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Babcock Ref	21802	Company	Babcock Energy & Marine Technology
Ref	21802-MS-01	Project	AOWFL

Project: Babcock FORECAST Deployment

Client: Aberdeen Offshore Wind Farm Ltd

Submitted by: Barry White
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Filename: **Deployment Method Statement**

Babcock Reference: **21802-MS-01**

Issue: **Issue C**

Date: **01/07/2016**

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BRITISH SAFETY COUNCIL

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1 Introduction

Babcock own and operate a floating LiDAR system based upon proven low motion buoy design which provides a stable platform to host wind resource and environmental data capture equipment. The complete system is collectively known as FORECAST and will be referred to as such throughout this document.

FORECAST is supplemented by a Waverider buoy which is deployed near to FORECAST location within the operating zone of the buoy.

This document details the methodology for shallow water deployment of FORECAST which will be subject to final selection of the marine contractor selected by Babcock to undertake the deployment. The shallow water deployment method has been developed by Babcock to enable FORECAST to be towed within water depths >6.5m.

FORECAST is made up of three main sections, allowing it to be disassembled and transported via road. Currently, the three sections are held at Rosyth, within Babcock's commercial port facility.

1.1 Scope

The deployment operation is divided into the following main stages

- Transport to Aberdeen port and assembly quayside
- Mooring installation
- Load-out from quayside Tow to site
- Connection to moorings

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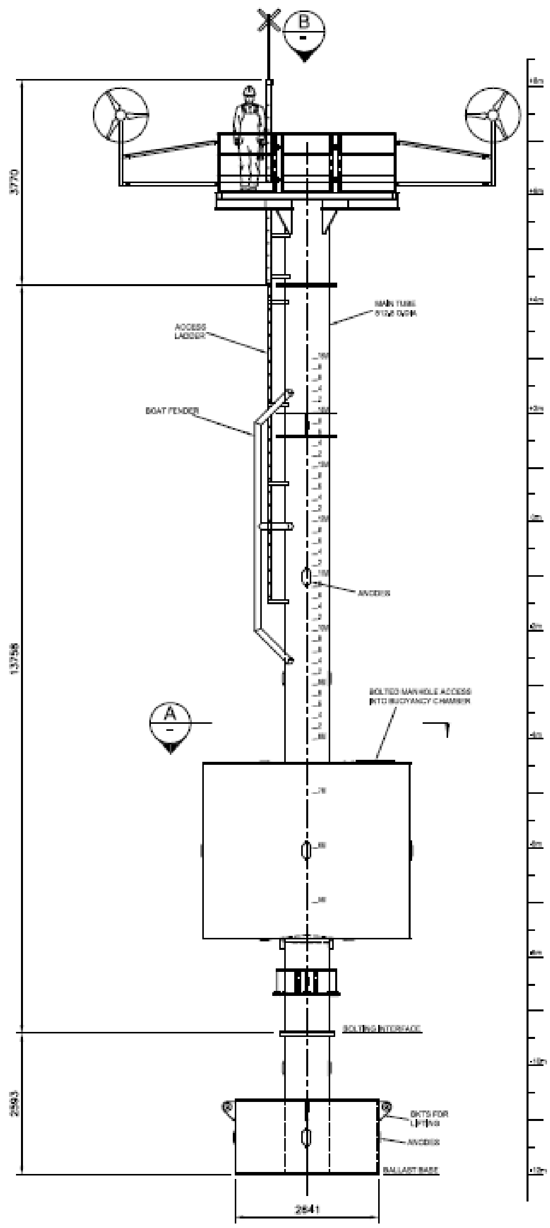
2 FORECAST General Particulars

[1]



ELEVATION A-A

Main General Particulars
Length of Structure: 20m
Length Overall: 23.3m
Operating draft: 12m
Air draft: 11.3m
Platform dimensions: 3m x 3m
Diameter of buoyancy chamber: 3.8m
Total Assembly Weight: 49Te
Construction Material: High grade mild steel

Mooring Arrangement
3 Point mooring system with either clump weight or embedment anchors, according to seabed conditions.
Survivability: 1 in 100 year storm

Operational parameters
Operating temp range: -20º to +50ºC
Drift Radius: 10m
Operating water depths: 20m to 100m
Max Operating wave height: 4.25m
Yaw: +/- 30º

Major Equipment
Zephir Lidar – 300 series
Data Logger System
3D Sonic anemometer
Satellite Compass
12V Electrical power system
2 x 350W Turbine Generators
4 x LG 300W Solar PV Panels

Communications
GSM / GPRS
SatCom
Local Wi-Fi

[1] The above illustration is an extract taken from the General Arrangement drawing and can be provided upon request.

3 Methodology

3.1 Transport and Assembly

The FORECAST structure is divided into three sections to enable transport by road. The sections are connected using bolted flanges with gaskets.

All FORECAST sections and the associated ground tackle (moorings) will be transported by road, from Babcock's commercial port located in Rosyth, to Aberdeen port. The three units are assembled quayside in the vertical position, ready for lift operation, into the water.

Quayside location within Aberdeen port is to be confirmed and will be subject to port availability at time of the deployment operation.

3.2 Three Point Mooring Installation

Step	Description
1.	Moorings assembled on quayside, Aberdeen Docks. Anchors located close to quay edge within safe lifting radius of vessel crane. The remainder of the mooring leg will be flaked to ensure sufficient slack during the anchor lifting operation.
2.	A tool box will be held to ensure all personnel are aware of the dangers associated with the load out. Particular attention will be paid to the dangers of heavy lifts and bights.
3.	The mooring anchor will be stropped in accordance with the lift plan.
4.	The anchor will be lifted by the vessels crane, swung over the quay and decked in a position close to the bow roller.
5.	A suitable bight of mooring line will be stropped using a webbing sling. The bight will be lifted and swung inboard on the vessel with proper attention being paid to the dangers of hanging lines.
6.	Once on-board, the mooring anchor and line will be lashed to a level commensurate with sea conditions expected during the transit to site.
7.	The vessel will transit to site, subject to the requirements of the Aberdeen Wind Farm site operation requirements.
8.	A tool box talk will be held to ensure all personnel are aware of the dangers associated with mooring deployment. Particular attention will be paid communications between bridge/ deck/ crane operator/ winch operator and to the danger of running lines and bights.

9.	The anchor winch line will be shackled into the end of the mooring line. The mooring line will be wound onto the anchor winch.
10.	The mooring anchor will be stropped using a sling with a minimum SWL of 20 tonnes.
11.	The vessel crane will be hooked to the anchor strop and sufficient tension taken to allow the safe unlashing of the anchor and mooring line.
12.	The vessel crane will take the anchor weight until it lifts from the deck. The crane will continue lifting until the anchor has sufficient height to clear the bow roller. Tag line will be rigged to prevent swinging.
13.	The anchor will be swung over the bow roller and lowered until the weight is taken by the anchor winch wire.
14.	The vessel crane hook will be released from the anchor strop and cleared.
15.	The vessel shall be manoeuvred until the bow roller is over the anchor landing position, accurately determined by the vessels on-board plotter.
16.	The anchor will be lowered to the seabed at the predetermined coordinates to enable FORECAST to enable FORECAST to operate at the installation coordinates. The position will be recorded by the vessel master and noted.
17.	As the vessel is manoeuvred astern, the mooring line will be paid out from the vessel winch.
18.	The temporary surface support buoy and pendant will be shackled into the tri-plate located at the end of the fibre riser.
19.	Once the bitter end is clear of the winch, a slip line will be rigged through the tri-plate / chain tail shackle.
20.	The winch wire will be disconnected, and the bitter end over-boarded on the slip line.
21.	The surface support buoy will be over-boarded and the mooring slipped.
22.	The mooring installation vessel would then transit to Aberdeen dock
23.	If deck space allows, all three anchors and their moorings will be transferred to the deck of the vessel for a single transit to the site location. If not Steps 3 to 23 will be repeated for each anchor mooring.

3.3 FORECAST Load out from Quayside

Step	Description
1.	FORECAST assembled on quayside at Aberdeen dock. FORECAST will be located close to quay edge within safe lifting radius of the quayside crane. The mooring leg chain tails will be shackled to the mooring lugs and lashed to the structure above the design waterline to allow connection to mooring lines at the site location.
2.	Towing vessel is manoeuvred alongside quay ready to take up FORECAST tow line.
3.	A tool box will be held to ensure all personnel are aware of the dangers associated with the load out. Particular attention will be paid to the dangers of heavy lifts.
4.	Using a suitable cherry picker, or suitably certified man riding basket, rig the Lidar to lift and readiness for towing once in the water. Towing line to be laid out to the towing vessel, on hand, quayside, with plenty of slack. Particular attention is to be given to ensure that the line does not interfere with the lift operation and hoist into the water. Pay particular attention to the clearance required by instrumentation. Rig tag lines assist control of inclined swinging.
5.	Rig structure with additional buoyancy bags to assist 60º incline when structure enters the water.
6.	Ensure all project personnel are aware that the heavy lift is about to commence. Standby vessel mooring lines.
7.	Take the weight on the quayside crane and lift slowly clear of the quay, allowing the structure to progressively incline to approx. 60º angle.
8.	Swing the buoy over the Quay edge, to the side of the attending towing vessel.
9.	Lower slowly until the buoyancy chamber is partly submerged. Continue to lower slowly until approximately 75% of the weight is transferred from hook by displacement structure (buoyancy).
10.	FORECAST will free float at the induced 60º angle, supported by the additional buoyancy aids to maintain the angle of heel in the water.
11.	Towing vessel to take up slack on tow line and temporarily hold FORECAST alongside vessel at the hip, fendered off and secured to ship side. Sufficient fenders are deployed and positioned to prevent damage occurring between vessel and FORECAST whilst secured at the hip.

