The Pathway

A program for regulatory certainty for instream tidal energy projects

Presentation

Imaging sonar review for marine mammal and fish monitoring around tidal turbines

Principle Investigators
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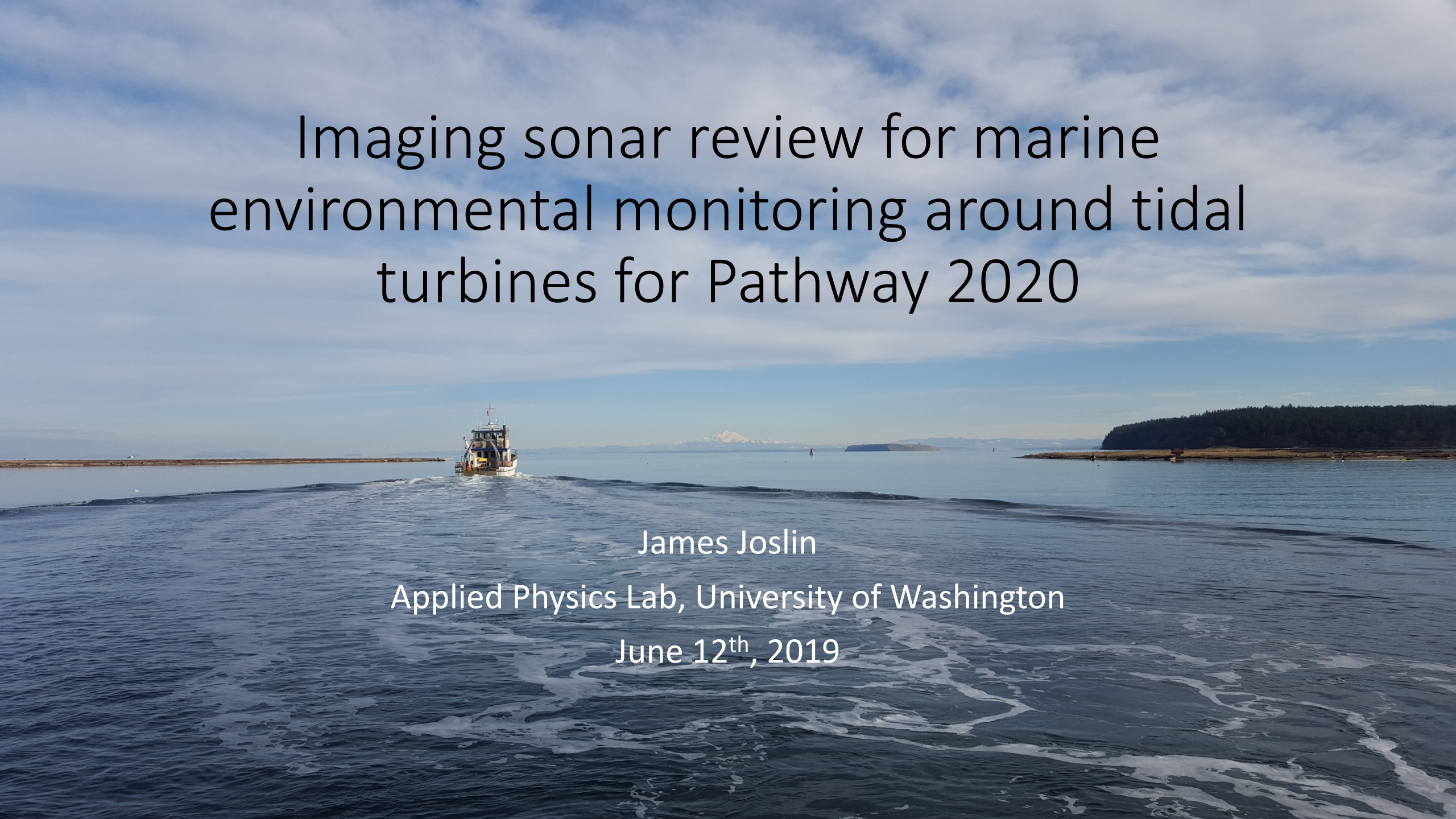
Monitoring for environmental interactions of tidal turbines presents many unique challenges and requires instrumentation that can withstand extreme environments. One of the best instruments for this task are acoustic imaging sonars which can provide high resolution imagery in turbid waters without the need for artificial illumination. This project presents a review of imaging sonars that are currently available to consumers along with recent examples of how they are used for marine mammal monitoring. Further discussion will include considerations for data collection and processing to enable long term monitoring of tidal turbines.

This project is part of "The Pathway Program" – a joint initiative between the Offshore Energy Research Association of Nova Scotia (OERA) and the Fundy Ocean Research Center for Energy (FORCE) to establish a suite of environmental monitoring technologies that provide regulatory certainty for tidal energy development in Nova Scotia.

Imaging sonar review for marine environmental monitoring around tidal turbines for Pathway 2020



James Joslin

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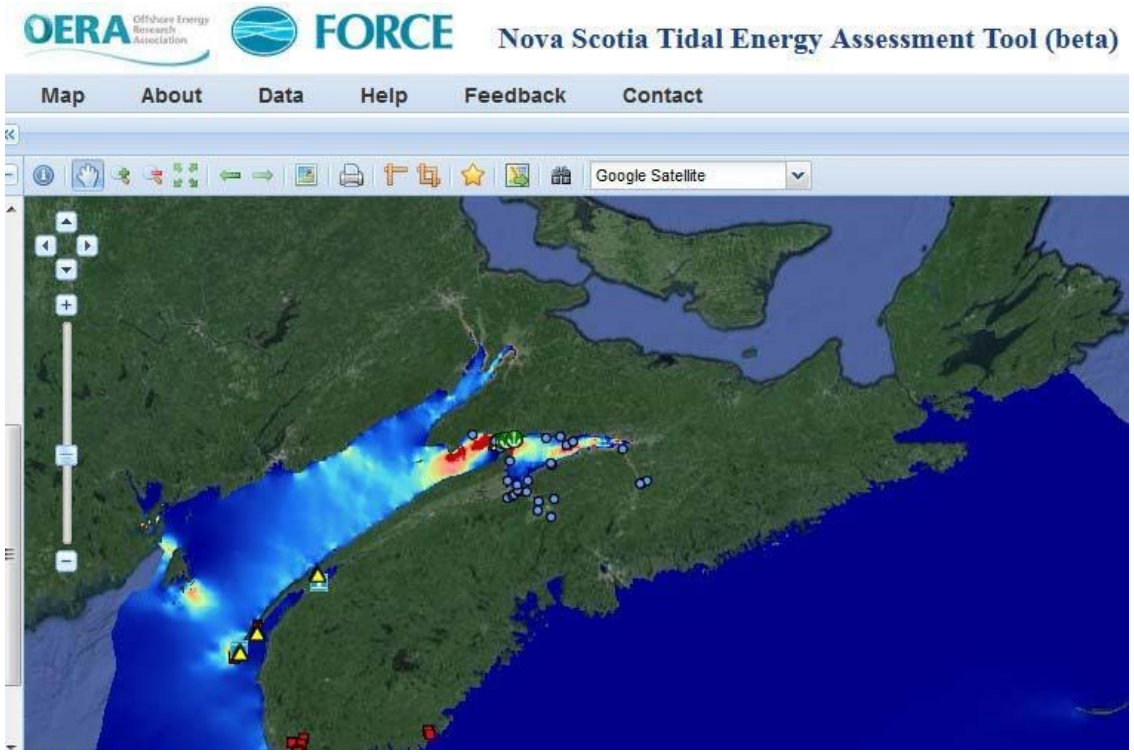
June 12th, 2019

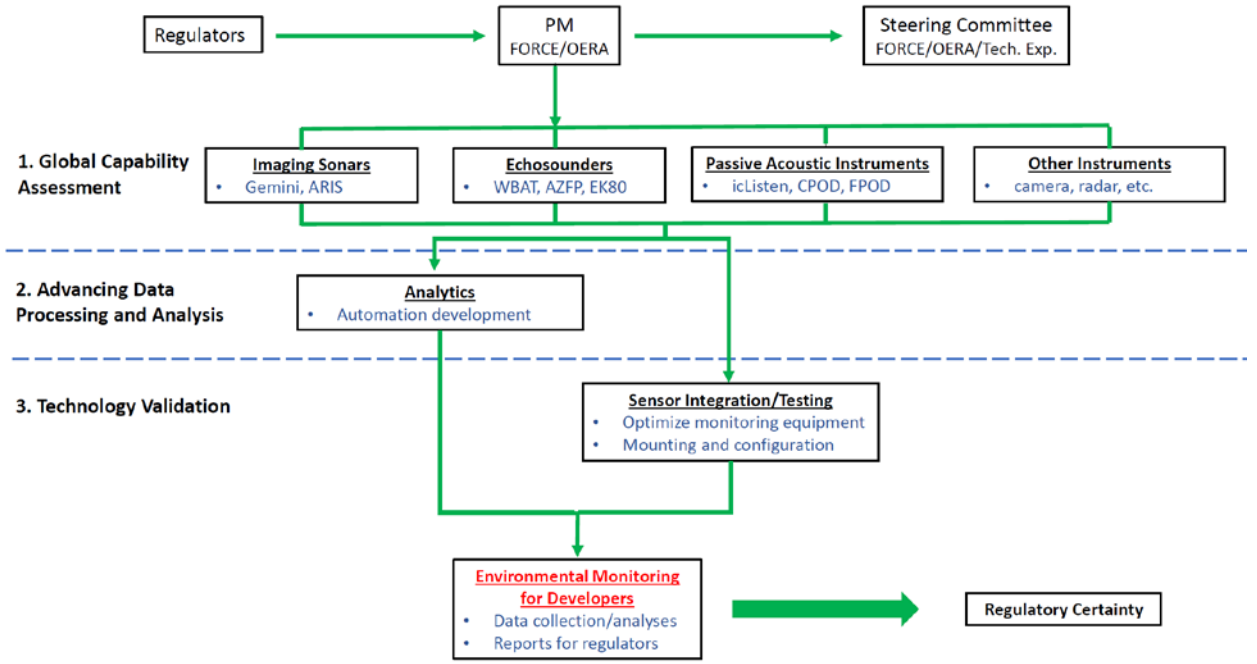
Overview

- Motivation
- Literature Review Summary
- Imaging Sonars
- Applications
- Key Considerations
- Common Issues
- Summary and Recommendations
- Acknowledgements



Motivation – Pathway 2020

- To develop an integrated, robust and cabled multi-instrument subsea platform to monitor interactions between tidal turbines and marine life in Minas Passage by December 2020.
- Phase 1 – Comprehensive literature review and current status survey of imaging sonars.
- Imaging sonars can provide high resolution imagery in turbid waters with ranges >100 m without artificial illumination.



