side of the cover. Lay on a surface with bolts facing up.
- Coat the hammerhead (and jumper plug interface) with Lanocote to further isolate it from acting as a seawater ground.
- Place HH in the cover with the jumper protruding through the appropriate hole and attach the fasteners. Tighten appropriately.
- Prep the HH strain relief by installing the bolts on one side and install the bottom of the jumper clamps.
- Lay the HH assembly onto the strain relief cover with jumper passing over the jumper clamp.
- Add the top half of the jump clamps.
- Add the top of the strain relief and attach fasteners, tighten appropriately.
- On the surface buoy, route the inductive modem cable through the buoy.
- Connect the brass seawater ground to the modem cable
- Sandwich the seawater ground and modem cable with the dogbone assembly and tighten bolts. The middle section should be over the seawater ground.
- Connect the HH shackle assembly to the surface buoy.
- The wire jumper can now be connected to the seawater ground and clamped in place by the lower clamp on the dogbone.
- For retrieval, these last two steps are all that are required to remove the wire from the buoy.

The final assembly should look like the bottom image in the photo panel to the right. Note that there is no swivel under the buoy.

PAYLOAD BALLASTING CONSIDERATIONS

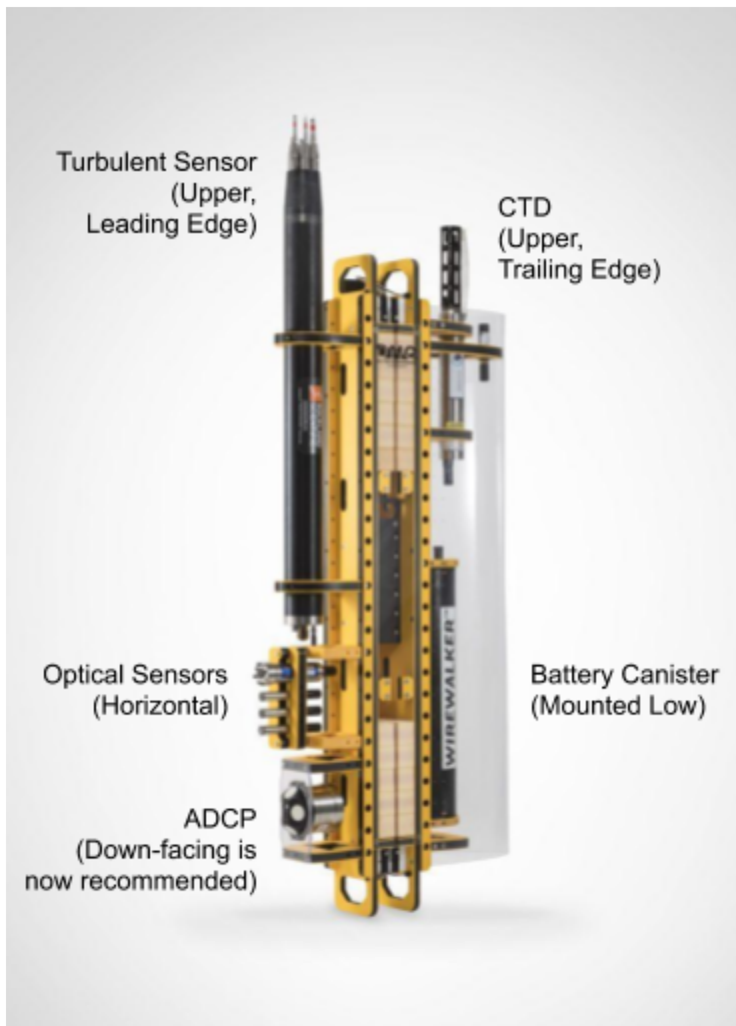
Technical Note

Floatation material is inserted into the profiler to ballast the Wirewalker so that it ascends at the desired rate. This means that as buoyancy changes from adding a payload, it must be counterbalanced. Additionally, it's ideal to keep the ballasting symmetrical so that the WW doesn't lean to one side (i.e. all the buoyancy is on one side). Floatation material should be distributed on, and equally about, the centerline. When removing floatation material, it's preferred to remove foam blocks located near the bottom (base) of the profiler to prevent the WW from wanting to invert (although the wire won't let it).