3.4 FORECAST Tow to site

Once the Tow vessel reaches a safe operating distance outside Aberdeen harbour with sufficient depth of water to ensure buoy under keel clearance of at least 3m, FORECAST will released from the ship side and manoeuvred astern of the vessel for commencing towing to its deployment location.

The towing arrangement utilises the mooring chain tails rigged to the FORECAST for connection to the pre-deployed moorings, arrangement TBC. This may be part wire/ part fibre stretcher or all fibre.

Note: A towing analysis will be carried prior to the deployment operation to determine towing characteristics with buoyancy aids at the 60º angle and predict the anticipated loads.

Step	Description
1.	Vessel will tow FORECAST whilst secured on the hip, until a safe operating distance outside of Aberdeen harbour and sufficient depth of water.
2.	Ensure all personnel are aware of executing tow transition.
3.	FORECAST is released from the hip and manoeuvred astern of the vessel in the towing position, paying out the tow line. Once in the correct position and orientation the tow vessel then takes up the tow line slack, ready to commence tow to site location.
4.	The tow vessel (multicat) will proceed at slow speed (c 4kts) on a medium to short tow (c 40-60m)
5.	The tow route will be monitored and recorded by vessel master

3.5 FORECAST Mooring and Commissioning

The final part of the operation will be the connection of the buoy to the pre-laid three point mooring. The final 10m of the mooring legs consist of chain tails shackled into the lower lugs. These tails will be fitted whilst the buoy is on the quay and led to a lashing point above the design water line. This will enable the deck crew to make the mooring connection in way of the tri-plate.

Step	Description
1.	During the tow, a toolbox talk will be held as a final briefing for the mooring operation. Particular attention shall be paid to bridge/ deck communications and the dangers of lines under tension/ bights.
2.	Upon arrival on site, the multicat will shorten up the tow and bring the buoy alongside. Lines and fenders will be rigged to allow the buoy to be towed “on the hip”.
3.	It is important that the buoy is correctly aligned to ensure the mooring legs are attached in the correct sequence and FORECAST is in the correct orientation with the solar array facing south.
4.	The first surface support buoy will be grapnelled and brought inboard using the vessels *drum end / capstan.*
5.	The mooring line will be heaved inboard until there is sufficient slack to allow the line to be handled safely on deck.
6.	The mooring line shall be stoppered off inboard of the bow roller.
7.	The chain tail shall be led from the buoy, outboard of the vessel then inboard over the bow roller. It will be stoppered off just inboard of the roller.
8.	The surface support buoy will be unshackled from the tri-plate.
9.	The chain tail shall be shackled into the tri-plate. Split pins will be fitted and verified as secure.
10.	The sub-sea support buoy shall then be shackled into the tri-plate.
11.	A slip hook shall be attached to the crane wire and hooked over one of the links of the chain tail.
12.	The bight will be lifted clear of the deck with the crane and the weight taken off the stoppers.

13.	The bight will be lowered into the water until the weight is taken by the subsea buoy. The slip hook would then be recovered inboard.
14.	Once the first two legs are secure, one member of Babcock project team to board the buoy from the multicat using the access ladder.
15.	Carry out equipment commissioning. Recover person from buoy ladder to deck.
16.	Recover last chain tail to deck and stopper off.
17.	Let go buoy lines and manoeuvre vessel clear.
18.	Manoeuvre vessel towards last surface support buoy.
19.	Vessel Master to confirm and record FORECAST positional coordinates.
20.	Multicat transit back to Aberdeen port.

4 Waverider buoy

FORECAST will be supplemented by a Waverider buoy to record metocean data at the site location. The Waverider buoy will be deployed within the designated 100m radius operation exclusion zone, centred about FORECAST location.

The below provides an example for the type of Waverider buoy that will be deployed

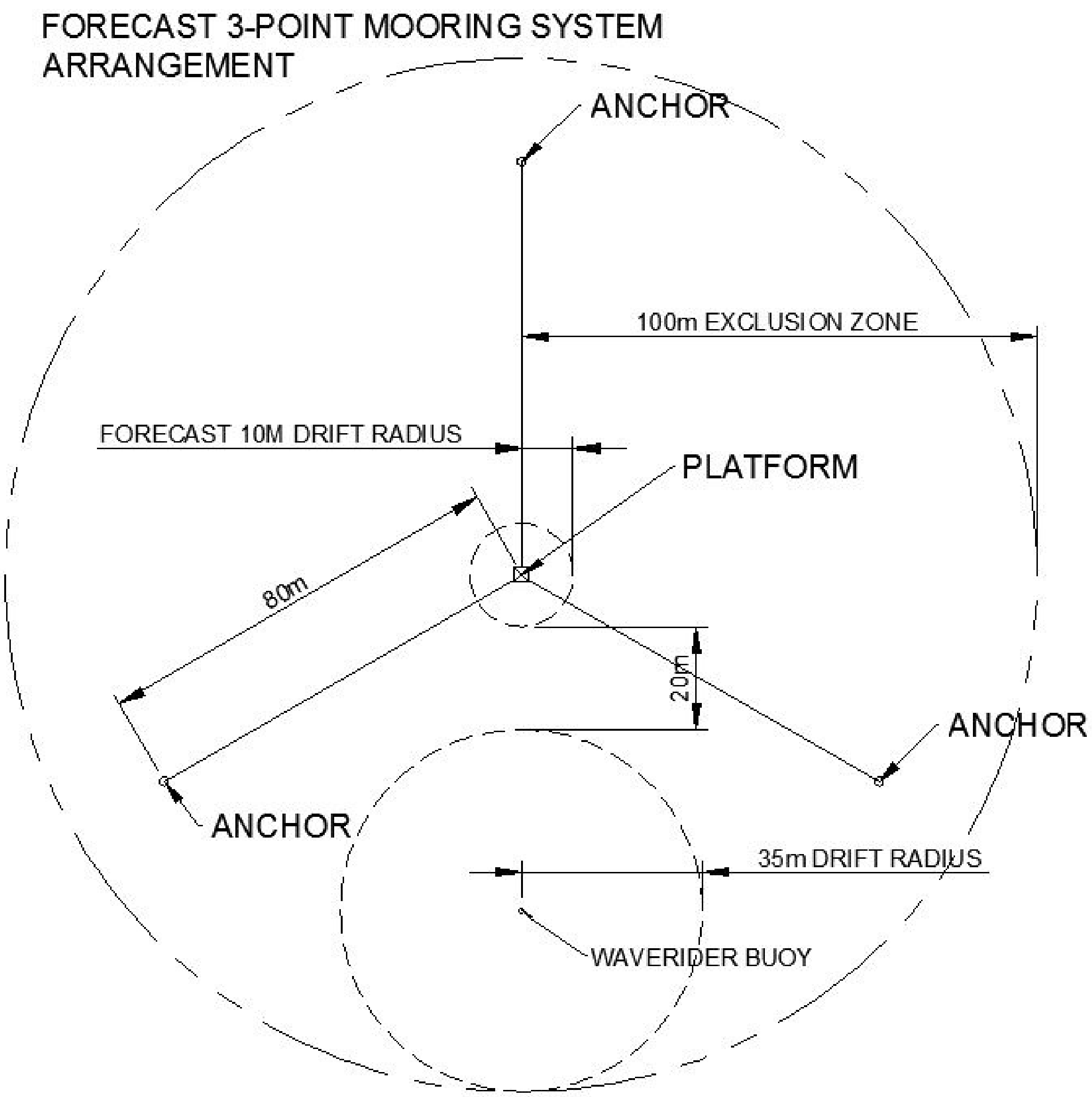
Directional Waverider DWR4/ACM

- wave motion sensor based on a stabilised platform, accelerometers, and magnetic compass
- **measures wave height** for wave periods of 1 to 30 seconds, accuracy 0.5 % of measured value
- **measures wave direction**
- **measures surface current**
- **measures water temperature**
- GPS for buoy monitoring and tracking through HF link
- internal logger
- power switch
- LED flash antenna
- 0.9 m diameter spherical hull of AISI 316 including eccentric mooring eye
- optional Cunifer hull, warranted not to corrode
- 1.3 years battery life (30 batteries)
- HF transmitter range 50 km over sea
- optional **Iridium SBD module** for ocean wide coverage and unlimited range
- optional Iridium Internet module
- optional **Argos module** for ocean wide coverage and unlimited range
- optional **Solar Panel system**
- optional hull painting

The Waverider buoy has a single mooring system.

5 Mooring installation arrangement

The below diagram illustrates the mooring arrangement and the relationship between the three point mooring system and FORECAST, located at the centre of the zone. It also shows the location for the Waverider buoy.

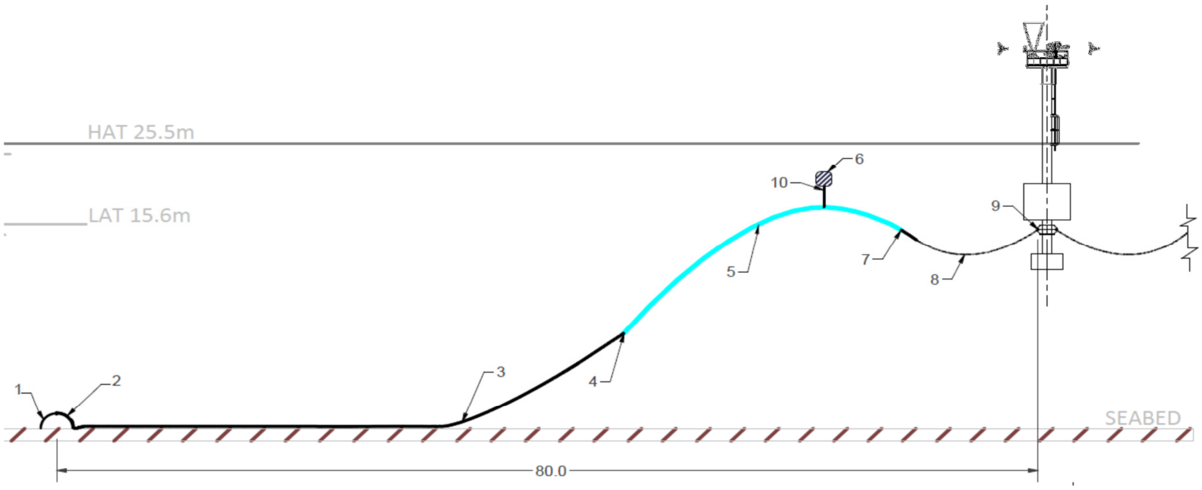


5.1 Three pint mooring system

The mooring consists of 3 x chain / fibre / chain legs, each of which is attached to stockless anchors weighing 17 tonnes.