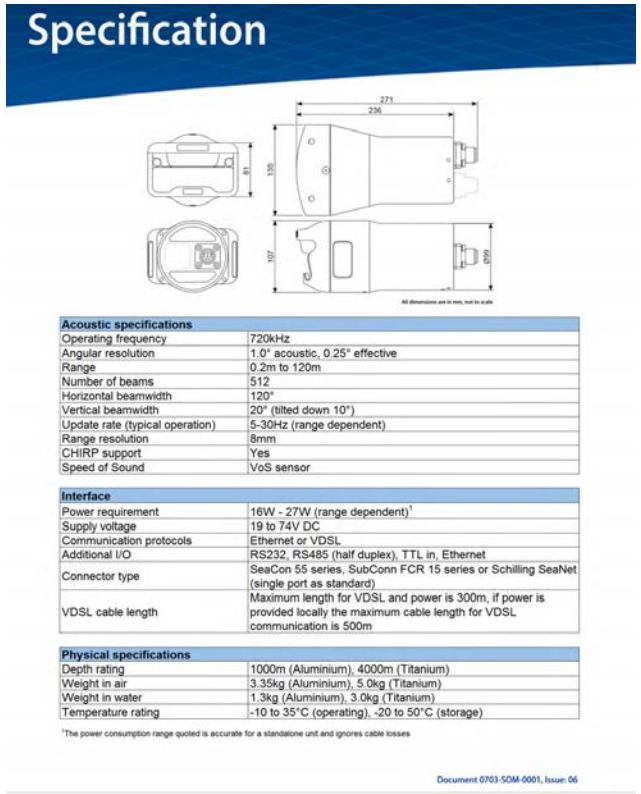
Literature Review Summary

- 20+ papers and reports on relevant uses of imaging sonars for marine life monitoring in high float environments.
- Deployment methods:
  - Vessel based surveys or short term testing monitoring
  - Bottom lander in close proximity to tidal turbines
  - Integrated with turbine platform
- Applications: 6 specific application presented here in more detail
  - Marine mammal monitoring: harbor seals, grey seals, porpoises
  - Fish monitoring
- Challenges:
  - Data management and processing delays
  - Biologic vs. non-biologic target detection and tracking
  - Instrument durability for long term deployments

Imaging Sonars - General Specifications

Operating manuals for each sonar contain the following specifications:

- Operating Frequency: >260 kHz to 3 MHz
- Swath/Field of view angles
- Range: 5 to 200 m
- Resolution
- I/O trigger option
- Connector type
- Power requirements
- Housing material
- Software and SDK
- Typical applications



Specification

Acoustic specifications	
Operating frequency	720kHz
Angular resolution	1.0° acoustic, 0.25° effective
Range	0.2m to 120m
Number of beams	512
Horizontal beamwidth	120°
Vertical beamwidth	20° (tilted down 10°)
Update rate (typical operation)	5-30Hz (range dependent)
Range resolution	8mm
CHIRP support	Yes
Speed of Sound	VoS sensor

Interface	
Power requirement	16W - 27W (range dependent)[1]
Supply voltage	19 to 74V DC
Communication protocols	Ethernet or VDSL
Additional I/O	RS232, RS485 (half duplex), TTL in, Ethernet
Connector type	SeaCon 55 series, SubConn FCR 15 series or Schilling SeaNet (single port as standard)
VDSL cable length	Maximum length for VDSL and power is 300m, if power is provided locally the maximum cable length for VDSL communication is 500m

Physical specifications	
Depth rating	1000m (Aluminium), 4000m (Titanium)
Weight in air	3.35kg (Aluminium), 5.0kg (Titanium)
Weight in water	1.3kg (Aluminium), 3.0kg (Titanium)
Temperature rating	-10 to 35°C (operating), -20 to 50°C (storage)

[1]The power consumption range quoted is accurate for a standalone unit and ignores cable losses

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Example Spec Sheet for Tritech Gemini

Imaging Sonars – Assessment Table

Technology Assesment Rubric

Instrument / Sensor Category: Imaging Sonars

No.	Instrument/ Sensor Type	Commercially Available (Can) or R&D?		Instrument Name/ Part Number	Manufacturer(s)/ Vendor(s)	Operational Frequency	Description and Target Use	Target or Typical Use	Other Use(s)?	Capabilities & Limitations	Anticipated Range	Sector(s) Use	Experience/ Robustness in High Flows			Experience with High Flows	Software Considerations		Swath/Field of View Angles	Housing Material	Depth Rating	Power Requirements	Connector Type	Supplemental / Other Details	References/ Web Links
		CA	R&D?										0-3 m/sec	3-5 m/ sec	5+ m/sec		Required or Additional Software	Data Processing & Analysis Considerations						
1	Multibeam Sonar	Yes		M900/2250 Dual Frequency	Teledyne BlueView	900 and 2250 kHz	Good for both near and far ranges	UUV surveys, navigation, obstacle avoidance, operations monitoring	Situational awareness, close range identification, touch down monitoring, diver/swimmer detection and tracking	Input trigger line available	10 m(2250 Head),100 m (900 Head)	Broad, DoD, Industry, Research	Yes, used on the AMP	Yes, on vessels	unknown	Unknown	ProViewer or SDK	Background subtraction and target detection requires custom software	130 deg x 20 deg	Anodized Aluminum	1000 m	20 to 25 w at 12 to 48 vdc	MKS, Burton, Schilling SeaNet	Some noise issues with other instruments, some grounding issues.	http://www.teledynemarine.com/M900-2250%20Dual%20Frequency%20Series
2	Multibeam Sonar	Yes		M900-130	Teledyne BlueView	900 kHz	Good for long ranges	UUV surveys, navigation, obstacle avoidance, operations monitoring	Situational awareness, close range identification, touch down monitoring, diver/swimmer detection and tracking	Input trigger line available	up to 100 m	Broad, DoD, Industry, Research	unknown	unknown	unknown	Unknown	ProViewer or SDK	Background subtraction and target detection requires custom software	130 deg x 20 deg	Anodized Aluminum	1000 m	20 to 25 w at 12 to 48 vdc	MKS, Burton, Schilling SeaNet	Some noise issues with other instruments, some grounding issues.	http://www.teledynemarine.com/blueview-m900-series5?BrandID=3
3	Multibeam Sonar	Yes		Gemini 720is	Tritech	720 kHz	Ideal for poor visibility, deep, or long term deployments	ROV/AUV Navigation, Obstacle avoidance	Diver operations, target recognition, subsea monitoring and inspection	Input trigger line available	up to 120 m	Broad, DoD, Industry, Research	Yes, used on the AMP	Yes	Yes	Used on Open Hydro turbines at Force	Seanet Pro or SDK	Software has built in target detection algorithms	120 deg x 20 deg (tilted down 10)	Anodized Aluminum or Titanium	1000 or 4000	16 to 27 w at 19 to 74 vdc	SeaCon 55, SubConn FCR 15, or Schilling SeaNet		https://www.tritech.co.uk/product/gemini-720is-1000m-or-4000m, https://www.tritech.co.uk/media/products/gemini-720is-datasheet.pdf?id=e365949f
4	Multibeam Sonar	Yes		Gemini 720ik	Tritech	720 kHz	Ideal for small ROVs and shallow water operations, lower cost than the 720is	ROV/AUV Navigation, Obstacle avoidance	Diver operations, target recognition, subsea monitoring and inspection	Input trigger line available	up to 120 m	Coastal, DoD, Industry, Research	unknown	unknown	unknown	Unknown	Seanet Pro or SDK	Software has built in target detection algorithms	120 deg x 20 deg (tilted down 10)	Anodized Aluminum	350 m	16 to 27 w at 19 to 74 vdc	Impulse MKS-307-FCR		https://www.tritech.co.uk/media/products/Gemini-720ik-datasheet.pdf?id=127b74d8
5	Multibeam Sonar	Yes		Gemini 720im	Tritech	720 kHz	Worlds smallest multibeam sonar	Micro ROV/AUV Navigation, Obstacle avoidance	Diver operations, aquaculture monitoring, vessel/pole mount target search	Input trigger line available	up to 50 m	Coastal, DoD, Industry, Research	unknown	unknown	unknown	Unknown	Seanet Pro or SDK	Software has built in target detection algorithms	90 deg x 20 deg	Anodized Aluminum	350 m or 750 m	4.5 to 17 w at 12 to 48 vdc	Seacon HUML-12, Impluse MKS-3L10 and Tritech Micron		https://www.tritech.co.uk/media/products/Gemini%20720im.pdf?id=d2c70f48
6	Multibeam Echosounder	Yes		M3 Sonar	Kongsberg Mesotech	500 kHz	Both imaging and profiling capatilities	Marine engineering, shallow water bathymetry surveying, environmental monitoring	Site inspection, site clearance, defense and security	Input/output trigger line available	up to 150 m	Broad, DoD, Industry, Research	Yes, used on the AMP	Yes, on vessels	unknown	Unknown	M3 Software		120 deg x 3, 7, 15, or 30	Anodized Aluminum or Titanium	1000 or 4000	22 w at 12 to 36 VDC	MINK-10-FCRL		https://www.kongsberg.com/maritime/products/mapping-systems/multibeam-echo-sounders/m3-sonar-multibeam-echosounder/
7	Multibeam Sonar	Yes		Oculus M370s	Blueprint Subsea	375 kHz	Small and light weight, good for micro sized platforms	Long range navigation and situational awareness		Input/output trigger line available	up to 200 m	Broad, DoD, Industry, Research	unknown	unknown	unknown	Unknown	Oculus ViewPoint Software		130 deg x 20 deg	Anodized Aluminum or Titanium	300 m	10 to 35 w at 18 to 32 VDC	Teledyne Impulse IE55		https://www.blueprintsubsea.com/pages/product.php?PN=BP01041
8	Multibeam Sonar	Yes		Oculus M750d	Blueprint Subsea	750 and 1200 kHz	Small and light weight, good for micro sized platforms	ideal for navigation and high resolution imagery for near field target identification		Input/output trigger line available	up to 120 m (LF) or up to 40 (HF)	Broad, DoD, Industry, Research	unknown	unknown	unknown	Unknown	Oculus ViewPoint Software		130 deg x 20 deg (LF) or 70 x 12 (HF)	Anodized Aluminum or Titanium	300 m	10 to 35 w at 18 to 32 VDC	Teledyne Impulse IE55		https://www.blueprintsubsea.com/pages/product.php?PN=BP01032
9	Multibeam Sonar	Yes		Oculus M1200d	Blueprint Subsea	1200 and 2100 kHz	Small and light weight, good for micro sized platforms	Ideal for specialized inspection tasks where image quality is critical		Input/output trigger line available	up to 30 m (LF) or up to 10 (HF)	Broad, DoD, Industry, Research	unknown	unknown	unknown	Unknown	Oculus ViewPoint Software		130 deg x 20 deg (LF) or 60 x 12 (HF)	Anodized Aluminum or Titanium	300 m	10 to 35 w at 18 to 32 VDC	Teledyne Impulse IE55		https://www.blueprintsubsea.com/pages/product.php?PN=BP01042
10	Multibeam Sonar	Yes		837A Delta T	Imagenex	260 KHz		ROV/AUV, Offshore oil and gas, Sunken Timber Recovery, Diving Support	Surveying, search and recovery, inspection, underwater archaeology, scientific research, harbour surveillance	NO trigger capability, much more expensive than other options	up to 150 m	Broad, DoD, Industry, Research	unknown	unknown	unknown	Unknown	DeltaT.exe	Built in GPS track plotter	120 deg x 10 deg	Titanium	6000 m	5 w at 22 - 36 VDC	Subconn MCBH8M-Ti		https://imagenex.com/products/837a-delta-t-6000-m-120-x-10
11	Multibeam Sonar	Yes		Aris Explorer 1200	Sound Metrics Didson	1200 and 700 kHz		Fisheries Management, Target Detection, Search and Recovery, Environmental Monitoring	Construction monitoring, equipment and tool placement, hull and berth inspection, port and harbor security, search and recovery, fisheries management	NO trigger capability, much more expensive than other options	up to 35 m (LF) and 80 m (HF)	Broad, DoD, Industry, Research	Yes	Yes	unknown	Used on OPRC Tidgen	windows based platform		28 deg x 14 deg		300 m	18 w typical at 48 VDC			http://www.soundmetrics.com/Products/ARIS-Sonars/ARIS-Explorer-1200/ARIS-1200-Brochure-English
12	Multibeam Sonar	Yes		Aris Explorer 1800	Sound Metrics Didson	1800 and 1100 kHz		Underwater inspection, Operations and diver monitoring, Environmental monitoring	Construction monitoring, equipment and tool placement, hull and berth inspection, port and harbor security, search and recovery, fisheries management	NO trigger capability, much more expensive than other options	up to 35 m (LF) and 15 m (HF)	Broad, DoD, Industry, Research	Yes	Yes	unknown	Used on OPRC Tidgen	windows based platform		28 deg x 14 deg		300 m	18 w typical at 48 VDC			http://www.soundmetrics.com/Products/ARIS-Sonars/ARIS-Explorer-1800/ARIS-1800-Brochure-English
								Underwater inspection,		NO trigger														