The top, leading edge (i.e. short cowling) holds the highest valued real estate on a WW due to the position being the first to "see" undisturbed waters. The most sensitive, or critical, measurement should hold this position when appropriate and typically goes to a turbulent sensor (such as MicroRider-1000) or a CTD.

If the prime position is already occupied, the up facing position on the trailing edge is the second most desirable mounting location. We have little to no indication that wake off of the wire has been problematic; therefore, the above recommendation is out of an abundance of caution.

While the upper portion of the WW is often the most desirable, optical measurements should not be integrated facing up as direct sunlight can have adverse effects on the measurement or degrade the sensing element. For this reason, optical sensors such as those used for dissolved oxygen or fluorescence, are best integrated horizontally. The sensing element should slightly poke through a suitable hole in the cowling. Priority is generally given to the leading edge, but some sensors are simply too long to fit well. In this case, or if there's no additional real estate, sensors are mounted on the trailing edge. Again, there is little to no indication that being mounted on the trailing edge has any effect on the upcast data.



Battery canisters are often the heaviest portion of a payload. It's best that they get mounted as low as possible, and typically on the opposite side of the primary measurement (i.e. DMO generally integrates a battery canister on the lower, trailing edge side). The WW can bear a battery canister behind each cowling.

If necessary (due to balancing issues or lack of real estate), the buoyant rail foam blocks can be cut/trimmed to fit behind mounted components such as loggers and/or battery canisters.

