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# **Triton: Environmental Monitoring Technology Development, Collision Risk Data Collection**

Final Report

September 2022

Asa Packer  
Tim Acker  
Garrett Staines

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Prepared for  
the U.S. Department of Energy  
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Pacific Northwest National Laboratory  
Richland, Washington 99354

## Summary

Current energy converters like tidal and in-river turbines are a promising technology for clean electrical power generation in a variety of locations in the US. The environmental risk of most concern in relation to these turbines is collisions between animals such as fish or marine mammals with moving parts of the turbines. Monitoring technologies like video cameras and active acoustic sensors can collect data about animal interactions with turbines that regulators and stakeholders can use to assess this risk.

Video and acoustic cameras can generate compelling images, allow identification and classification of targets, and give insight into the behavior of animals near a turbine. However, analyzing data from these sensors, particularly from long-term continuous monitoring, is time-consuming and costly. The goal of this project was to develop software tools that will reduce the time and cost of analyzing data from these sensors.

In this project, we assembled a sensor suite that combines a scientific echosounder (sonar) system with video and acoustic cameras (secondary sensors). The sensor suite generates data that is amenable to automated target detection algorithms and can provide inputs to animal encounter models. We developed software (archiving software) to collect data simultaneously from all sensors in the suite, analyze the sonar data automatically in near-real-time to identify time periods when targets of interest were present, and automatically archive data from the secondary sensors for these time periods. The product of the archiving software is a data set for the secondary sensors, containing data only for the times when targets of interest were determined to be present by the sonar. We performed controlled field testing to verify the operation of the sensor suite and the archiving software.

In real-world applications we expect that the secondary sensor data set produced by the archiving software will be significantly smaller than the full continuous data set for those sensors and will therefore be faster and cheaper to analyze. The exact reduction in data accumulation, and the associated time and cost savings, will be specific to each site, determined by such factors as number of animals present and water column dynamics like entrained air or debris drift. Further work is required to quantify the reduction that can be achieved at sites of interest.

The sensor suite used for this project consists entirely of sensors that are available commercially from established manufacturers. The software developed for this project leverages proven commercial off-the-shelf software applications and software development kits. It is designed to be robust, for long-term, continuous, unattended monitoring deployments. The software allows for the sensors in the suite to be collocated or not and is extensively configurable to allow use near different sized turbines, in various environments (rivers, dams, marine) where the targets of interest may be of different types, such as large individual animals, or dense groups of small animals.

At the conclusion of this project, the sensor suite and software are at Technology Readiness Level 4. The software works reliably as designed, and successfully archives data from video and acoustic cameras when the sonar detects targets of interest.

Our recommendation for the next step is to deploy and beta-test the system near an operational turbine, to demonstrate that the system can reliably collect useful monitoring data in an operational environment and to quantify the reduction in secondary sensor data volume that can be achieved at a realistic site.

## Acknowledgments

The authors thank the Water Power Technologies Office of the U.S. Department of Energy for funding this project and providing ongoing advice and in particular Samantha Eaves for her input. They would also like to thank Ryan Hull for preliminary project research, and Nolann Williams for video camera integration.

## Acronyms and Abbreviations

2D	two-dimensional
3B	Target made of 3 Big air-filled spheres
3L	Target made of 3 Little air-filled spheres
4B	Target made of 4 Big air-filled spheres
5B	Target made of 5 Big air-filled spheres
5L	Target made of 5 Little air-filled spheres
ADF&G	Alaska Department of Fish & Game
AVI	Audio Video Interleaved file format
BioSonics	BioSonics, Inc., Seattle, WA
BioSonics Sonar	BioSonics DT-X echosounder technology
BF	Blackfly video camera
BFA	Blackfly Acquisition software module
BF <sub>end</sub>	End Time of Blackfly Snippet
BF <sub>start</sub>	Start Time of Blackfly Snippet
BP1	Billing Period 1
BP2	Billing Period 2
BV	BlueView acoustic camera
BV2250	BlueView 2,250 kHz data
BV900	BlueView 900 kHz data
BV <sub>end</sub>	End Time of BlueView Snippet
BV <sub>start</sub>	Start Time of BlueView Snippet
COTS	commercial off-the-shelf
CPU	central processing unit
CRDC	Collision Risk Data Collection
CS	Calibration Sphere target
CSV	comma-separated-values file format
dB	decibel
DOE	Department of Energy
FLIR	forward looking infrared
FOV	field of view
GB	gigabyte
GHz	gigahertz
GPS	Global Positioning System
IO&M	Installation, Operation & Maintenance
IP	Internet Protocol
kHz	kilohertz