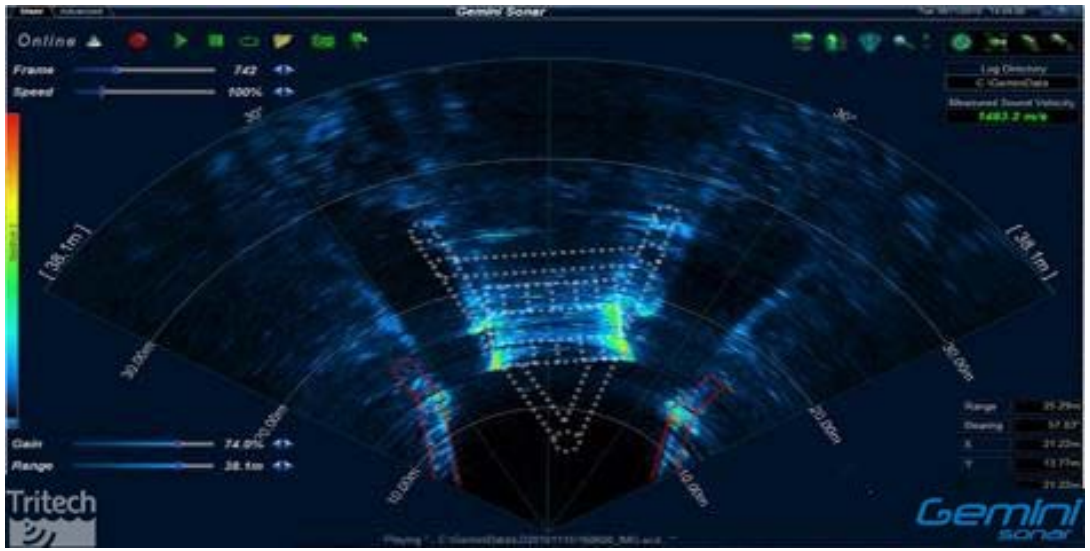
Imaging Sonars – Summary Table

Sonar	Frequency	FOV	Range	Trigger	SDK?	Applications
Tritech Gemini	720 kHz	120 x 20 deg	<120 m	Yes	Yes	SeaGen, AMP
Teledyne Blueview	900/2250 kHz	130 x 20 deg	<100 / <10 m	Yes	Yes	AMP, vessel surveys
Kongsberg Mesotech	500 kHz	120 x 3, 7, 15, or 30 deg	<150 m	Yes	No	AMP, vessel surveys
Blueprint Subsea Oculus	375 or 750/1200 or 1200/2100 kHz	130 x 20 deg or 70 x 12 deg or 60 x 12 deg	<200 or <120 / <40 or <30 / <10 m	Yes	Yes	Other, vessel surveys
Imagenex Delta T	260 kHz	120 x 10 deg	<150 m	Yes	Yes	FLOWBEC
Sound Metrics Aris	1200/700 or 1800/1100 or 3000/1800 kHz	28 x 14 deg or 28 x 14 deg or 30 x 15 deg	<80 / <35 or <35 / <15 or <15 / <5 m	No	No	ORPC, Verdant RITE

Imaging Sonars - Tritech Gemini 720is

Sonar	Frequency	FOV	Range	Trigger	SDK?	Applications
Tritech Gemini	720 kHz	120 x 20 deg	<120 m	Yes	Yes	SeaGen, AMP

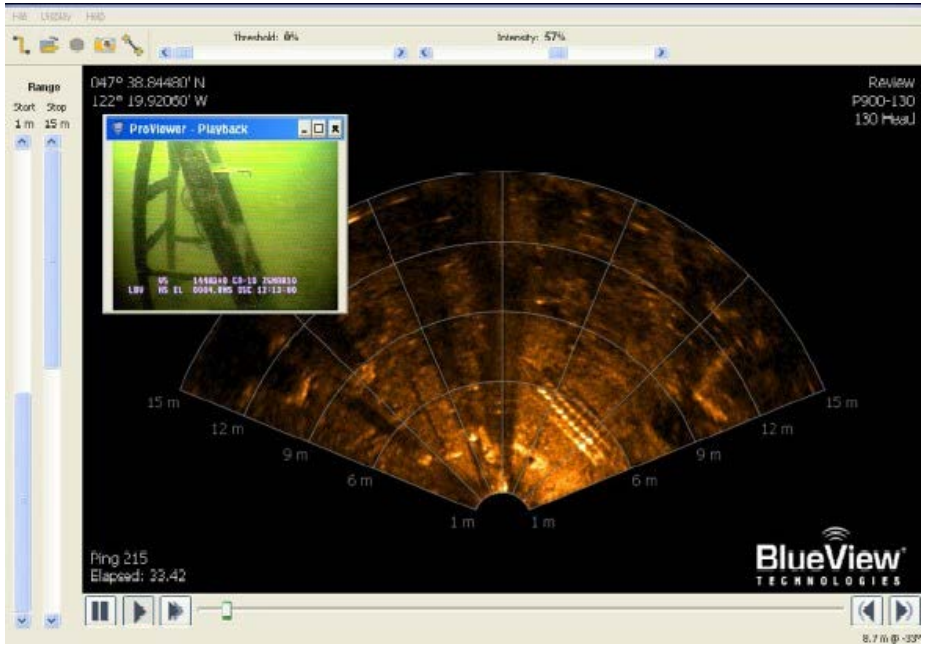
- Key features:
  - Most use cases across industry.
  - Adjustable range up to 120 m with high resolution and 120 x 20 deg swath
  - Good software control with built in target detection and optional SDK