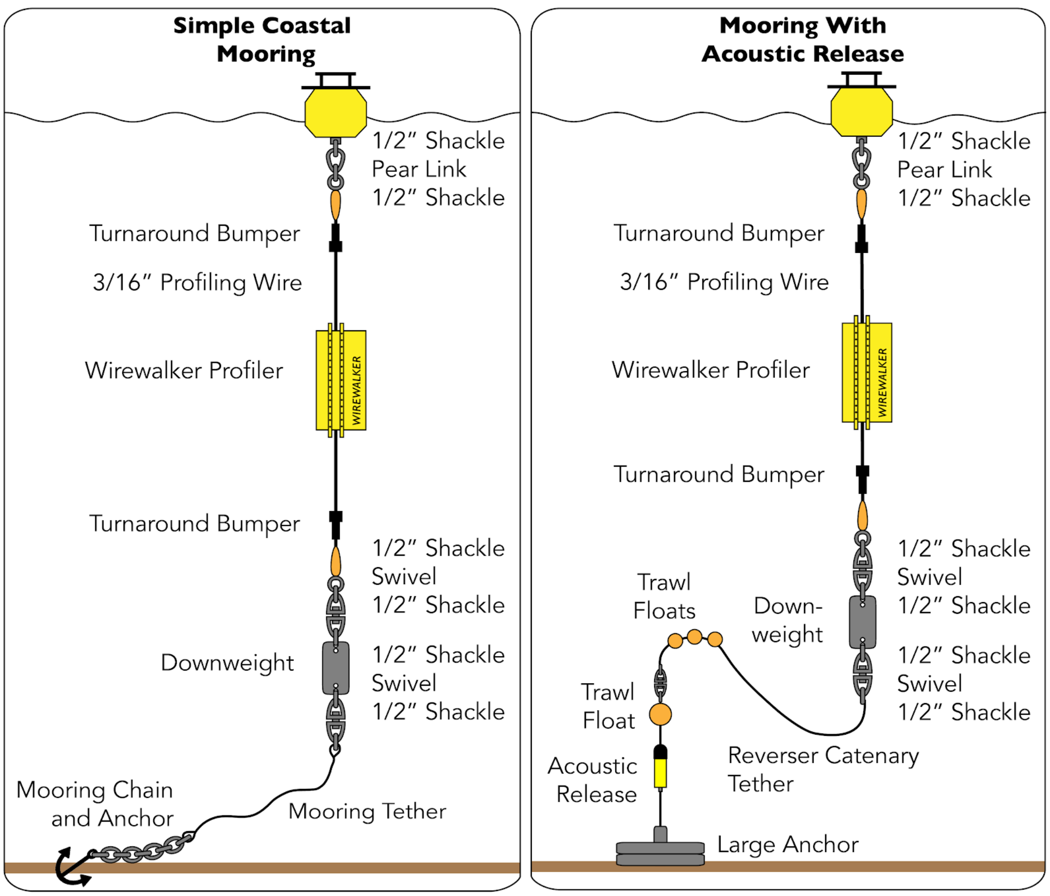
PRINCIPLES OF WIREWALKER MOORING DESIGN

Technical Note

The Wirewalker Profiling System is, at its core, a simple mooring suspended from the surface. Each component is outlined in WIREWALKER SYSTEM COMPONENTS. That basic mooring can be used as-is in free-drifting deployments, or it can be tethered to the bottom to keep it anchored in place. WWs have been deployed in just a few meters of water to full ocean depths. Here, we introduce some basic concepts to consider when designing a WW mooring.

In both free-drift and moored designs, the following apply,

1) The surface buoy must freely follow the vertical excursions of surface waves.