PBV	PingBlueView software module
PC	personal computer
PCP	PnnlCrdcPlugin software module
PNNL	Pacific Northwest National Laboratory
RAM	Random Access Memory
ROI	Region of Interest
RR	Radar Reflector target
RTPX	BioSonics Real-Time Packet eXtended file format
SDK	Software Development Kit
Snippet	Data from a sensor for a time period when targets of interest were present
SON	BlueView SONar file format
STS	SnippetScript software module
$S_v$	Acoustic volume backscattering
$T_0$	Time at which a target was pulled from the water
$T_{10}$	Time at which a target approached within 10 m of sensors
$T_5$	Time at which a target approached within 5 m of sensors
TB	terabyte
Triton	The Triton Initiative
TRL	Technology Readiness Level
TS	Acoustic Target Strength
UTC	Coordinated Universal Time
VisAcq	BioSonics Visual Acquisition software
WPTO	Water Power Technologies Office
$X_n$	Transducer number n

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# 1 Introduction

The Triton Initiative (Triton) is a program funded by the Department of Energy (DOE) and managed by Pacific Northwest National Laboratory (PNNL). Its aim is to reduce barriers to testing marine energy devices by researching and developing monitoring technologies and methods to enable better understanding of the potential environmental risks associated with marine energy installations. The environmental risk, or stressor, of most concern for marine current energy converter turbines, is the collision risk to animals such as fish with moving parts like turbine foils. This risk requires monitoring to inform the marine energy community, researchers, regulators, and other stakeholders of fish interactions with a turbine. Information about fish interactions with turbines is needed and monitoring is usually conducted with video cameras and active acoustic sensors like sonar and acoustic cameras. Collecting meaningful data using these sensors in energetic environments where turbines are likely to be installed is difficult and when used often accumulates large amounts of data. Reviewing these data is time-consuming and costly. To date most of these data are of little interest because most of the time there are no fish observed interacting with a turbine. A means of collecting data but only archiving data of interest when fish are present in the sensors and deleting or storing separately data of no interest, is needed to reduce monitoring effort and cost.

## 1.1 Project Purpose and Scope

In response to this need, Triton led the Collision Risk Data Collection task to investigate a solution for reducing data volumes by archiving only data of interest using a suite of sensors. This final technical report summarizes collaborative efforts by Triton and BioSonics, Inc. located in Seattle. These efforts include the acquisition of a suitable sensor suite and the development of software that communicates with all sensors and uses sonar detection of fish to archive data from other sensors. Thus, when no fish are detected in the sonar, no data are archived, reducing accumulated data during a monitoring campaign. Archived data of interest featuring potential fish interactions can be reviewed by experts for analysis of behavior, strike, and near-miss events. The complete system of sensors and software can be operated from a single computer. All sensors in the suite are commercially available from established manufacturers. The software developed for this project was based on existing commercially available data collection software and software development kits (SDKs). The software developed for this project is referred to throughout this report as the “archiving software.”

## 1.2 Report Contents and Organization

The ensuing sections of this report describe the suite of sensors used, the development and operation of the archiving software, field testing of the software and sensor suite, conclusions based on field testing results, and recommended next steps. The appendix contains detailed software configuration information.

## 2 Sensor Suite

The goal of this project was to use a commercially available primary sensor that operates as the first data stream that detects targets of interest in the water column. BioSonics, Inc. (BioSonics) sonar technology (BioSonics Sonar) was chosen for this because it is commercially available with operational hardware and software. This sensor was the backbone of the system from which detection and subsequent secondary sensors are referenced spatially and temporally.

### 2.1 Sensors Used

The BioSonics DT-X Extreme echosounder (surface unit) can control multiple transducers, either single-beam or split-beam, each located within 100 m of the echosounder. The transducers can be selected from a range of acoustic frequencies and beamwidths. BioSonics Visual Acquisition software (VisAcq) is Windows-based and is used to acquire data from BioSonics Sonar systems. VisAcq collects data from multiple transducers using a multiplexing approach (transducers are pinged one at a time in round-robin order) and the data for all transducers are logged to a single stream of data files. VisAcq logs acoustic data up to a user-specified end range for each transducer. Meaningful data can be collected at distances of up to several hundred meters depending on the environment and the operating acoustic frequency. VisAcq also logs GPS data, and transducer orientation (i.e., heading, pitch, and roll) data from BioSonics transducers with integrated orientation sensors. It has an extensive configuration dialog that allows the user to specify data collection parameters such as end range, transmit pulse length, ping rate, and to configure real-time processing such as bottom, fish-echo, and fish-track detection. VisAcq also contains a feature called “Clutter Mapping”, which maps static targets present in the acoustic environment and then ignores them for subsequent target detection. During data collection, the live visual displays (echogram and oscilloscope) show the data for the sampled part of the water column (Figure 1). For more information about VisAcq, see <https://www.biosonicsinc.com/products/software/>.