Imaging Sonars - Teledyne BlueView M900/2250

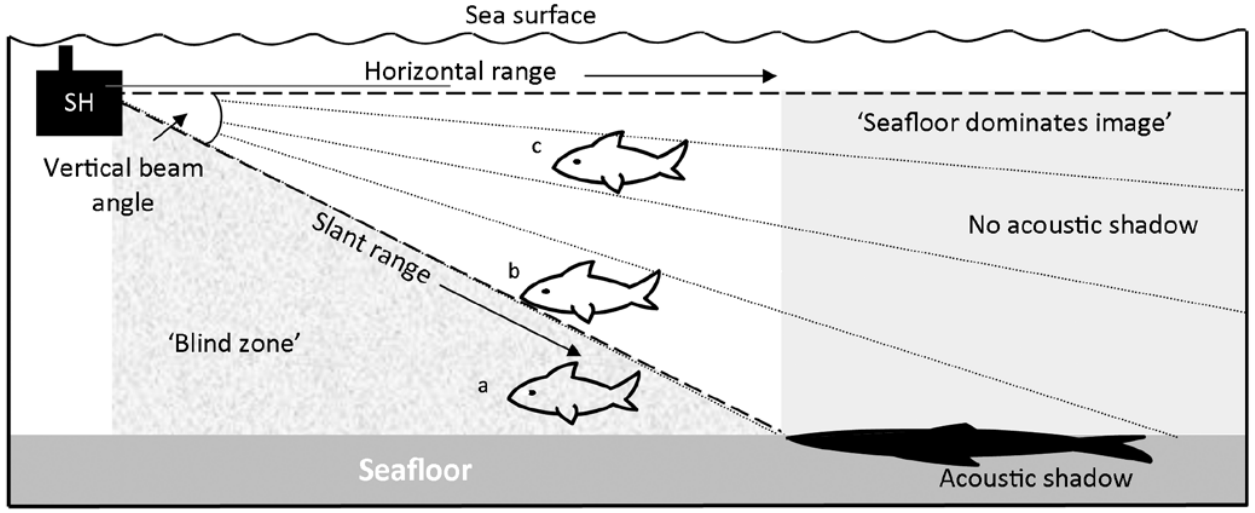
Sonar	Frequency	FOV	Range	Trigger	SDK?	Applications
Teledyne Blueview	900/2250 kHz	130 x 20 deg	<10 / <100 m	Yes	Yes	AMP, vessel surveys

- Key Features:
  - Dual frequency head provides options for monitoring range
  - Short range head has very high resolution good for target classification

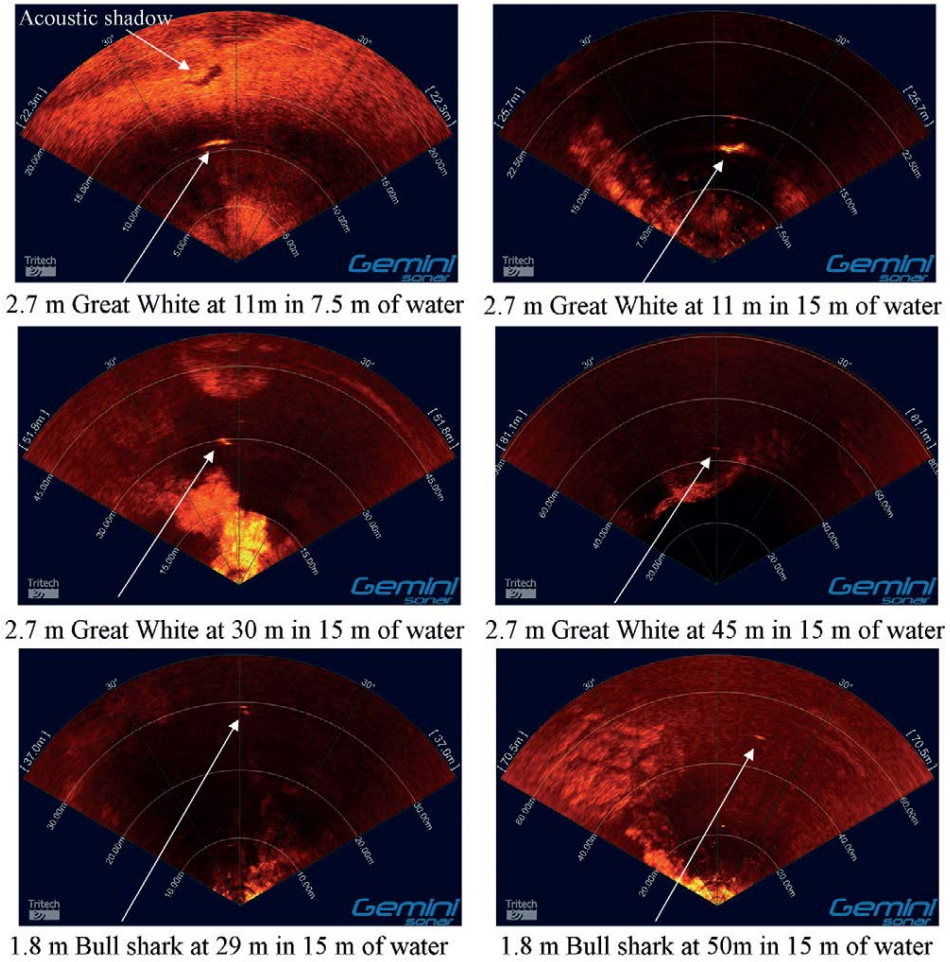


Applications – Vessel Surveys

- Parsons, Miles JG, et al. "Detection of sharks with the Gemini imaging sonar." Acoustics Australia 42.3 (2014): 185-190.
- Broad applications of vessel based multibeam surveys using many different sonars
- Generally short duration with continuous data collection and post processing
- Complicated by vessel motion and continuously changing background



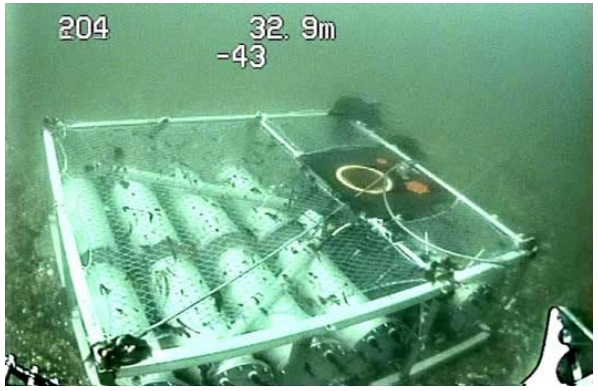
Example vessel based configuration



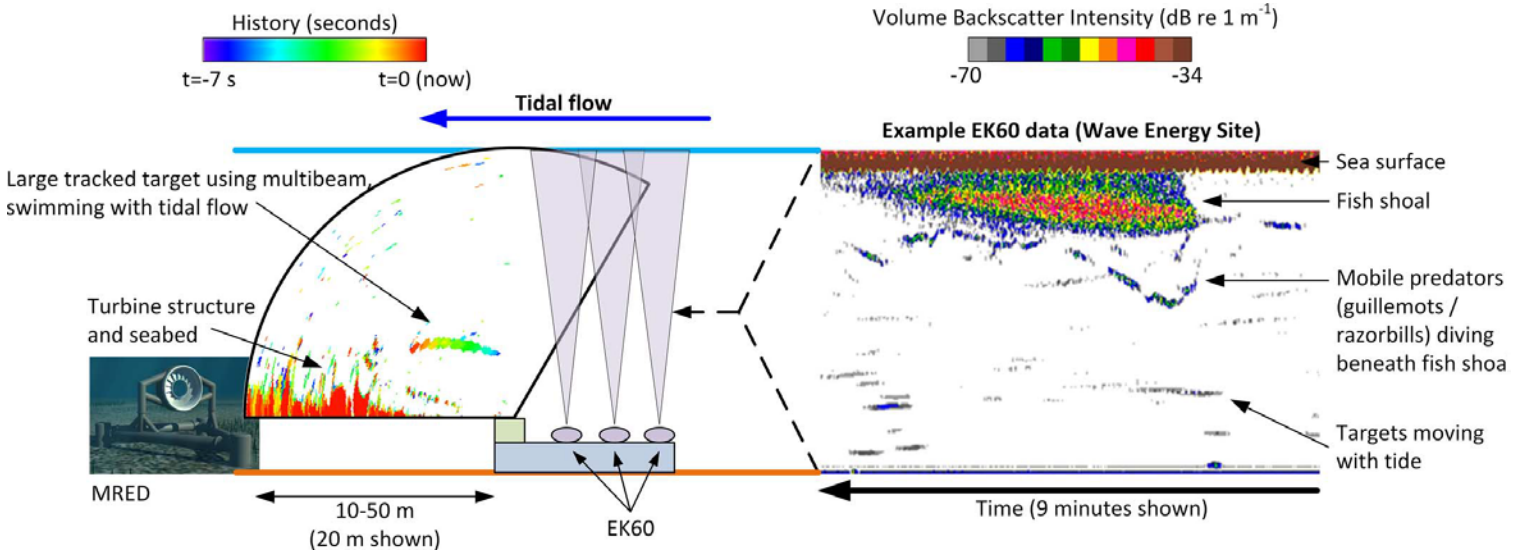
Example data from survey to track sharks in Australia

Applications – FLOWBEC-4D

- B. J. Williamson, S. Fraser, P. Blondel, P. S. Bell, J. J. Waggitt and B. E. Scott, "Multisensor Acoustic Tracking of Fish and Seabird Behavior Around Tidal Turbine Structures in Scotland," in *IEEE Journal of Oceanic Engineering*, vol. 42, no. 4, pp. 948-965, Oct. 2017. doi: 10.1109/JOE.2016.2637179
- Flow, Water column and Benthic Ecology 4-D (FLOWBEC-4D), developed in the UK for monitoring at wave and tidal energy sites.
- Integrates Imaginex Delta T multibeam sonar with EK60 echosounder, an ADV, and fluorometer.
- Battery powered for 2 week deployments with continuous data collection and post processing