The last 10m of each mooring leg will consist of chain tails secured to the buoy mooring lugs pre-attached and towed to site with the buoy. The mooring system also requires a sub-sea buoy attached to the connection between the fibre riser and chain tail. This will be fitted during the buoy mooring operation.

The composition of each mooring leg required to be pre-installed will be as follows;



Component	Length	Weight
Stockless anchor	N/A	17.5 tonnes
Ground chain	55m	700 kgs
Fibre Riser	30m	52 kgs
Associated shackles	N/A	TBC
Temporary surface support buoy	Circa 2m diameter with light	TBC

5.2 Installation coordinates

FORECAST - 57º13.509'N : 1º59.895W

Waverider Buoy - 57º13.47396'N : 1º59.895W

Note: The Waverider buoy is located 65m directly south of FORECAST, central between the moorings as illustrated on the previous page.

5.3 Vessel Selection

The following information provides details of the typical vessel that will be used in the deployment of FORECAST and the Waverider buoy. Final vessel selection will be subject to vessel availability and contractor selection, however the below vessel information is considered typical for the vessel required to undertake the deployment operation.

Example Vessel: Whalsa Lass

General Particulars:

General

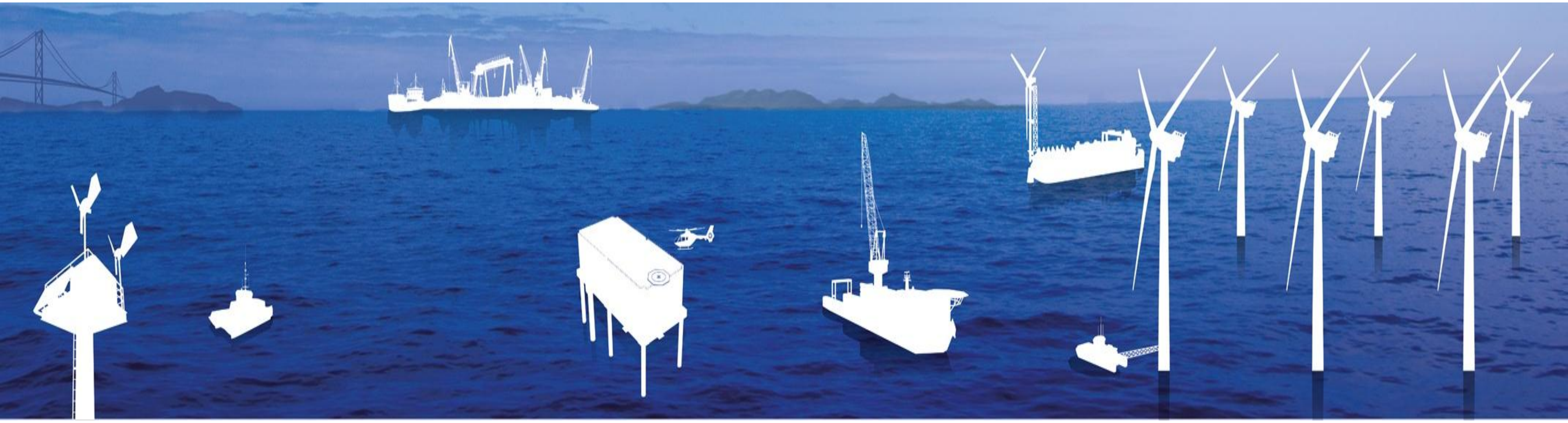
Type of vessel	: Damen Multicat®2611
Builder	: Damen Shipyards Hardinxveld
	: Yard No. 571661
Basic Functions	: Anchor handling, dredger service, supply, Towing, hose handling, survey, ship assist
Classification	: Bureau Veritas I✠Hull•MACH Tug
	: Unrestricted Navigation
	: Nat. Authorities
	: MCA workboat Category 1
	: 150 miles from shore

Dimensions

Length o.a.	: 26.00m
Beam	: 11.50m
Depth at sides	: 3.50m
Draught aft	: 2.25m
Displacement	: 515 ton (m)
Free deck space	: 160m^2
Deck Loading	: 10t/m^2

Whalsa Lass

A full specification sheet is provided separate to this method statement as a reference.



Babcock FORECAST

www.babcockinternational.com

Babcock International Group

The Leading Engineering Support Services Company

We take real responsibility for delivering outcomes

Managing **Assets and Infrastructure**

and assure those outcomes through process excellence

Delivering **Projects and Programmes**

by bringing together leading-edge skills

Integrating **Engineering Expertise**

The UK's leading engineering support services company

FTSE 100

- Market cap. £4.4bn
- £3.25bn revenue in 2013
- **£12bn order book**

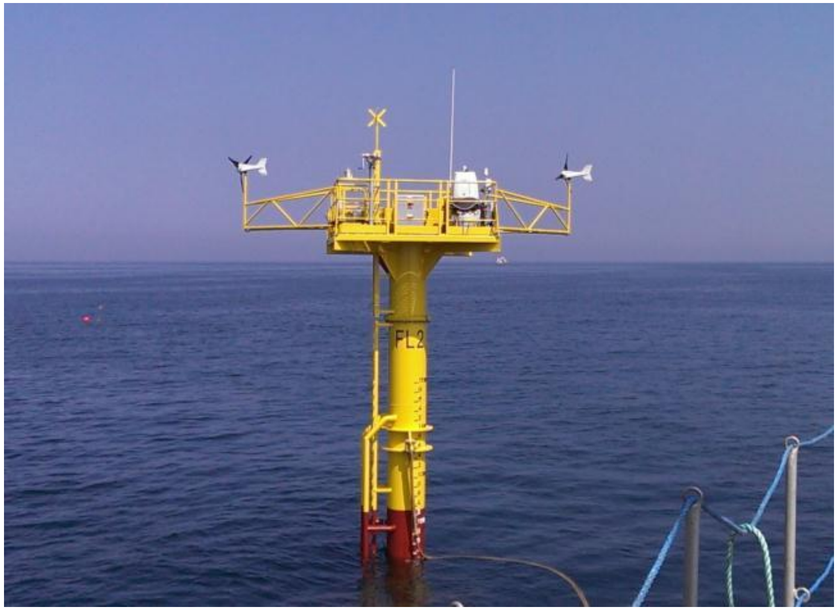
Managing customer assets worth **c. £42bn**

27,000 **skilled employees** worldwide

FORECAST Overview

Key Features

- Inherently stable platform
- Industry leading ZephIR 300 LiDAR unit
- No mechanical compensation or data post processing required – reduced uncertainty
- Safe and easy access for maintenance etc
- Easily repositioned
- Elevated platform – improves survivability and marine safety
- N-2 redundant mooring system



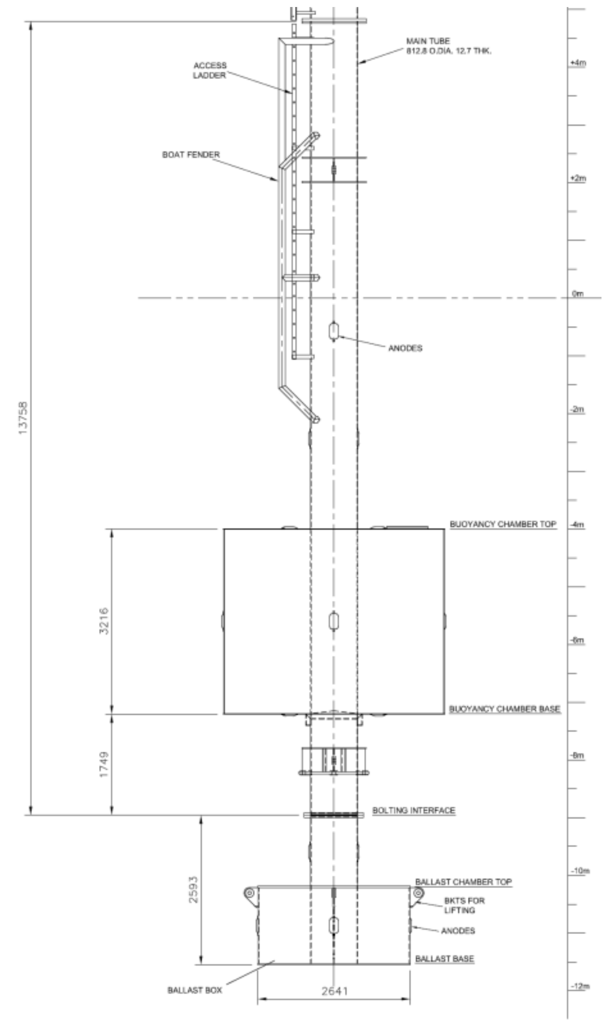
Buoy Design

Low Motion Buoy

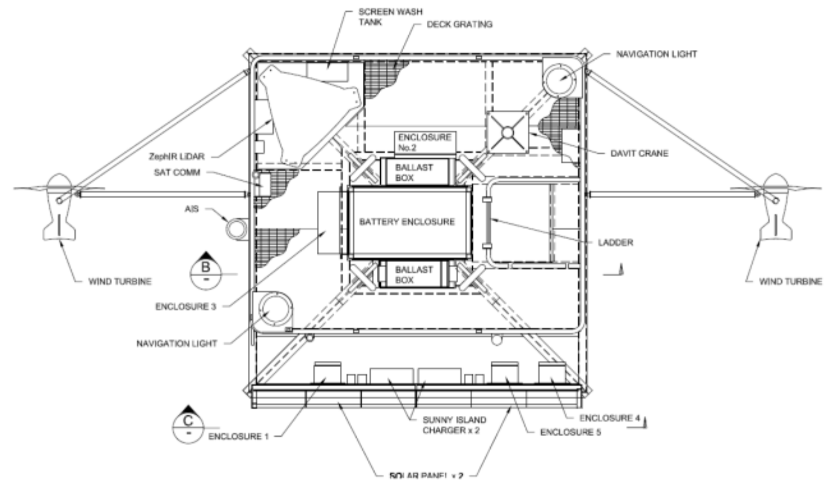
- Inherently stable, shallow draft spar buoy
- Low pitch, roll and heave
- Modular design