2) The downweights cannot become grounded. Both tides and waves should be considered for working near the bottom and in choosing a profiling wire length.
3) The core WW mooring (buoy to downweight) should remain vertical. The simplest way to straighten out the wire in strong currents/shear is to add additional downweight.



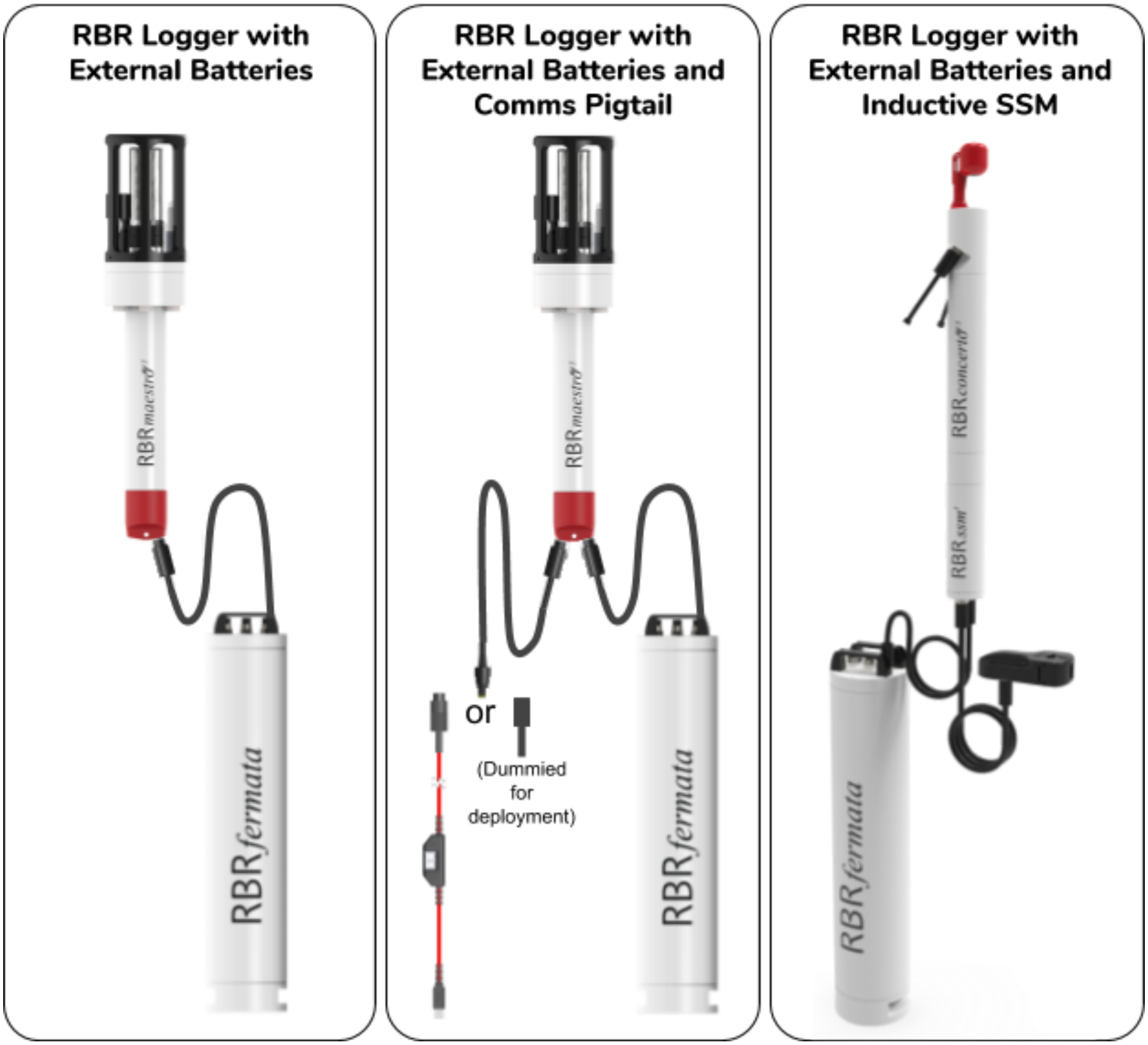
There are many factors to consider with any mooring. You should rely on expertise in your particular application, environment, location, and depth. However, in effort to provide some guidance, we present 2 designs which have proven useful.