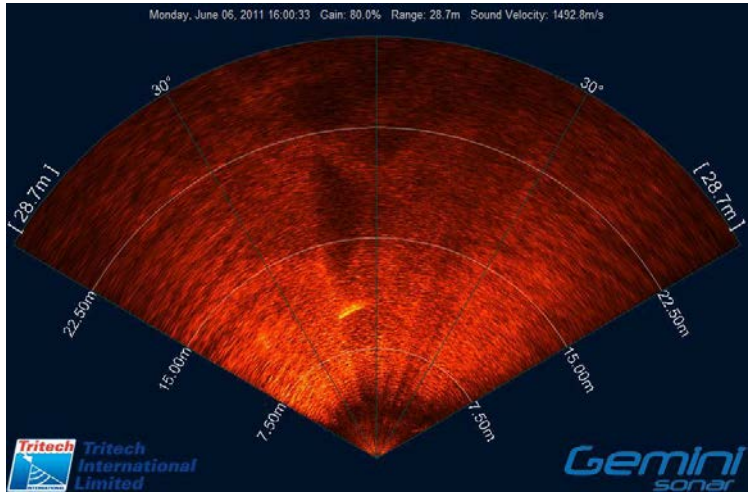
FLOWBEC platform during deployment



Example data from deployment

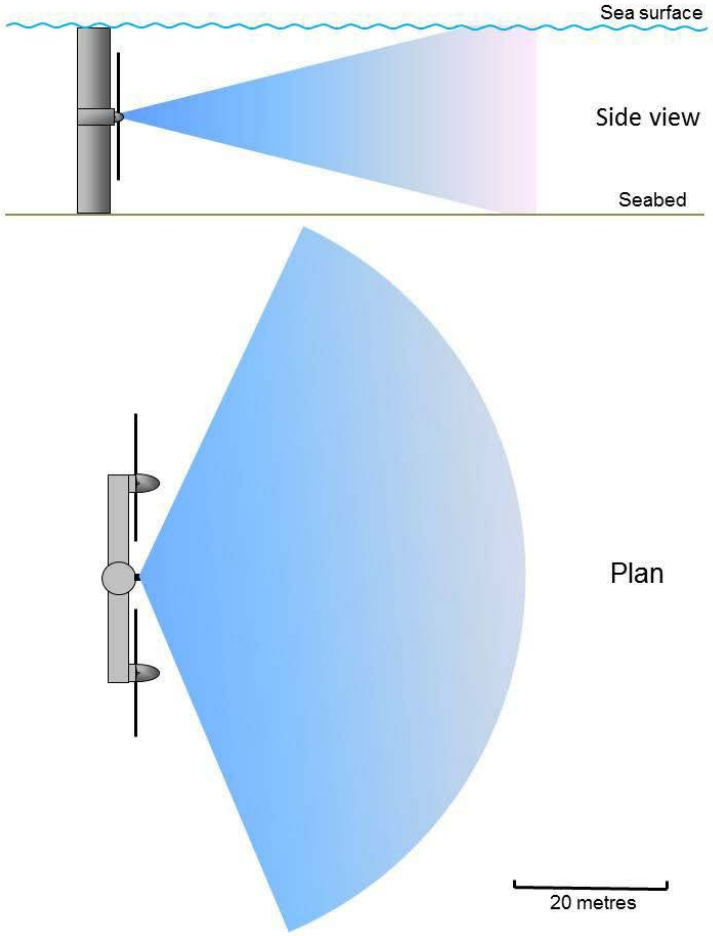
Applications – SeaGen, Strangford Lough

- Hastie, G. (2013). Tracking Marine Mammals Around Marine Renewable Energy Devices Using Active Sonar. Report by SMRU Consulting.
- Tritech Gemini integrated with turbine platform for harbor seal and porpoise monitoring.
- One of the longest term marine mammal monitoring demonstrations.
- Helped to develop native target detection and tracking software.
- Good review of sound levels produced by active acoustics and animal response to that sound.



Example image of a seal at 10 m

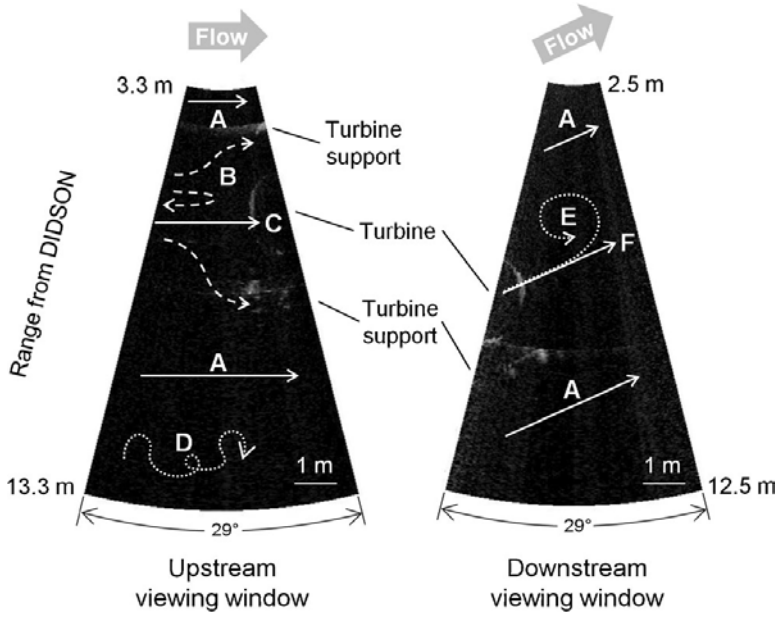
SeaGen Turbines in Strangford Lough



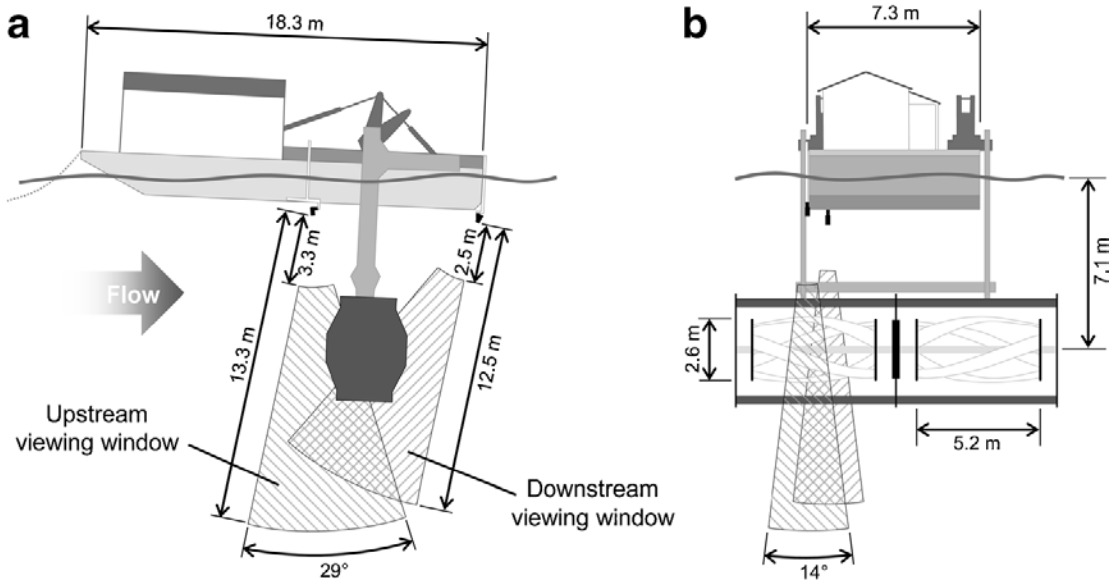
Gemini configuration on SeaGen turbine

Applications – ORPC, Cobscook Bay

- Viehman, H. a., & Zydlewski, G. B. (2014). Fish Interactions with a commercial-scale tidal energy device in the natural environment. *Estuaries and Coasts*, *38*(Suppl 1), S241–S252. http://doi.org/10.1007/s12237-014-9767-8
- Fish monitoring with 2 DIDSONs from vessel based turbine test platform.
- High resolution sonars able to track individual fish through cross flow turbine.
- Short term data collection with post processing.