Three main sections

- Main Tube – 812mm OD Pipe
- Buoyancy Tank – 3800mm Ø tank with internal stiffeners
- Ballast Tank – 2600mm Ø tank filled with high density concrete

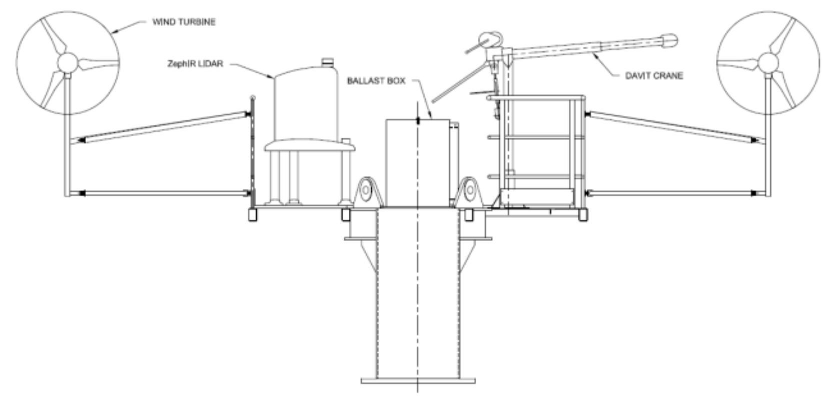


Platform Design



Platform

- 3.2m x 3.2m platform housing all systems
- Wind turbines mounted on outriggers
- GRP gratings provide walkway
- Main lifting points for whole buoy
- Access from ladder below
- Handrails all around



A SECTION

Systems On Board - Measurement

- ZephIR 300 LiDAR measuring:
  - Wind speed and direction at a number of heights
  - Turbulence intensity at each height
  - Temperature, pressure, humidity and rain
- 10m Met Station
  - Separate met station sited approximately 10m above MSL
  - Sonic Anemometer measuring wind speed, direction and Monin Obukhov length if required
  - Temperature, pressure and relative humidity sensors
- DGPS Compass
  - Accurately records bearing of buoy
  - Also reports pitch, roll and GPS coordinates

Systems On Board - Power

- 2 x Micro Wind Turbines
  - Pitch controlled blades for performance and survivability
  - Independently controlled and regulated for redundancy
- 2 x Solar PV Panels
  - South facing reliable monocrystalline panels
  - Independently controlled and regulated
- 2 x Battery Banks
  - >7 days of reserve power
  - Providing redundancy and maintenance during system operation
  - Additional emergency battery for nav aids only, ~14 days
- Methanol Fuel Cell Option
  - Optional fuel cell providing up to 20 days additional redundancy
  - Ideal for far shore deployments to allow additional repair time

Systems On Board – Data Capture

- Centralised Data Logger
  - Collects all data and provides “plug and play” option for other sensors
- Redundant Communications Link
  - GSM and Satcom link with auto switching
- Data Access
  - Daily emails or uploads with remote access as required
  - Wirless connection to ZephIR possible within ~50m
- System Status Monitoring
  - ZephIR status: wiper, voltage, temperature, fans on, heater on etc
  - Power Status: generator power (each source), battery voltage (each bank)
  - Alarms: gate opened, drift radius exceeded

Systems On Board – Nav Aids

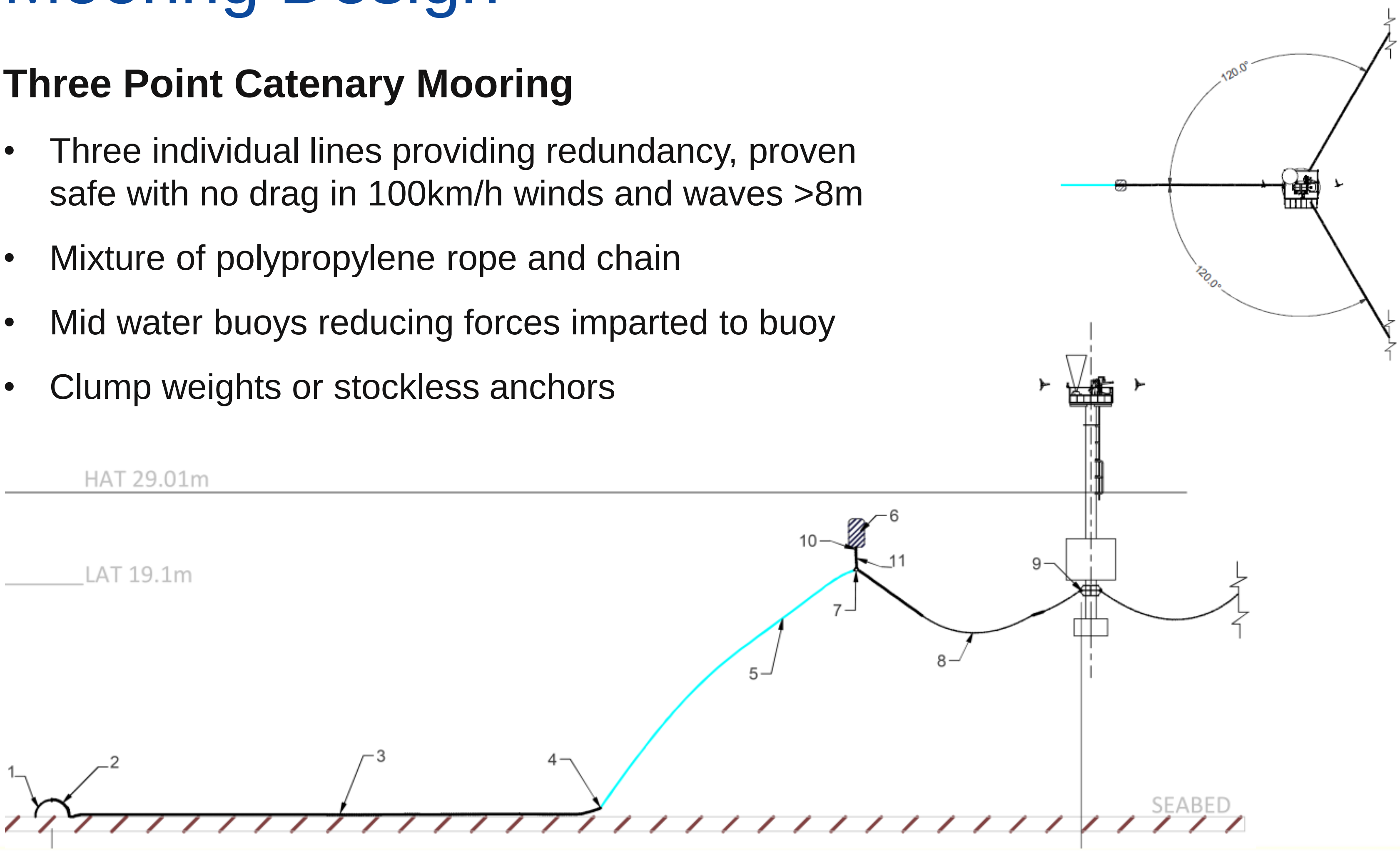
- Navigation Lanterns
  - 2 synchronised LED navigational lanterns providing redundancy and excellent all round visibility
  - Normally yellow with 2nm visibility, other colours possible
  - Auto switch on at dusk

- AIS AtoN
  - Automatic Identification System Aid to Navigation
  - Reports exact position to marine traffic every 3 minutes
  - Provides additional method of tracking position

Mooring Design

Three Point Catenary Mooring

- Three individual lines providing redundancy, proven safe with no drag in 100km/h winds and waves >8m
- Mixture of polypropylene rope and chain
- Mid water buoys reducing forces imparted to buoy
- Clump weights or stockless anchors



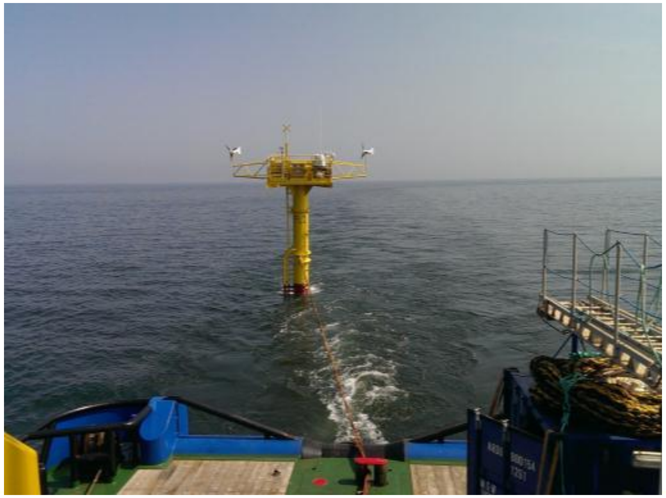
Fabrication & Installation

Fabrication

- Modular build allowing simultaneous fit out
- 12-14 week build time for new build
- All major commissioning done on shore