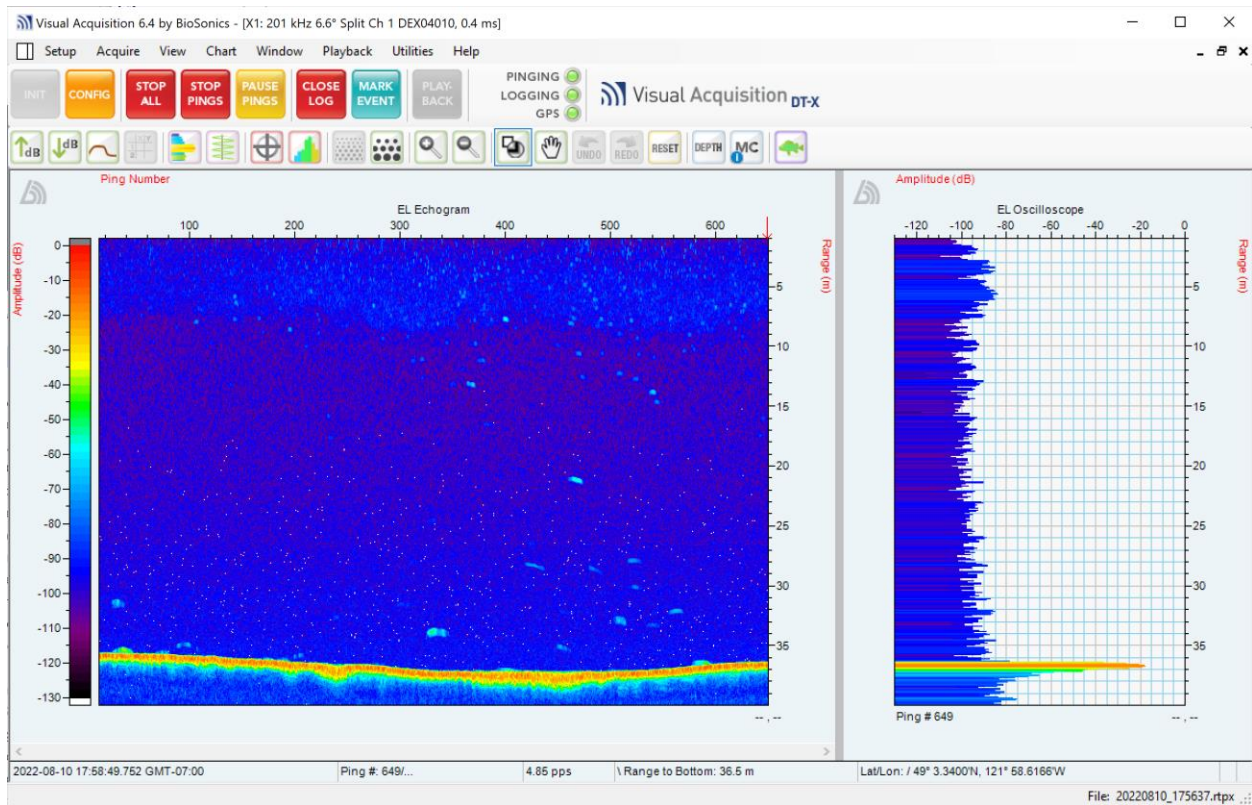


Figure 1. VisAcq echogram and oscilloscope displays.

For this project, the BioSonics echosounder was connected to 12 identical single-beam Airmar M-194 transducers transmitting at 200 kHz with beamwidths of 9 degrees. The transducers were arranged in a horizontal circular fan formation with each transducer spaced 7.5 degrees apart, so together they covered a 90-degree horizontal by 9-degree vertical sector (Figure 2). We will use the numbering indicated in Figure 2 to refer to individual transducers—when looking from above, X1 refers to the transducer that is farthest counter-clockwise, and the numbering increases as you go clockwise, up to X12.