Deepwater moorings, including full anchor-to-surface inductive designs, are possible and have been successful. However, they are generally deployed for much longer periods of time and often utilize specialized buoys. Therefore, these designs are outside the realm of this technical note as they require unique engineering and considerations.

RBR LOGGER END CAP VARIATIONS

Technical Note

RBR standard loggers have a variety of end cap options, each with a slightly different way it's integrated into the Wirewalker and connected to other components. The three most common options for integrated RBR loggers are shown below.



All scenarios where an end cap connector is present can connect the logger (MCBH-6-MP) to a battery canister (eg RBRfermata, MCBH-6-FS). A 12V power supply is typical, but other outputs may be present if the WW includes additional sensors (such as an ADCP). While the Gen3 RBR loggers handle a wide range of voltages (refer to RBR manual), the SSM is limited to 12V.

A RBR logger with a second connector (MCBH-6-MP) can utilize an extension data cable for easy access to the logger. The cable should be dummy plugged for deployment and secured to the WW, but accessible when the cowling is installed. A RBR 'patch cable' can be plugged in for active communications.

If using an SSM, the second connector (MCBH-2-MP) is dedicated for the cabled ferrite holder.

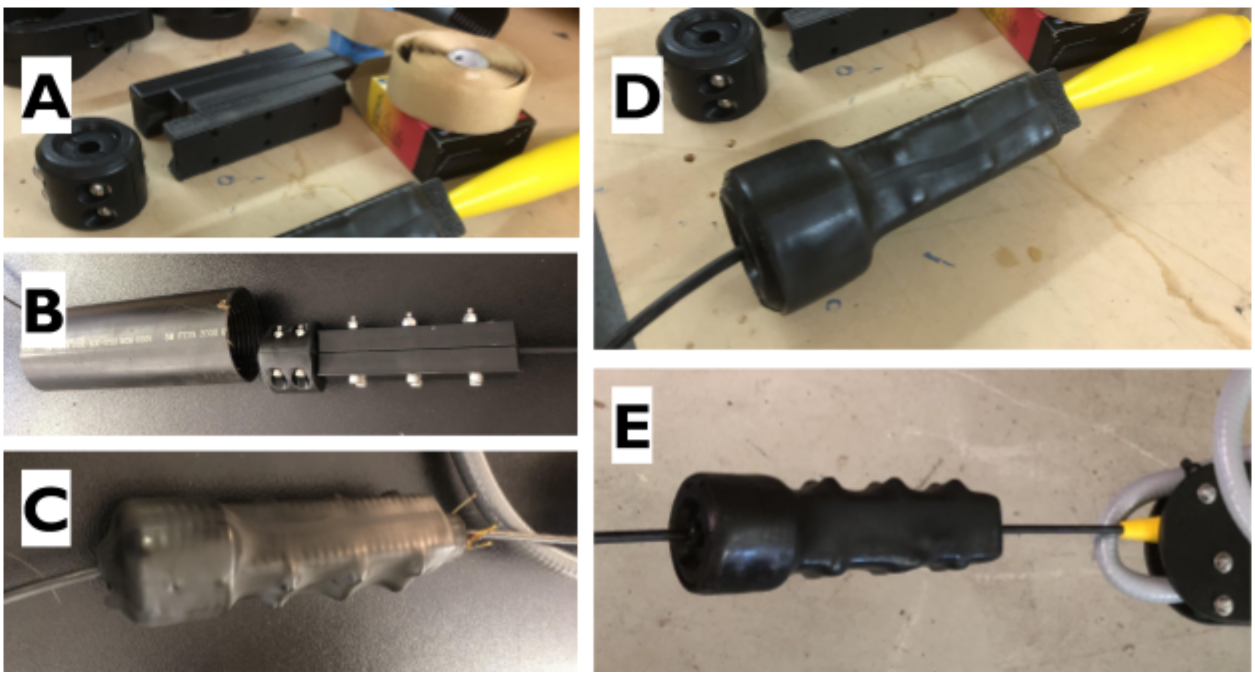
TURNAROUND BUMPER ASSEMBLY

Technical Note

Turnaround bumpers come installed on every DMO supplied profiling wire. They rarely need to be moved or adjusted. However, spare turnaround bumpers are available and there may be a few occasions where a bumper needs to be removed/installed. For example,

- If a tall sensor was integrated and there is a possibility that it could impact the surface buoy.
- A shorter profiling range is desired, particularly if you are utilizing an existing wire (and possibly shortening it).
- A new wire without bumpers was sourced without turnaround bumpers. NOTE: For compatibility, any profiling wire used must be within specifications of DMO supplied wire.

The following sequence of images demonstrates how to assemble the turnaround bumpers for such occasions.



A. Turnaround bumper assemblies consist of two primary components, the cylindrical bumpers themselves, and a rectangular slip-resistant clamp.
B. Both components are clamped to the wire firmly, with the bumper toward the inside of the wire, and touching the slip-resistant clamp.
C. As a safety precaution, heat shrink tubing is placed over the assembly and shrunk (even with the glue, it can be cut off and removed when required). Be careful not to melt the jacket on the wire. For bumpers near hammerhead terminations, it may be necessary to feed the heat shrink over the other end (standard termination) of the wire.
D. Near standard terminations on the wire, the assembly is typically placed at the base of the strain relief boot. However, on the upper end of the wire, there may need to be an offset added if integrated sensors would be in danger of impacting the buoy.
E. Near hammerhead terminations (used with inductive modems), the assembly should always be offset from the base of the termination boot, allowing a safety factor for avoiding sensor impact with the inductive jumper cable service loop or the buoy. This distance is dependent on the sensor configuration; it's better to err on the side of caution.