Installation

- Towed to position using small tug / workcat
- Moorings deployed in advance
- Systems checked and commissioned
- Installation time 1-2 days (weather dependent)



Operation and Maintenance

Maintenance

- Design maintenance intervals of 6 months
- Routine maintenance includes:
  - Screen wash top up
  - Structural condition inspection
  - Systems condition inspection
  - Equipment wash down

Access

- Stable platform provides safe working environment
- Accessed via fendered ladder
- Small vessel used for transport
- Access weather limit of c1.5m significant wave height

Carbon Trust OWA Validation – Gwynt Y Mor

- Validation on Gwynt Y Mor under the Carbon Trust OWA programme
- Key Criteria measured against fixed met mast
  - Wind Speed Accuracy
  - Wind Direction Accuracy
  - System and Data Availability
- Frazer Nash Consultants conduct data validation, verified by GL Garrad Hassan

OWA Partners:

Gwynt Y Mor Trial – Accuracy Results

Wind Speed

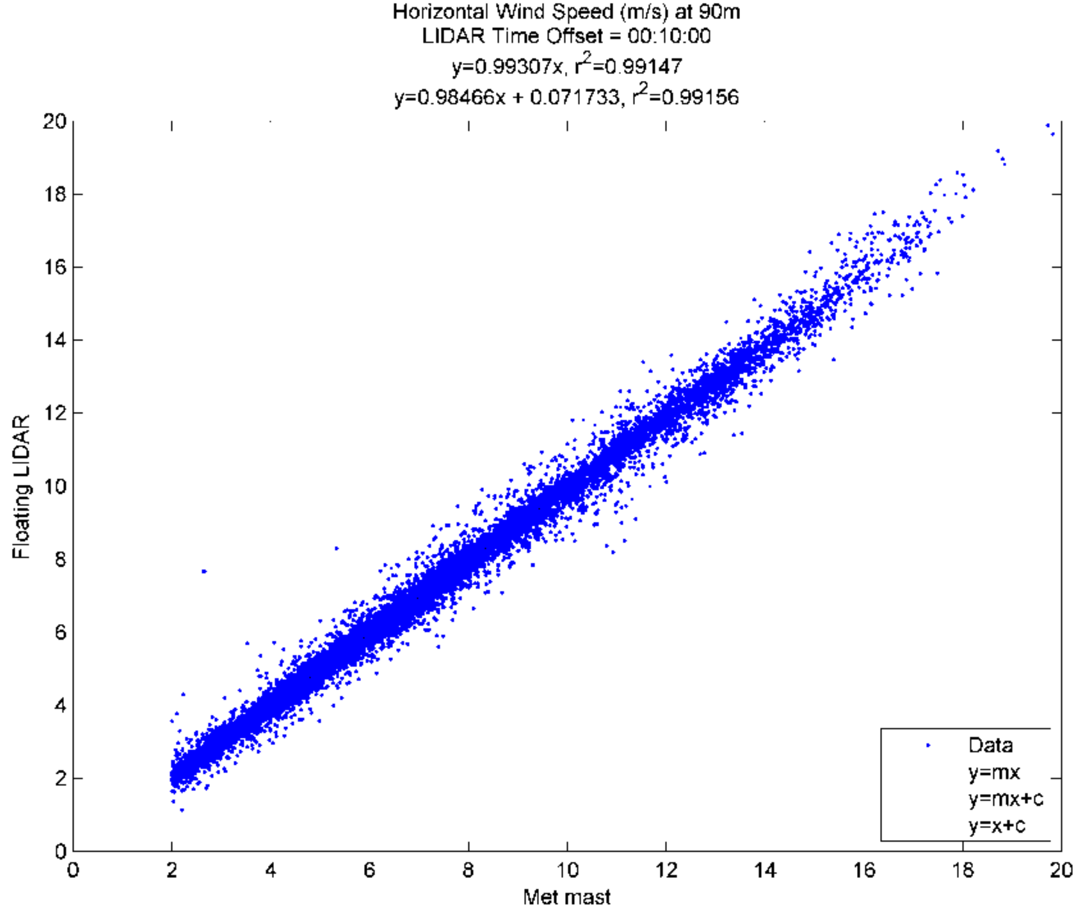
- Excellent correlation

Wind Direction

- Good correlation
- Robust commissioning procedure t eliminate offsets

Data Availability

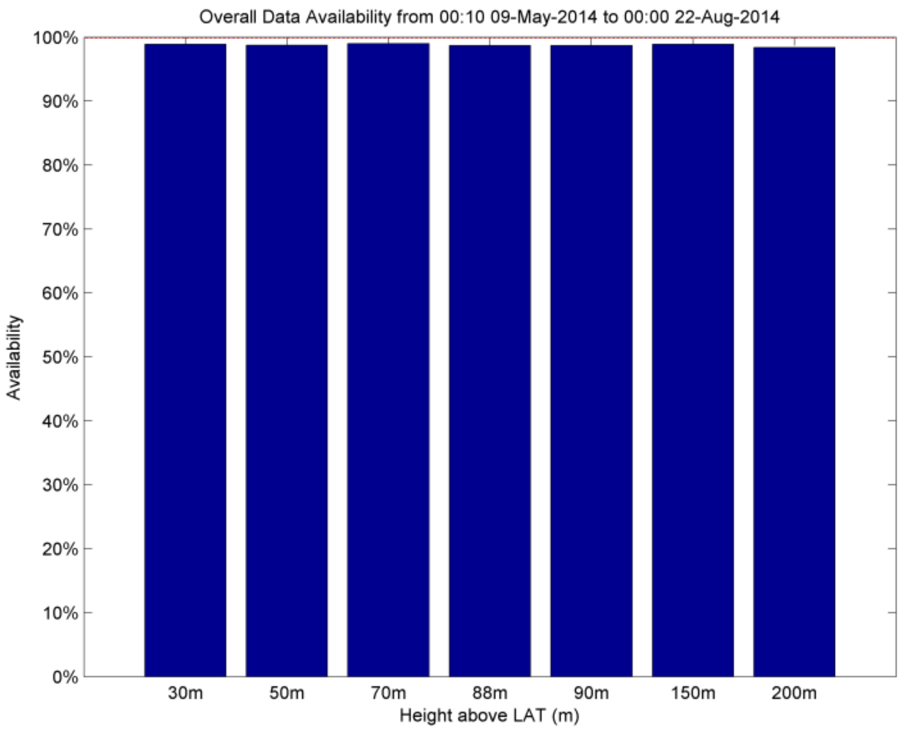
- 99.86% system availability
- >98.5% data availability



Gwynt Y Mor Trial – Availability Results

Excellent availability

- Data availability indicates percentage of data available after removing 9999 and 9998 values
- System availability indicates number of returned time stamped data entries compared to max possible
- Carbon Trust OWA roadmap acceptance criteria states a requirement for 95% system availability and 85% data availability



Summary of data availability (blue bars) and system availability (red dotted line)

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Whalsa Lass

Multipurpose Anchor- Handling Tug / Workboat — Built 2011

Call Sign – 2EZQ4 — **MMSI** 235.089.425

General

Type of vessel	: Damen Multicat®2611
Builder	: Damen Shipyards Hardinxveld
	: Yard No. 571661
Basic Functions	: Anchor handling, dredger service, supply, Towing, hose handling, survey, ship assist
Classification	: Bureau Veritas I✠Hull•MACH Tug
	: Unrestricted Navigation
	: Nat. Authorities
	: MCA workboat Category 1
	: 150 miles from shore

Dimensions

Length o.a.	: 26.00m
Beam	: 11.50m
Depth at sides	: 3.50m
Draught aft	: 2.25m
Displacement	: 515 ton (m)
Free deck space	: 160m^2
Deck Loading	: 10t/m^2

Tank Capacities

Fuel oil	: 119.00m^3
Fresh water	: 49.00m^3
Ballast water	: 60.00m^3
Black/grey water	: 9.20m^3
Dirty oil	: 2.00m^3

Performances

Bollard Pull Ahead	: 37.2 tons (Certified)
Bollard Pull Astern	: 24 tons
Speed	: 10.1 knots

Propulsion System

Main engines	: 3 x Caterpillar C32 TTA
Total power	: 1902 bkW at 1800 rpm
Gearboxes	: 3 x Reintjes WAF 464 5.591:1
Propulsion	: 3 x fixed pitch props in nozzles, 1700mm
Bowthruster	: Hydraulically driven 200kW, 360°

Auxiliary Systems

Generator sets	: 2 x Caterpillar C 04.4 107kVA each
Hydraulic power	: Caterpillar C18 375kW
Transfer pumps	: Fuel & Fresh Water 50m^3/hr

Deck Lay-out

Deck cranes	: 2 x Heila HLRM 230 3SL | 10 T @ 16.5m
Towing winch	: 50T pull, 90T brake | 650m x 40mm
Anchor handling	: 100T pull, 150T brake | 150m x 44mm
Tugger winch	: 13T pull | 75m x 20mm
Hydraulic pop-ups	: Fore deck – 1 x fork & 2 x guide pins
	: Aft deck – triple pin type
Towing hook	: Mampaey DCX 33T (Stern)
	: Mampaey DCX 7T (Bow)
Bow roller	: 100 T SWL 5m, Ø 1000mm
Stern roller	: 60 T SWL 2m, Ø 760mm
Capstan	: WK 5 tons

Accommodation

Comfortable heated and air-conditioned accommodation
For 6 persons, in 3 cabins, galley, sanitary facilities, etc.