This project used two secondary sensors that reference the primary BioSonics Sonar for archiving data of interest: a Teledyne BlueView model M900-2250-45 dual-frequency acoustic camera (BV) and a FLIR Blackfly S model BFS-PGE-16S2M-CS video camera with Tamron 8mm model LENS-80T4C lens (BF).<sup>1</sup>

The BV is a 2D imaging sonar (also called an acoustic camera) that operates at both 900 kHz and 2,250 kHz. Its acoustic beam array has 256 beams for each frequency, with a total beamwidth of 45 degrees horizontal and 20 degrees vertical (Figure 2). It can ping up to 15 times per second depending on the configured collection range (start and stop range for logging data). For each ping, it produces a visual display of the acoustic returns mapped onto a 45-degree wide sector of the plane. The acoustic data represent the magnitude of sound reflected from each range in each horizontal direction but do not contain information about the vertical direction from which the sound was reflected, so in a side-looking deployment the depth of a target in the beam array is not resolved. Data collection is limited to 60 m for the 900 kHz

<sup>1</sup> Secondary sensors are not limited to these two; sensor suite design allows for integration of numerous other commercial sensors with minimal incorporation effort.

frequency and 8 m for the 2,250 kHz frequency. The maximum usable ranges can be less than those limits depending on the environment such as water with entrained air or high levels of turbidity. In ideal conditions, the data can provide opportunities for visual classification of targets.

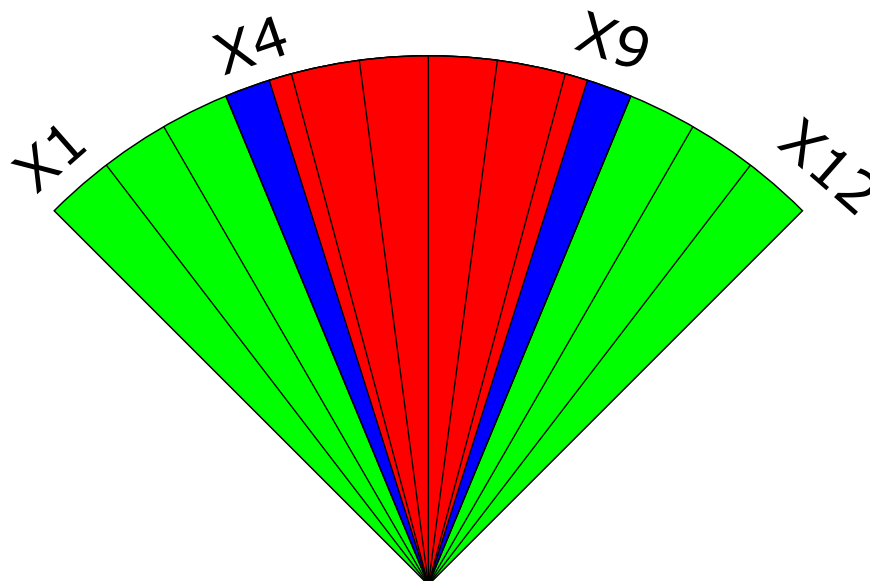
The commercially available software from Teledyne for data collection and analysis with the BV is ProViewer software. This software does not allow for multiplexed data collection with both acoustic frequencies—the user can only collect with a single frequency at a time and must manually switch between frequencies. Teledyne also provides the ProViewer SDK to allow for development of custom software solutions. We used this SDK (version 4.4.0.13443) to create software that allows multiplexed dual-frequency data collection for this project.

The BF is a visible light machine vision camera capable of collecting monochrome video at up to 1,440 x 1,080 resolution and a maximum of 78 frames per second. It is a small form factor (approx. 30 x 30 x 60 mm with lens) that is powered and transmits data via gigabit Ethernet. With the 8 mm lens, its field of view (FOV) was 35 degrees horizontal and 27 degrees vertical (Figure 2). The camera is not waterproof, so we put it in a submersible housing, with four lights attached to illuminate the observed water column to improve target detection. The lights were Blue Robotics Lumen Subsea Lights outputting 1,500 lumens each at 5,700 K color temperature with 135-degree beams underwater. For close-range targets, the BF video can provide opportunities for visual classification of the targets. However, depending on site-specific ambient light and water turbidity conditions, targets may be difficult to detect, identify, and classify.

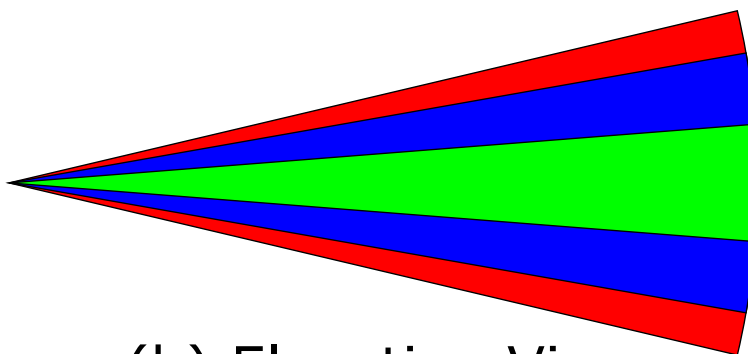
The secondary sensors selected for this project have sufficient FOVs for testing of the archiving software functionality. In other applications, wider FOVs might be desirable to capture fish moving through, or residing at, a particular site. Teledyne makes other BV units, such as the M900-2250-130-Mk2 with a 130 by 20-degree FOV. The BF can be used with a shorter focal length lens to achieve a wider FOV. These alternative sensors could be used without making any changes to the archiving software, thereby allowing for a wide array of configurations to capture site variability.