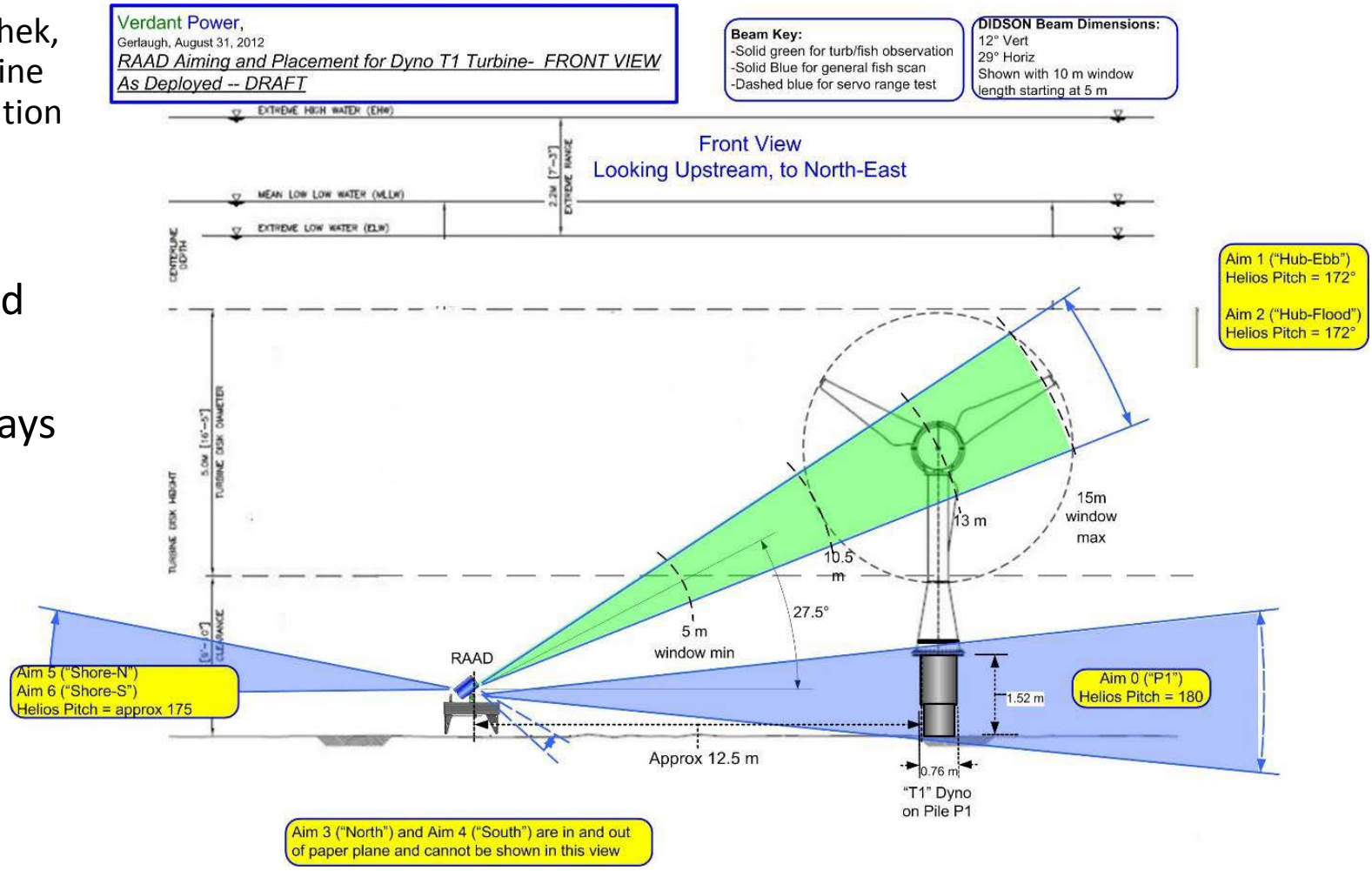
Example of annotated data



Sonar configurations on test platform

Applications – Verdant, RITE Project

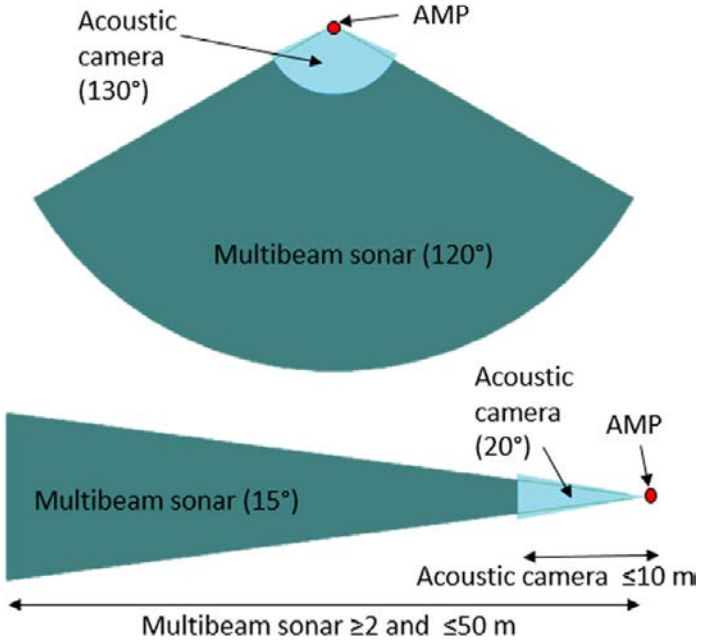
- Bevelhimer, M.; Colby, J.; Adonizio, M.; Tomichek, C.; Scherelis, C. (2016). Informing a Tidal Turbine Strike Probability Model through Characterization of Fish Behavioral Response using Multibeam Sonar Output. Report by Oak Ridge National Laboratory (ORNL).
- Fish tracking with a DIDSON mounted on a pan and tilt platform.
- Collected data continuously for 19 days with post processing.
- Evaluated fish behavior relative to turbine to look for avoidance.



Deployment configuration for RITE project

Applications – AMP, Sequim Bay

- Integrated instrumentation platform with Gemini, BlueView, WBTmini echosounder, stereo-optical cameras with illumination and wipers, ADCP, Vemco fishtag receiver, 4x icListen hydrophones, ecoBB water clarity sensor, and tilt motor for instrument head.
- Versions of the AMP have been tested in cabled and autonomous configurations on both bottom landers and surface buoys.
- Much more information available…

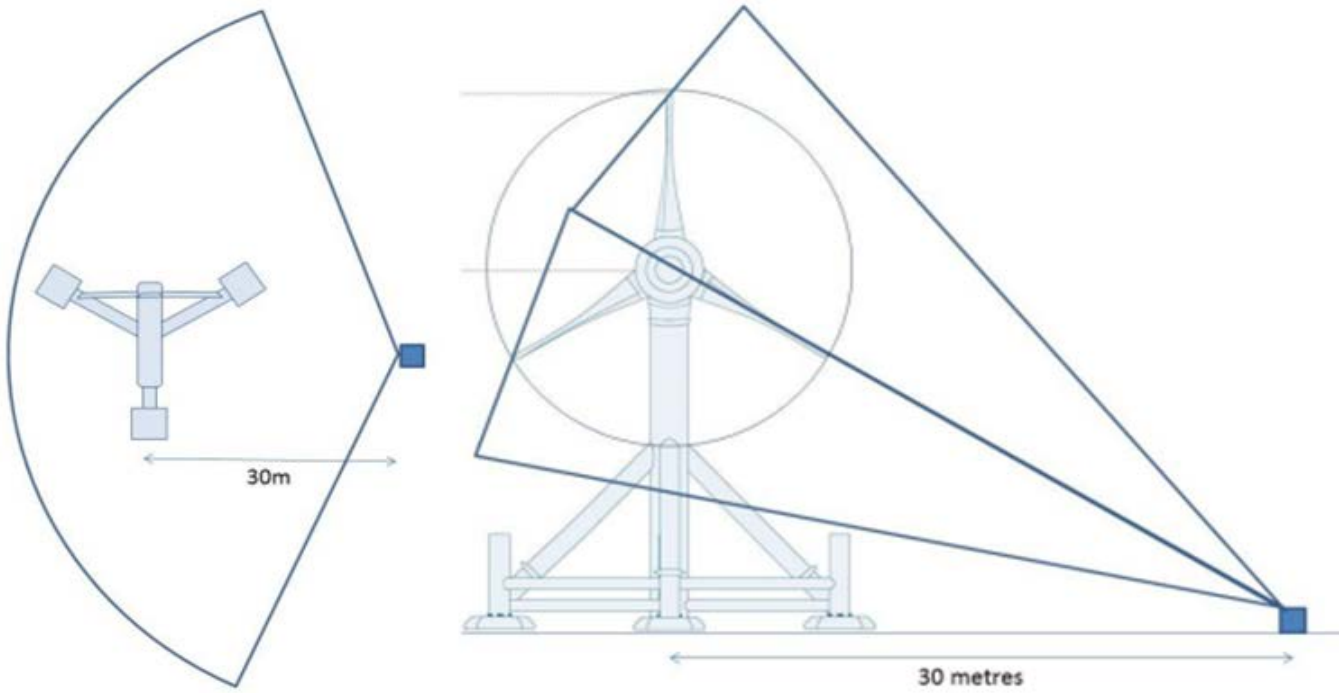


Sonar configuration on AMP

3G-AMP prior to deployment in Sequim

Key Considerations - Mounting and orientation

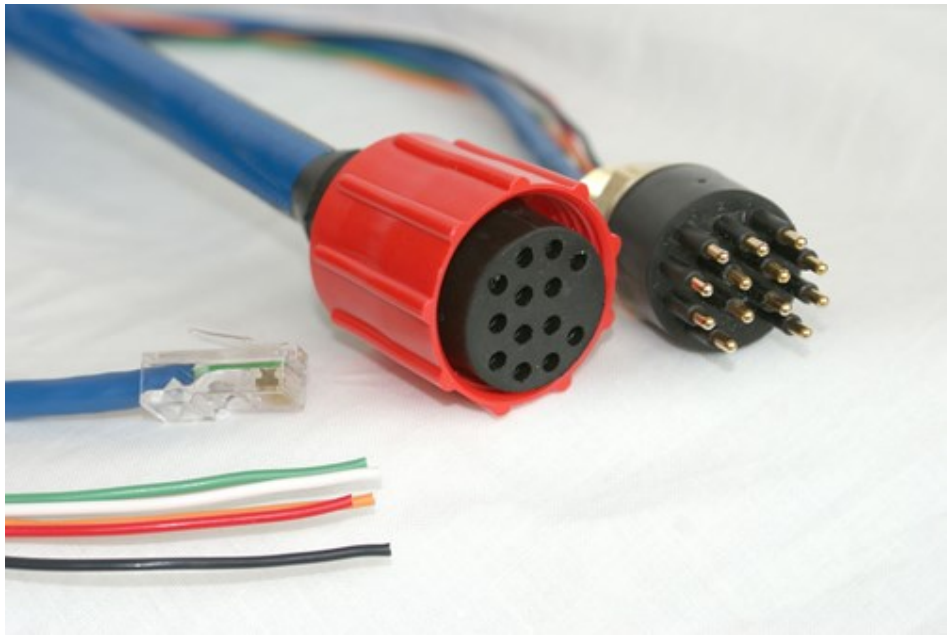
- For a bottom mounted lander deployment both horizontal and vertical orientations have been shown to be effective.
- Key Variables:
  - Turbine range
  - Deployment orientation control
  - Water depth
  - Sonar angle
- Pan/tilt mount option
- U-bolt of clamp mount options



Example of sonar orientation relative to turbines for Pentland Firth Meygen Project