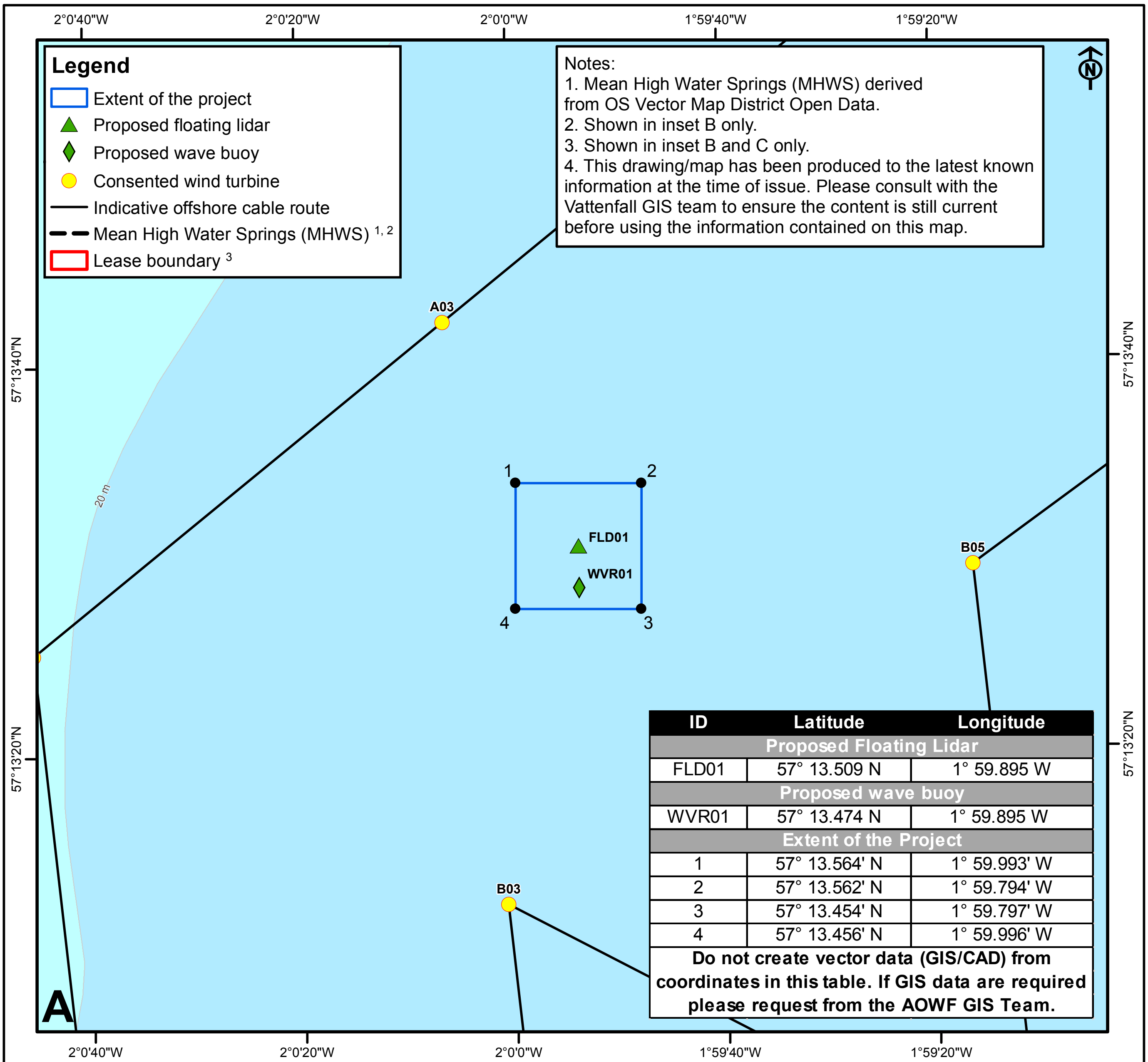
Navigation & Communication

Radar system	: 1 x Furuno FR 2117 6' (ARPA)
	: 1 x Furuno FR 8062 4'
Compass	: Cassens & Plath
Gyrocompass	: Anschuetz 22
Echosounder	: Furuno FE 700
DGPS	: Furuno GP-150D
Chart Plotter	: Transas Navisailor 3000ECS
Autopilot	: Radio Zeeland, Sea Pilot 75
Speedlog	: Furuno DS-80
Navtex	: Furuno NX 700
VHF	: 2 x Sailor RT 6222 / DSC
VHF handheld	: 3 x Icom BC-166
VHF GMDSS	: 2 x Jotron Tron TR20
Inmarsat-C	: 2 x Sailor TT-3000E
AIS	: Furuno FA-150 Class A
SSB	: Furuno FS-1570
Intercom	: Radio Zeeland Sigma 700 (7 stations)
UPS system	: APC 1600W – 220V

GSM cellphone, email & internet (coastal)

Additional

Spud poles	: 2 x Ø 650mm, 15m
Seabed levelling/dredging	: Aft Portal A-frame (1 x 60t SWL or 2 x 30t SWL)



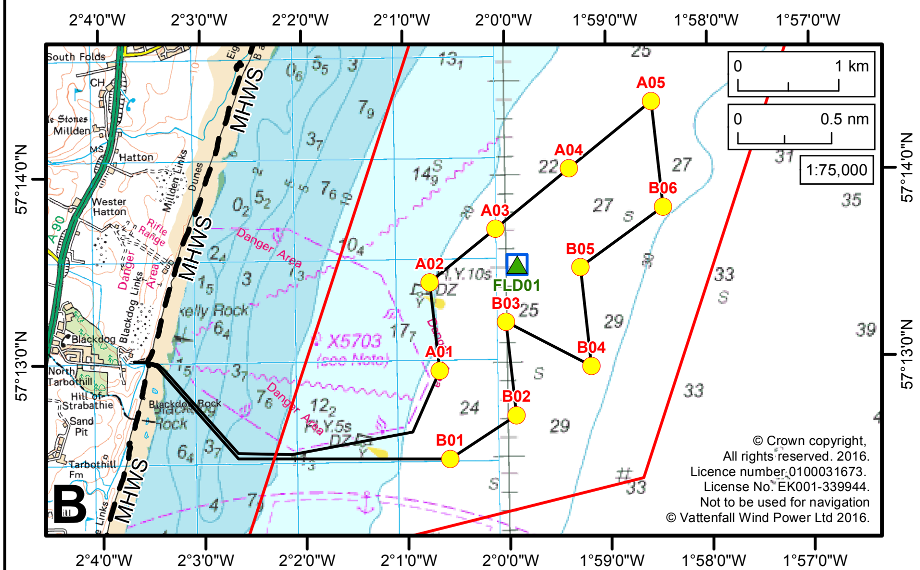
Legend

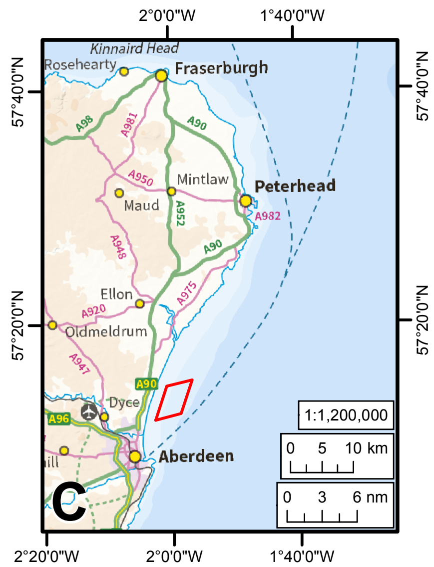
- Extent of the project
- Proposed floating lidar
- Proposed wave buoy
- Consented wind turbine
- Indicative offshore cable route
- Mean High Water Springs (MHWS) 1, 2
- Lease boundary 3

Notes:
1. Mean High Water Springs (MHWS) derived from OS Vector Map District Open Data.
2. Shown in inset B only.
3. Shown in inset B and C only.
4. This drawing/map has been produced to the latest known information at the time of issue. Please consult with the Vattenfall GIS team to ensure the content is still current before using the information contained on this map.

ID	Latitude	Longitude
Proposed Floating Lidar		
FLD01	57° 13.509 N	1° 59.895 W
Proposed wave buoy		
WVR01	57° 13.474 N	1° 59.895 W
Extent of the Project		
1	57° 13.564' N	1° 59.993' W
2	57° 13.562' N	1° 59.794' W
3	57° 13.454' N	1° 59.797' W
4	57° 13.456' N	1° 59.996' W

Do not create vector data (GIS/CAD) from coordinates in this table. If GIS data are required please request from the AOWF GIS Team.





VATTENFALL

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areg Aberdeen Renewable Energy Group

Aberdeen Offshore Wind Farm
Floating Lidar / Wave Buoy Location

0 100 200 m
0 0.1 nm

Rev	Date	Drawn By	Checked By	Comment
E	30/06/16	lmur	ahnt	Added WVR01
D	24/06/16	jjaw	lhop	Minor changes in template (logos, notes)
C	17/06/16	jjaw	lmur	Map layout changed. MHWS line added

Datum	Projection	Plot	Scale	Purpose	Layout	Rev	Drg No
WGS84	UTM30N	A4	1:10,000	For information	LABER041	E	61290-2AG-700-004

Ref: VATT_EU_Monitor_v01_150730lhop4258 (ID IN('FLD01' , 'WVR01') AND DATA_STATUS = 'Current'), ABER_LeBdry_v08_100526bo_UTM30N, LABER041_v01_151210lm_32630, ABER_CabRo_v11_160122lm_UTM31N, ABER_BDMO_MaBdry_v02_160606lm_32630, TidalBoundary

DWR4 with ACM

Datawell - Oceanographic Instruments

The long anticipated, in-home developed, Directional Waverider that integrates wave and current measurements has been launched.