## 2.2 Sensor suite mounting

Collocation of sensors, including the primary BioSonics Sonar, is not required for successful use of the archiving software. However, for efficient testing of the system described in this report, we did mount all of the sensors together. The 12 transducers were mounted in a horizontal circular arc, with a FOV of 90 degrees in the horizontal direction and 9 degrees in the vertical direction. The BV and BF were mounted on top of the middle of this arc, with their FOVs centered on the midline of the BioSonics Sonar. This assembly was mounted on a Remote Ocean Systems model PT-25 pan/tilt unit for aiming the sensor suite vertically and horizontally during testing. Figure 2 shows a diagram of the sensor FOVs, ignoring the slight translation offsets between them. The actual sensor assembly can be seen in Figure 3, as well as in this video: <https://www.youtube.com/watch?v=BRDmu4bkxAY>.



(a) Plan View



(b) Elevation View

- = BioSonics FOV
- = BV FOV
- = BF FOV

Figure 2. (a) Plan view showing the horizontal fields of view (FOVs) of the BioSonics Sonar transducers in green that covers 90 degrees, the BlueView (BV) acoustic camera that covers 45 degrees, and the Blackfly (BF) video camera that covers 35 degrees; (b) elevation view showing the vertical FOVs of the BioSonics Sonar in green that covers 9 degrees, the BV that covers 20 degrees, and the BF that covers 27 degrees.