Key Considerations - Electrical and communications connections

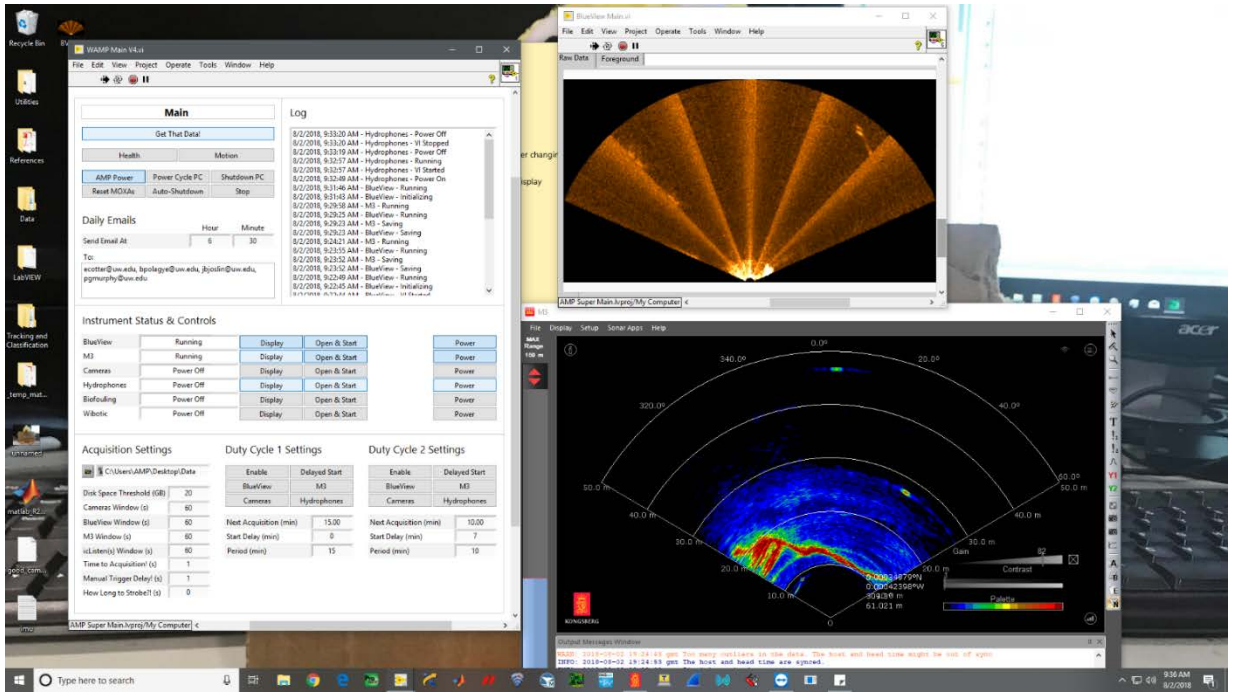
- Sonars use a variety of electrical connectors but they will all need DC power, I/O lines, and Ethernet comms
- Some require a secondary connector for trigger I/O, this can be “wyed” into a single connector for a control bottle
- Electrical isolation for ground faults



Subconn 13 pin power and Ethernet connector

Key Considerations - Software for instrument control and data acquisition

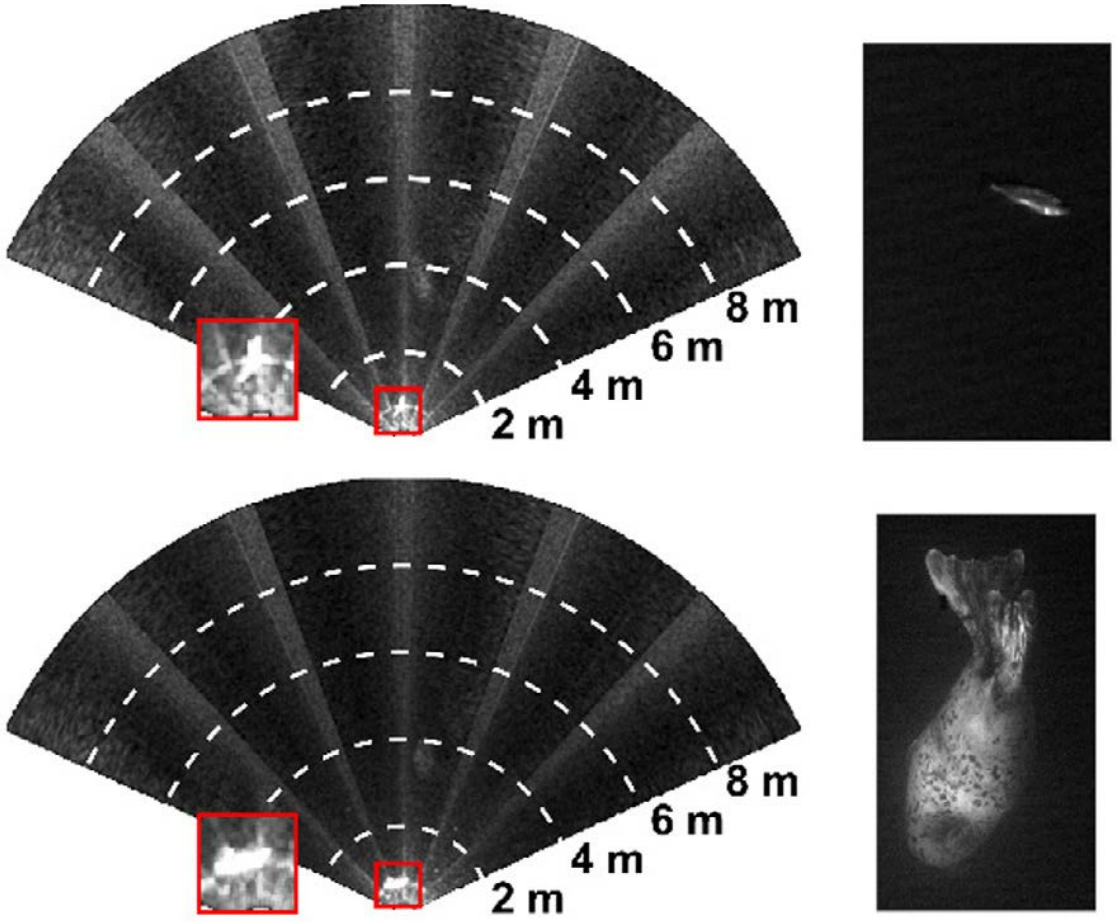
- Every sonar developer has their own software, but not all play well with others.
- Integration requires custom software to synchronization control.
- Custom software is easier to develop with an SDK supported by instrument developer.



Examples of sonar VIs developed in LabView for the AMP

Key Considerations - Software for data processing

- Development and testing of autonomous data processing algorithms is an active area of research.
- While some lessons can be taken from other deployments, every new deployment will require tuning of detection algorithms.
- Develop data collection objectives early and process data continuously throughout deployment to allow for algorithm optimization.



Examples of AMP data of seal and fish detection and classification with optical cameras

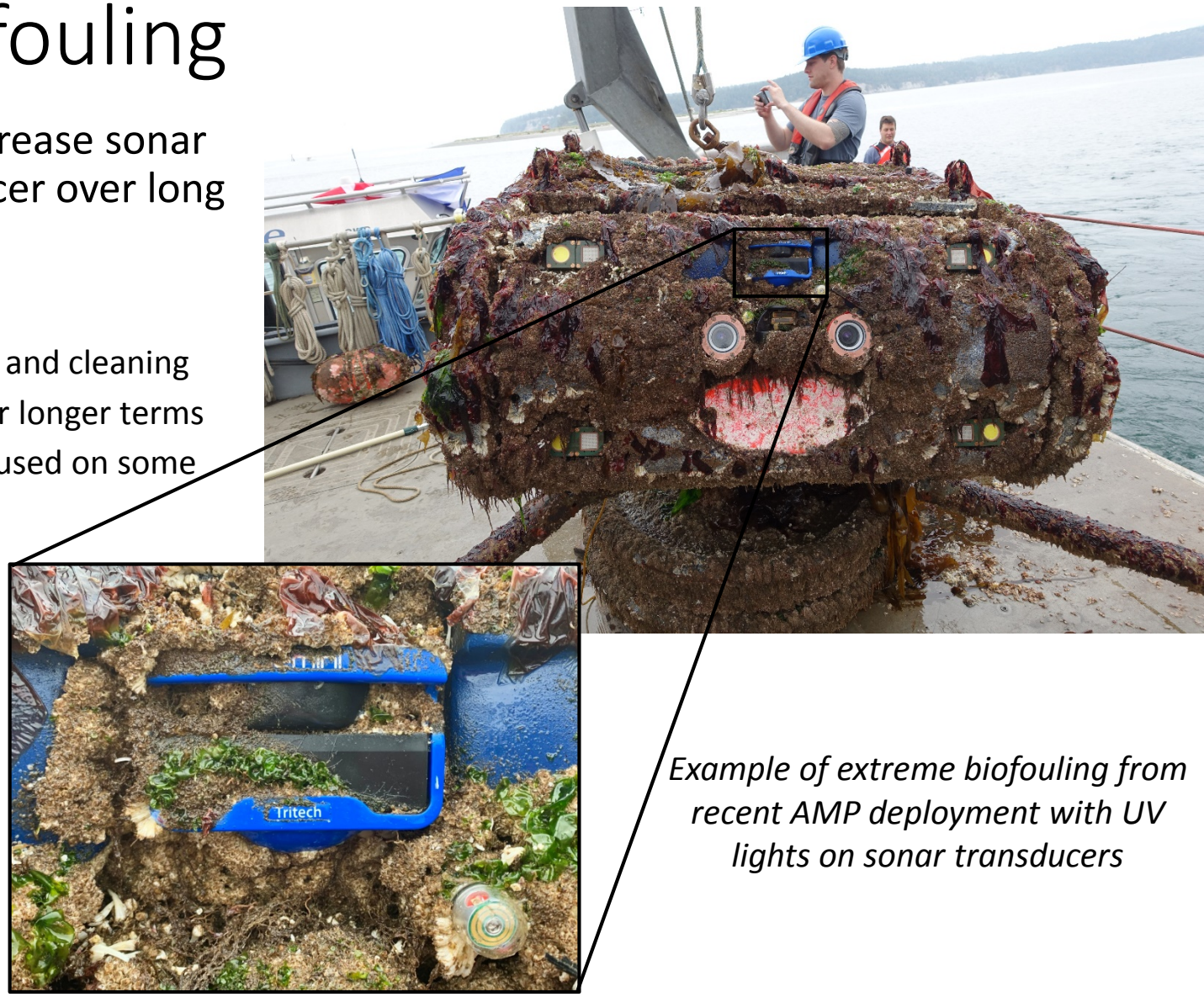
Common Issues – Corrosion

- Durability of instrumentation is often complicated by corrosion.
- Many sonars have housings, connectors, and locking sleeves with dissimilar metals.
- Solution:
  - Ensure there is no dissimilar metal contact or, if this is not possible, add a sacrificial anode.
  - Test for and eliminate ground faults during pre-deployment testing.