DWR Wave measurements: same sensor, new data processing

The wave sensor of the Directional Waverider equipped with the Acoustic Current Meter option (DWR4/ACM for short) is identical to the sensor in the well known Directional Waverider MkI, II and III. Processing of the measured data is now performed at the doubled sample frequency of 2.56 Hz. The high frequency limit of the heave and direction signals is shifted from 0.58 to 1.0 Hz. With this choice, the high frequency limit of the wave buoy is determined by the hydrodynamic response of the hull, not by the onboard instrumentation.

In addition, the DWR4 transmission protocol allows for a superior heave and horizontal displacement resolution. Easy comparison of the new DWR4 output to the familiar DWR-MkIII results is facilitated in the accompanying waves4 software suite.

Operational improvements

Extra features of the DWR4 compared to the DWR-MkIII to facilitate operation are:

- For identification, the buoy is tagged with an electronic ID-number (or actually two ID's for hull and hatch cover separately) which is transmitted along the measured data.
- As a kind of health parameters, the temperature of the Hippy-40 sensor as well as that of the hatch cover electronics are measured.
- For better energy management, the energy used from the batteries and the energy supplied by the optional solar panel are measured.
- For ease of operation, an optional power switch on the hatch cover is available.

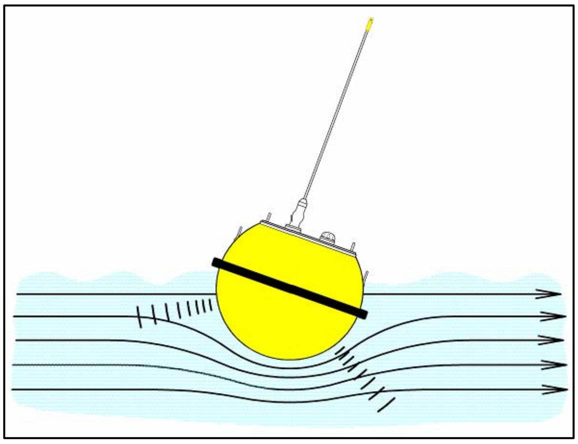
An operational difference between the DWR-MkIII and the DWR4 is the criterion for the flashlight. This has changed from light detection to a sunset/sunrise algorithm based on the GPS position and time.

DWR4 with ACM

Datawell - Oceanographic Instruments

The Acoustic Current Meter

The DWR4 is extended with a surface current meter. This Acoustic Current Meter, or ACM for short, combines a robust measuring principle, Doppler shift, with a mechanical design that avoids vulnerability. This results in a coherent oceanographic instrument that meets the challenges at sea.



By integrating three acoustic transducers in the hull of the well known Directional Waverider, the surface water velocity can be measured. The current is determined at roughly one metre below sea level, by measuring the Doppler shift of reflected 2 MHz pings. This robust and reliable method accords well with the Hippy 40 wave sensor, the standard in wave direction measurements.

Every 10 minutes, the magnitude and direction of the surface current are measured by three acoustic transducers. The transducers all face 30° down and are 120° laterally apart. Each transducer measures the projection of the current velocity along its axis. By time-gating the sensitive distance for the water velocity measurement is between 0.5 and 1.75 m from the hull. The current flow is affected by the presence of the Directional Waverider; close to the hull, the radial component of the velocity will be small, as opposed to the tangential components. Potential theory predicts thus an underestimation of a few percent. No compensation for this effect is applied.

The velocities as measured by the transducers are converted into a North-West-Vertical water velocity by means of the pitch-roll sensor and the compass of the DWR.

During one minute each transducer fires 150 acoustic pings. The velocity measurements are quality-controlled and averaged.

Impact of waves on the current measurement

Due to the orbital nature of the wave motion, the horizontal velocity is not a constant over time and place. Different ranges of wave periods have a different impact on the water velocity measurement. Short waves, up to 1 second (1.5 m wavelength) average out in the volume over which the velocity is measured. Due to the size of the DWR, the wavelength is too small to make the buoy follow the waves and introduce artificial water velocity.

Waves which have a period smaller than 30 seconds (wavelength smaller than 1.5 km), can affect the velocity measured by the individual pings. Being moored flexibly, the Waverider buoy is able to follow the wave motion, which reduces the impact by the horizontal wave velocity significantly.
Wave periods beyond 30 seconds (wavelength longer than 1.5 km) will affect the individual water velocity measurement in the case of a moored buoy.

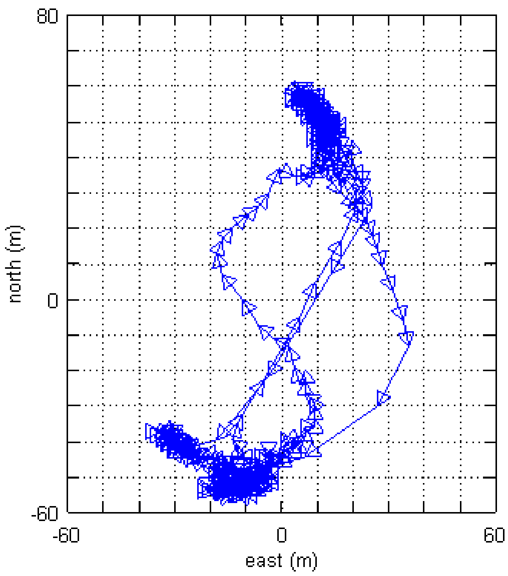
Impact of tidal motion on the current measurement

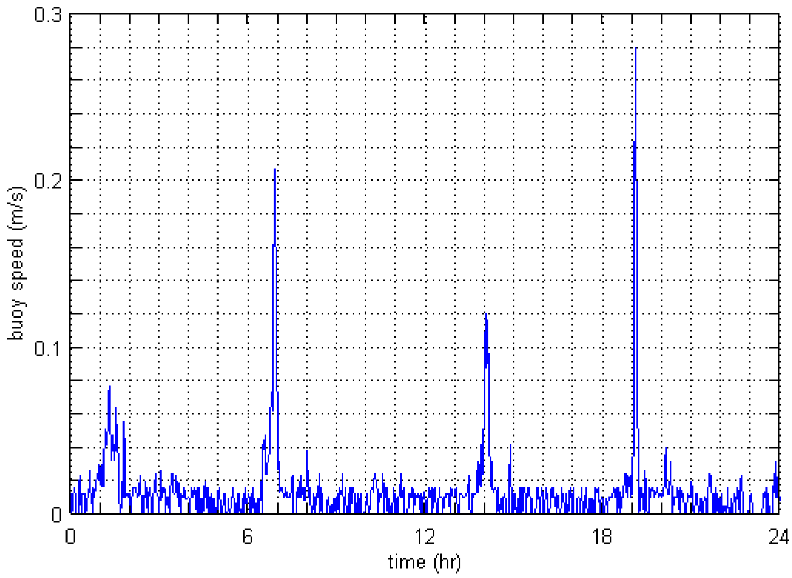
At the change of tide, the direction of the current typically changes by some 180° and the buoy traverses from one stationary position to the other. During the crossing, the actual water velocity is the vector-sum of the current as measured by the buoy plus the velocity of the buoy itself. The velocity of the buoy when moving from one location to the other is typically small, up to a couple of centimetres per second, depending on the location and the mooring line length. At some locations however, the buoy velocity can be one or more decimetres per second at every change of tide.

By measuring the position of the buoy by means of GPS every 2 minutes the buoy velocity is obtained. Each GPS-location is validated and results in a calculated buoy velocity that is transmitted alongside the velocity by the acoustic transducers.