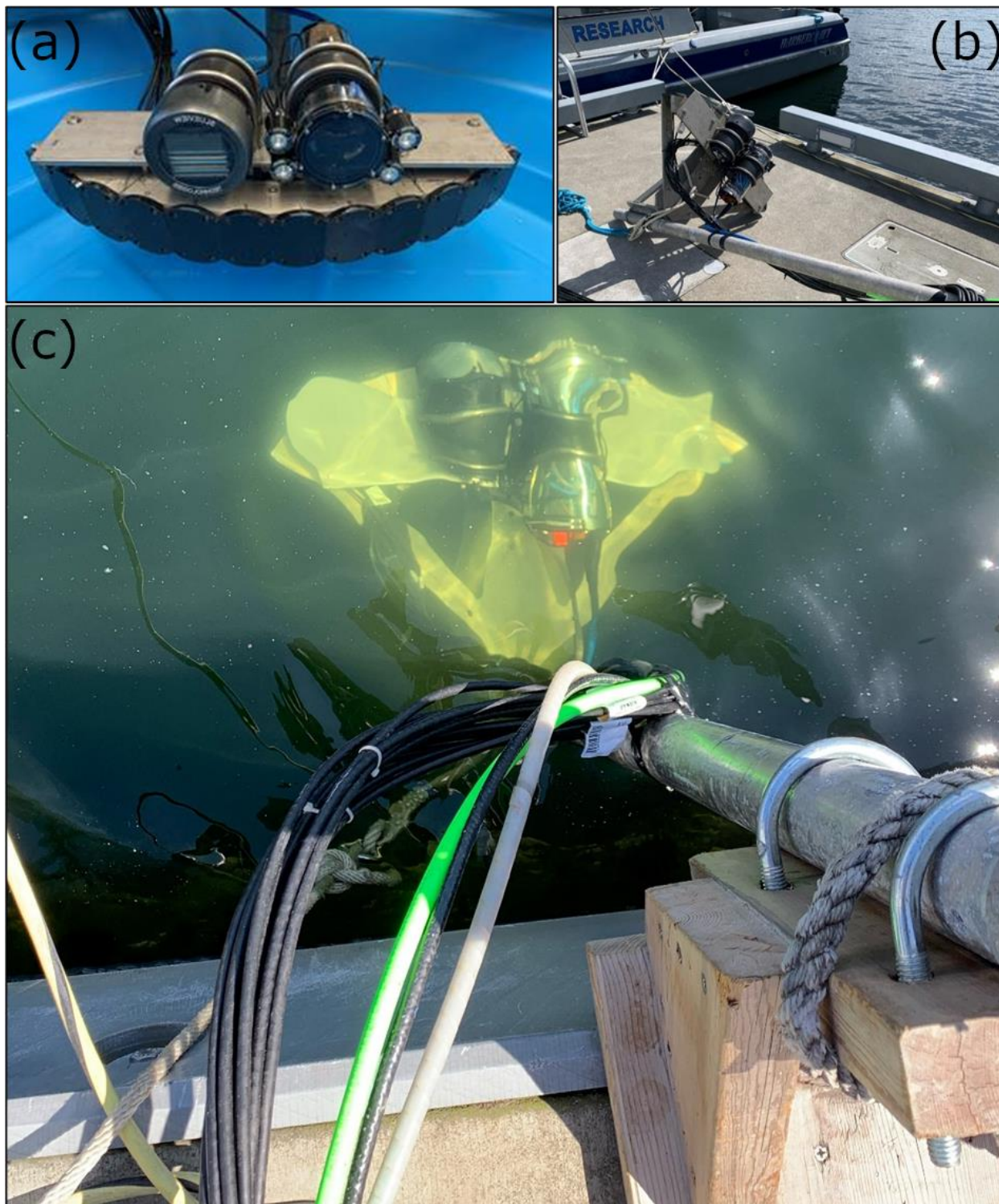


Figure 3. (a) Sensor assembly in tank; (b) on dock and (c) deployed in the water for testing.

### 3 Software Development

The main goal of this project was to assemble a suite of software applications that can operate from a single computer and perform the following actions:

- Continuously and simultaneously log BioSonics Sonar, BV, and BF data.
- Analyze the BioSonics Sonar data in real-time to identify time periods of interest when targets are present.
- In near-real-time (<1 h), archive BV and BF data (snippets<sup>2</sup>) corresponding to time periods of interest when targets were present.

Once configured, the software runs without operator intervention.

#### 3.1 Software Architecture

To maximize reuse of existing software, and segregate the operational parameters of the secondary sensors from BioSonics Sonar software, we divided the software design into the following software modules (see Appendix A for details on the configuration options for these modules):

- VisAcq was used to control the BioSonics Sonar, configure data collection parameters, log, and display the BioSonics Sonar data, and perform target detection. The data are logged in proprietary BioSonics Real-Time Packet eXtended (RTPX) file format in files of user-specified length (e.g., 1 minute).
- Standard VisAcq does not report target detection results in real-time. Therefore, a new module was added to VisAcq to determine, in real-time, the start and end times of target presence in one or more transducer beams. These start and end times define a snippet. This software is called PnnlCrdcPlugin (PCP), and it is the heart of the archiving software. PCP is separate from VisAcq but is loaded by VisAcq at runtime (i.e., when a user opens VisAcq) to make additional capabilities available to the user within the standard user interface. PCP provides a real-time display during data collection that shows the status of BioSonics Sonar target detection and snippet start/end times as they are determined. This display was useful for monitoring and tuning the archiving process during field testing. PCP also adds configuration options to the standard VisAcq configuration dialog, allowing the user to configure the snippet archiving parameters (see Section A.1.1 in the appendix). As the logging of each RTPX file is completed, PCP writes a comma-separated-values (CSV) file with the start and end times of all snippets that have been identified during the time period covered by the RTPX file. PCP was designed to be independent of which secondary sensors are being used so that it will not need to be changed to work with other types of secondary sensors in the future. It simply processes VisAcq target detection results and reports the time periods of interest.
- A module called “PingBlueView” (PBV), using Teledyne’s ProViewer SDK, was created to control the BV and log continuous raw data from both operational frequencies. PBV runs as a Windows application separate from VisAcq. The BV data are logged in BlueView SONar (SON) file format, in files of user-specified length (e.g., 1 minute).

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<sup>2</sup> The term snippet is used in this report to refer to a specific time bin of data for the BV and/or the BF that is created when targets are detected in the BioSonics Sonar.

- A module was created called “Blackfly Acquisition” (BFA), using FLIR’s Spinnaker SDK, to control the BF camera and log data continuously. BFA runs as a Windows application separate from VisAcq and PBV. The video data are logged in Audio Video Interleaved (AVI) file format in files of user-specified length (e.g., 1 minute).
- A module was created called “SnippetScript” (STS) that is referenced by PBV and BFA periodically (i.e., every time a new secondary sensor raw data file (SON or AVI) is logged). STS reads the CSV files produced by PCP containing the start/end times of BioSonics Sonar periods of interest with targets present, then extracts the appropriate data packets from the raw secondary sensor files to create a new SON or AVI file containing just the data from that time period—a snippet. These snippet files are stored in a different directory than the raw data files. Raw data files can be deleted once the snippets are created, although most users are likely to store them for some amount of time in case troubleshooting or configuration changes are necessary during a deployment.