Examples of corrosion on anodized aluminum housing and connectors with dissimilar metals

Common Issues – Biofouling

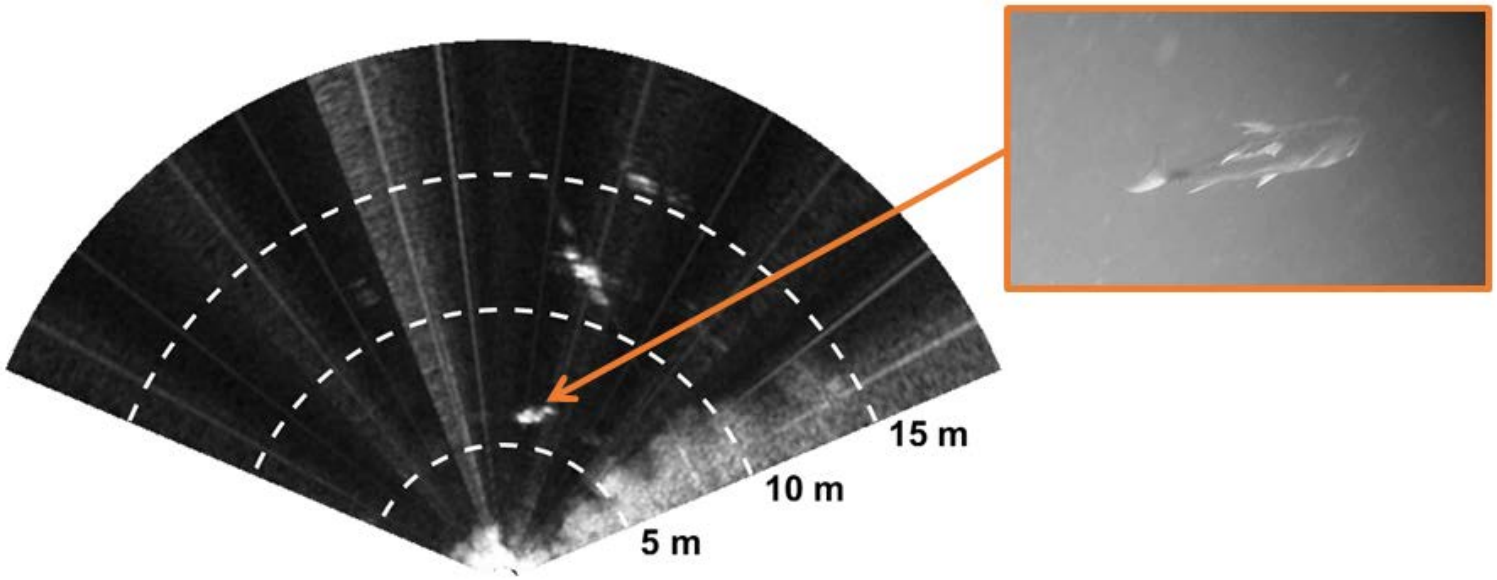
- While biofouling does not inherently decrease sonar performance, it will damage the transducer over long deployments.
- Solutions:
  - Limiting deployment lengths for maintenance and cleaning
  - UV lights are a good option for mitigation over longer terms
  - Antifouling paint and zinc-oxide paste can be used on some transducers



Example of extreme biofouling from recent AMP deployment with UV lights on sonar transducers

Common Issues – Electrical interference

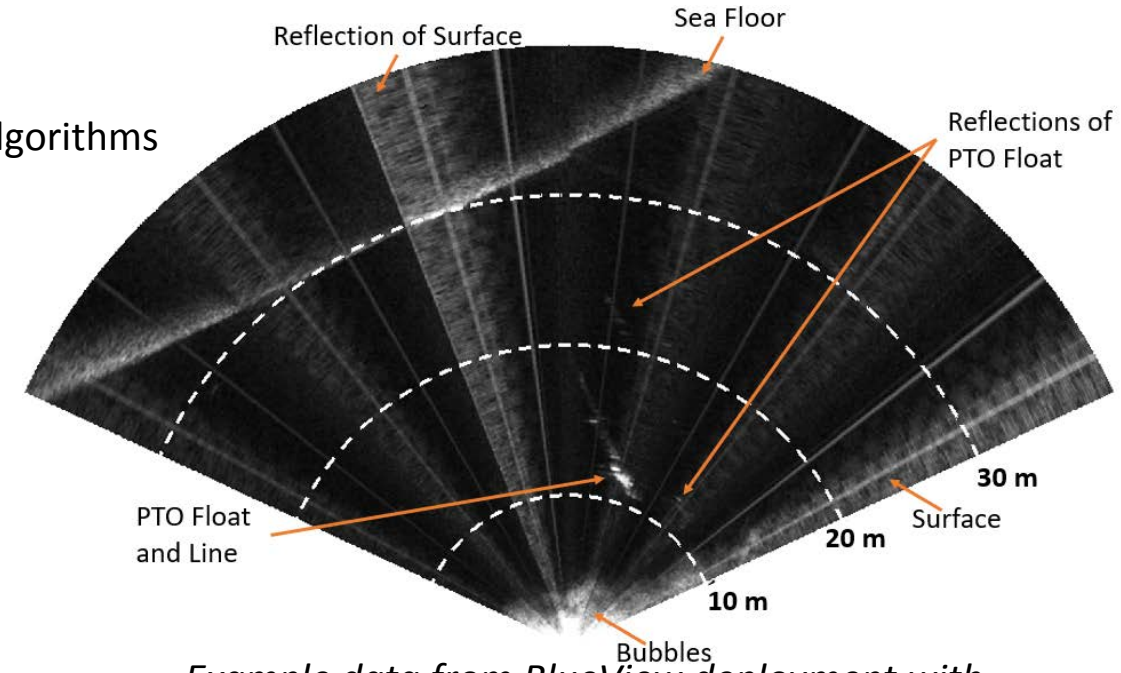
- Electrical noise on integrated instrumentation platforms can cause noise in sonar data.
- Often due to DC/DC converters.
- Solution: Power and comms channels should have electrical filtering and isolation.



Example data from BlueView deployment where thin radial lines appear when strobe lights fire

Common Issues – Noisy images

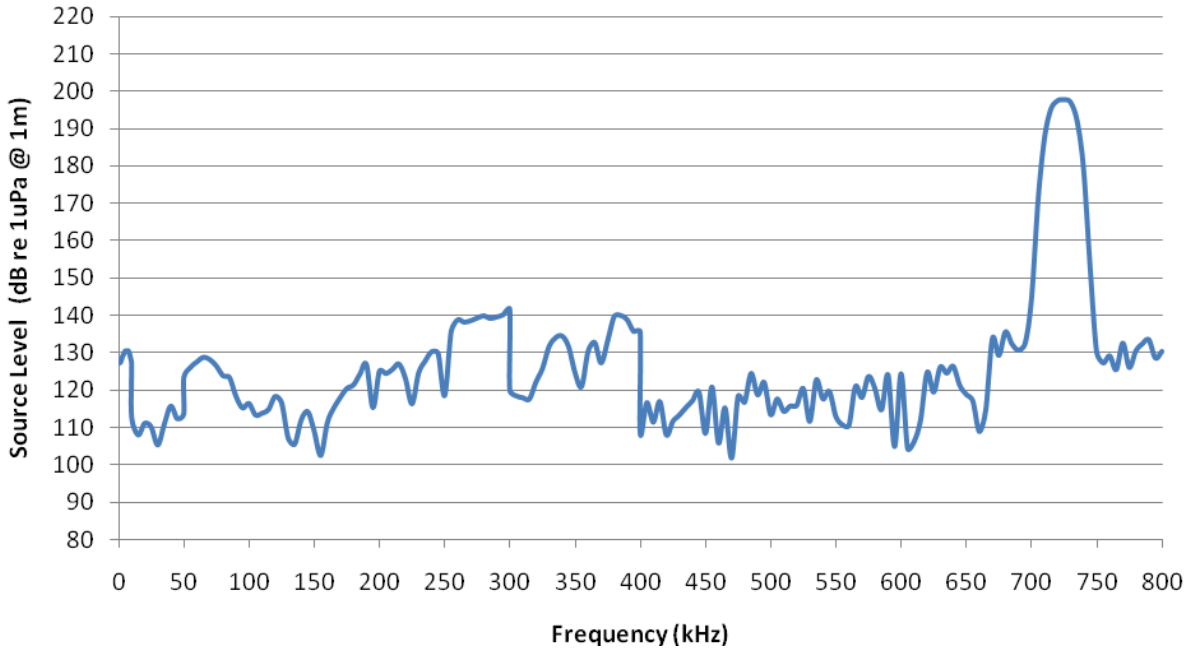
- Many common issues with sonar data processing that include:
  - Persistent moving targets in the field of view
  - Boat or turbine wakes entraining bubbles
  - Turbulence entrained bubbles
  - Non biologic drifters in the water column
- Solution:
  - This is currently an active research problem
  - More development is needed for common data processing algorithms



Example data from BlueView deployment with multiple targets creating non-biologic triggers

Common Issues – Sound levels

- Imaging sonars operate by generating sound pulses that are generally considered to be above marine animal hearing. However, they do generate some noise at lower frequencies.
- More information is needed to understand animal response to this sound.



Source level of Tritech Gemini from G. Hastie Report

Summary and Recommendation

- Best in class recommendations are the Tritech Gemini 720is and the Teledyne BlueView M900/2250 depending on range requirements
- Software integration and data processing options should drive selection process
- Mounting and deployment orientations will have a large impact on data quality
- Considerations for electrical isolation, corrosion resistance and biofouling are essential for the overall platform
- Pre-deployment testing and data collection is essential

Tritech Gemini 720is

BlueView M900/2250

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Thank you

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