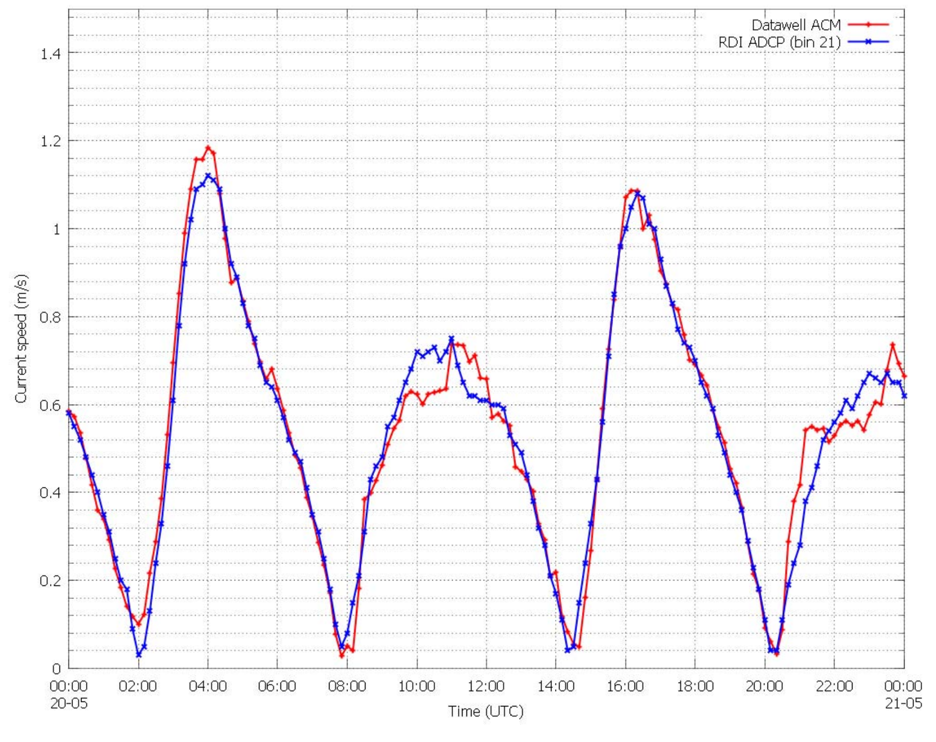
Operational performance

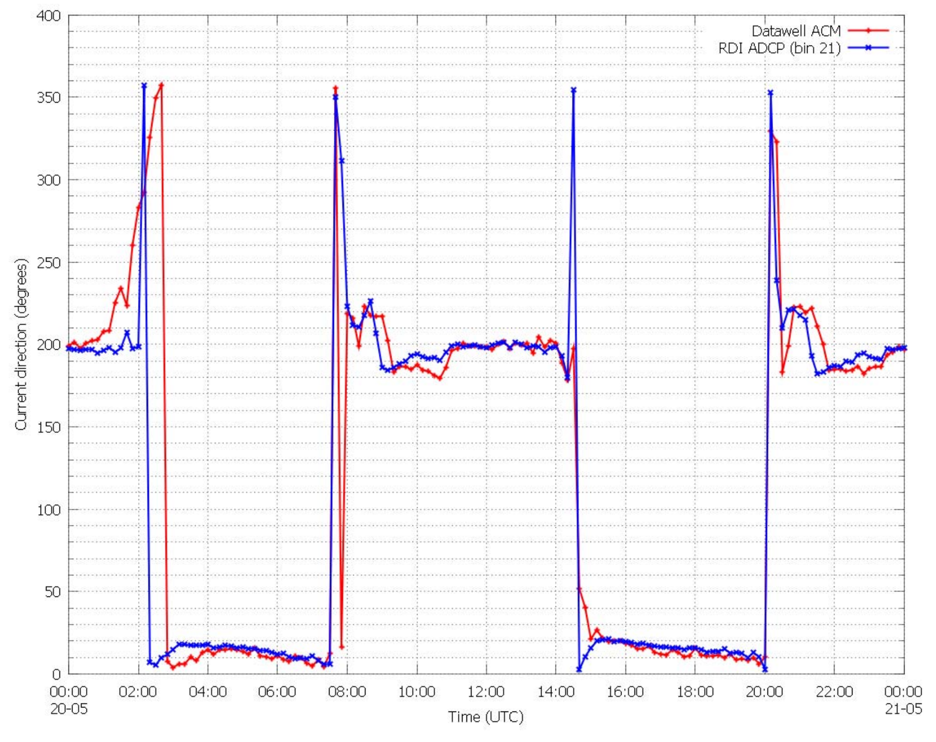
During the development of the ACM option, several field tests have been performed off the coast near Ymuiden, The Netherlands, where a pole mounted ADCP provided reference data. Significant wave height during the test period rose to 4.5 m. Water velocity oscillated with the tides between 1 m/s to the south and 1 m/s to the north. Agreement with the ADCP is typically within 2 % and 0.02 m/s.





GPS buoy positions during a field test in 14 m deep water off the Dutch coast, near IJmuiden. Two clusters of points can be discerned, corresponding with flood tide (North) and ebb tide (South).





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DWR4 with ACM

Datawell - Oceanographic Instruments

Fouling

The main reason for low signal to noise ratio of the received acoustic signal is fouling. In order to monitor the performance of the ACM, the RSSI of each transducer is determined and transmitted ashore.

Fouling after fourteen weeks at sea.

To reduce fouling on the sensor, the user can apply an antifouling coating. This does not necessarily affect the quality of the current measurement. Care should be taken that the used antifouling does not interfere with the active surface which is made of epoxy.

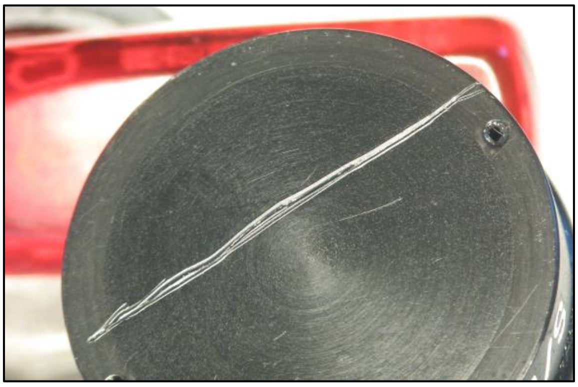
Transducer hardly visible, still measuring.

Transducer damage

The basis of the ACM are the well proven acoustic sensors made by Reson. Their intrinsic robustness is ruggedized by placing them in recess in a stainless steel housing. Should the surface of the transducer yet get damaged, this does not inevitably lead to failure of the current measurements. Even severe damage of the surface turns out to be acceptable.

Recessed transducer in the hull.

In the hostile environment of the sea, vessel interference cannot always be avoided. Collisions with ships or boats may leave a bump or a dent in the hull, which in turn may destroy the initial transducer alignment. A mechanical realignment of the transducers may be no easy job, or even impossible. In order to meet this situation, the azimuth and elevation directions of the transducers can be recalibrated. The new alignment matrix is stored in the ACM memory.



Severely damaged surface still measuring well. The scratch is 0.3 mm wide and 0.2 mm deep.

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A perfectly floating buoy in water with a constant current profile, is not expected to measure vertical water velocity. A sudden change of measured vertical velocity may be indicative of a serious transducer misalignment, due to e.g. vessel interference, or of other incidents that necessitate service to the system.

Preparing the DWR with ACM

Prior to launching the DWR, some preparations are required. In case the hull needs to be sandblasted and/or painted, the acoustic transducers can be replaced by dummies to avoid damage. Three grey dummies are supplied with the buoy, as well as a special tool for removing and (re)mounting the transducers.
To protect the Hippy-40 sensor a triangle is placed on the fender of the buoy.

Power switch option

An optional power switch on the hatch cover of the DWR4 ACM is available. Switching off the power starts the procedure of closing and storing the current data file on the data logger. Data stored on the data logger is retained when the buoy is switched off or when the batteries are removed.
The actual switch is covered by a small watertight dome that can be opened and closed with a standard 19 mm wrench, identical to the wrench for the standard Datawell 12 mm D-shackle in the mooring.

Solar option

For extension of the operational life of the DWR4 /ACM, a solar panel plus boostcaps can be installed. Solar energy will power the DWR4 /ACM, the surplus energy is stored in boostcaps. When solar energy is not sufficiently available, energy is used from the boostcaps. When they are depleted, the primary batteries are used.

Argos satellite communication

The Argos satellite system can help to retrieve a buoy that has broken from its mooring and can relay the measured wave and current data.

Operational issues

An eye-catching difference between the DWR4 /ACM and its predecessors is the mooring eye no longer being placed “at the south pole”, on the axis of symmetry, but somewhat higher up, on the ‘meridian’ of one of the transducers. This symmetry breaking gives the spherical buoys for the first time a kind of ‘bow’ and ‘stern’. The asymmetric mooring eye limits the buoy’s average pitch, thus keeping the buoy upright and the acoustic transducers underwater even in high current conditions.
In operation the DWR4 with ACM option is very similar to the DWR MkIII:

- The layout of the mooring line is identical.
- A triangle is strongly recommended in order to avoid damage to the Hippy40 sensor.
- The HF range is identical.

DWR4 with ACM

Datawell - Oceanographic Instruments

Specifications

Current Meter	General	Method: Doppler Cell size: 0.4 m - 1.1 m from surface Update rate: every 10 minutes Sensors: t three 2 MHz acoustic transducers
	Speed	Range: 0 - 3 m/s, resolution: 1 mm/s Accuracy: 1% of measured value +/- 2 cm/s Std. (1σ): 1 - 3 cm/s (depending on wave height)
	Direction	Range: 0° - 360°, resolution 0.1° Accuracy: 0.4° - 2° (depending on latitude) typical 0.5° Reference: magnetic north
Wave sensor	Type and processing	Type: Datawell stabilized platform sensor Sampling: 8-channel, 14bit @ 5.12 Hz Data output rate: 2.56 Hz Processing: 32bits microprocessor system
	Heave	Range: –20 m - +20 m, resolution: variable, 1 mm smallest step Accuracy: < 0.5% of measured value after calibration < 1.0% of measured value after 3 year Period: 1.0 s - 30 s
	Direction	Range: 0° - 360°, resolution: 0.1° Heading error: 0.4° - 2° (depending on latitude) typical 0.5° Period: 1.0 s - 30 s (free floating) 1.0 s – 20 s (moored) Reference: magnetic north
Other	Water temperature	Range: –10 °C - +50 °C, resolution: 0.01 °C Sensor accuracy: 0.1 °C Measurement accuracy: 0.2 °C
	Integrated data logger	Compact flash module 512Mb - 2048Mb
	LED Flashlight	Antenna with integrated LED flasher, colour yellow (590 nm), pattern 5 flashes every 20 s. Flashing or no-flashing is determined by means of the GPS position and time.
	GPS position	50 channel, fix every 2 min, precision <10 m
	Datawell HF link	Frequency range 25.5 - 35.5 MHz (35.5 - 45.0 MHz on request) Transmission range 50 Km over sea, user replaceable. For use with HVA compatible Datawell RX-C4 receiver.
General	Power consumption	DWR4 ACM 500 mW (DWR4 430 mW ACM 70 mW)
	Operational life with current meter	0.9 m diam.: > 1 year (typical 16 month)
Options	power switch solar panel plus boostcaps Argos data transmission	Data files are closed and secured peak power: 5 W capacity: 2WH spectral wave data and water velocity

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