The full collection of these modules (VisAcq, PCP, PBV, BFA, and STS) is referred to as the “archiving software.” From a user’s perspective, VisAcq, PBV, and BFA are separate Windows applications that must be opened and interacted with independently. PCP and STS are modules that operate behind the scenes, so the user is not aware of them as separate applications.

See Figure 4 for a diagram of the software architecture and data flow.

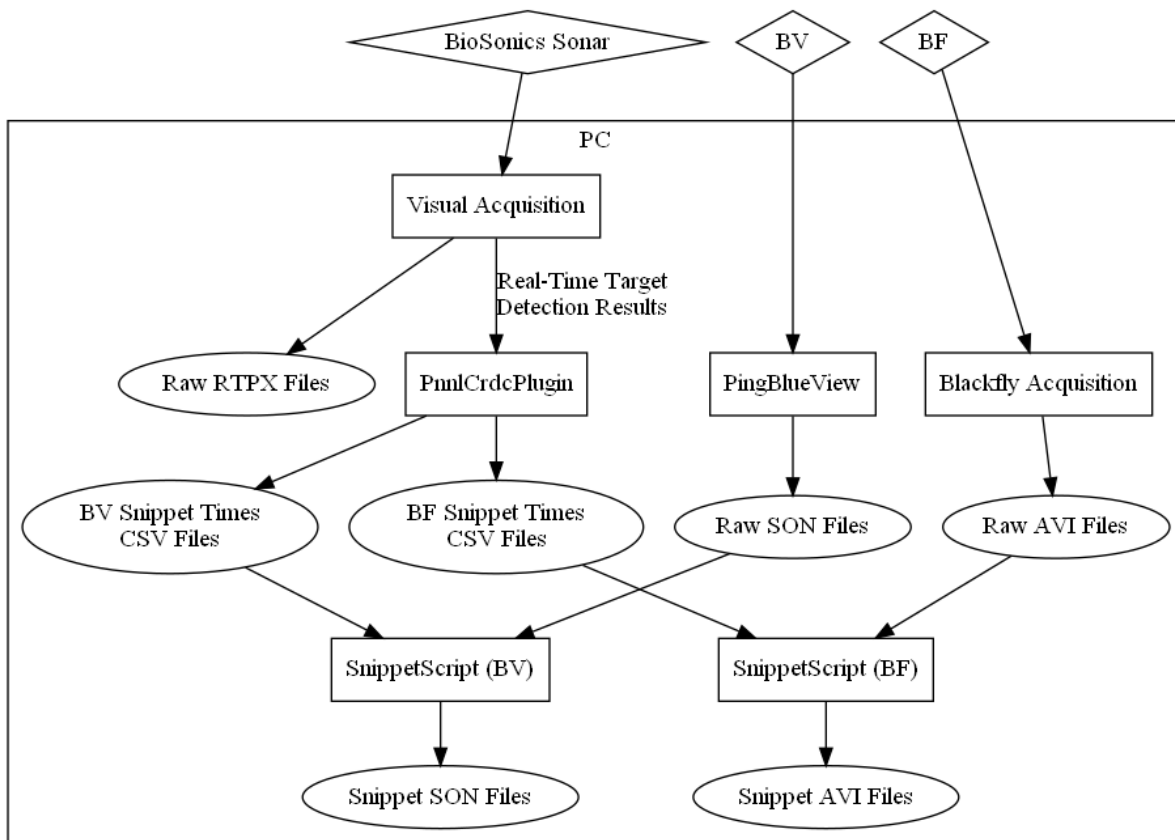


Figure 4. Software architecture. Diamonds represent sensors (BioSonics Sonar, BlueView acoustic camera (BV), and Blackfly video camera (BF)). Rectangles represent

software modules (PCP, PBV, BFA, and STS). Ovals represent data files originating from hardware or processed by a software module.

## 3.2 Design Objectives

There were several important design objectives for the development of the software, as follows:

- Use commercial-off-the-shelf (COTS) BioSonics software for the BioSonics Sonar and use COTS secondary sensor SDK options.
- Make the PCP software sensor agnostic to secondary sensors, thereby facilitating integration of other sensor types in future applications and maximizing configurability.
- Make the software agile and configurable, allowing for its application at sites with different characteristics (e.g., river or tidal estuary) and different types of targets of interest (e.g., different sized fish or even diving birds). In particular:
  - Allow BioSonics Sonar and any secondary sensors to be spatially separated or collocated as needed depending on the site and application. Allow configuration of time delays between sonar target detection and snippet archiving, to account for expected target travel time between sonar FOV and secondary sensor FOV.
  - Allow for multiple secondary sensors, potentially having different regions of coverage and different archiving criteria for each sensor. For example, one might have multiple video cameras, each covering a different part of a transducer's FOV, so the Region of Interest (ROI) for each video camera would be different. Because the size of the transducer beam increases with range, it also might not be appropriate to require the same number of echoes to trigger archiving for each camera.
  - PCP should allow the three major sonar data processing/analysis methods (echo integration, echo detection, or target tracking)<sup>3</sup> for the software archiving criteria for secondary sensors. This allows efficient archiving for sparse single fish passage and dense school or shoal passage.
  - Allow configuration of archiving thresholds (i.e., size, number, and range of targets) and archiving time bins.
- Provide immediate visual feedback about archived secondary sensor snippet data file creation, and target statistics such as the number of targets detected per time bin, to facilitate making on-the-fly tuning changes to the archiving parameters.
- Secondary sensor, archived snippet data files are created and accessible for manual review in less than one hour, thereby allowing for fast creation of data products if needed.

There were important design objectives for the BFA module in particular:

- Maximize use of the FLIR Spinnaker SDK. This means the software will support many other models of cameras with few or no changes. This is important for future applications that may call for different resolution, frame rate, or possibly the need for color image sensors.
- The software must acquire video data and log them in a way that makes the snippet archiving process efficient. For example, most standard video formats do not contain information about the actual timestamp of each video frame. BFA logs such data in auxiliary

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<sup>3</sup> These are established fish biomass, abundance, and density analysis methods for sonar technology (Simmonds and MacLennan 2005).

files along with the AVI files, so it is easy for STS to extract the video frames from the raw video files for the time ranges identified by PCP.

- Embed timestamp information in the video frame images, so when playing back snippets it is easy to correlate them with BioSonics Sonar, BV, or other data sets if they use different secondary sensors.
- Allow the user to configure standard camera properties such as exposure time, gain, gamma, and black level. This is important for optimizing image quality at different sites with different ambient lighting conditions. This also provides consistent data collection parameters that can make automated image analysis methods more successful.
- Allow the user to configure video resolution, compression, and frame rate to manage the tradeoff between video quality and data accumulation.
- Allow the user to configure the visual update rate (real-time user reference of the BF frames) of the software to decrease load on the computer.

### 3.3 Computer Specifications

The computer used to run the software is a PC, running Windows 10 Professional x64. It has a dual-core Intel i3 processor running at 3.3 GHz, 8 GB RAM, 2 TB disk space, and an NVIDIA Quadro FX 580 graphics card. The computer has three gigabit Ethernet ports. One port was connected to the BioSonics Sonar, one to the BV, and one to the BF. For the sensors we were using, this computer was sufficient. For a deployment involving more secondary sensors (e.g., multiple video cameras or acoustic cameras) or more powerful sensors (e.g., higher resolution or frame rate, color instead of monochrome), a more powerful computer might be required.

### 3.4 Software Operation

In this section, we describe the software usage flow in general terms. Detailed descriptions of specific configuration options for the various modules are given in Appendix A. From the user's point of view, three Windows applications are visible: VisAcq for the BioSonics Sonar, PBV for the BV, and BFA for the BF.

In VisAcq, the user can configure the operating parameters of the BioSonics Sonar. This includes ping rate, transmit pulse duration, start and end range of data collection, and echo and track detection parameters. All of these are standard parameters in fisheries acoustics (Simmonds and MacLennan 2005) that any user can control in VisAcq, and they are a required precursor to typical data collection for the BioSonics Sonar. However, because we have added PCP to VisAcq, additional configuration options are available that control the archiving software. Once all options are set, VisAcq allows the user to start and stop data collection. Once data collection is started, RTPX data files start being logged, and VisAcq's standard live displays (Figure 1) are available to visualize the water column and the targets that are detected within it, such as fish, the seafloor, or other objects in the water that pass through one or more transducer beams.

With PCP running, each ping is being analyzed as it is received to see if the level of detected targets meets the configured snippet archiving criterion. Information about the status of the archiving can be displayed in real-time in VisAcq using the PCP real-time status display (Section A.1.2 in the appendix). PCP keeps a list of the snippet start/end times it has identified,

and every time an RTPX file is finished being logged, CSV files are written out to one or more user-specified directories, containing those start/end times.

The PBV and BFA programs each have similar interfaces and usage flows. They have configuration dialogs allowing the user to control various parameters of the sensor (described in detail in Appendix A), and they also allow the user to start and stop data collection from the sensor.

When data collection is running for the secondary sensors (i.e., BV and BF), the PBV and BFA programs run STS every time they finish logging another raw data file. STS reads the CSV files that PCP (embedded in VisAcq) has produced containing snippet start/end times, and automatically creates the appropriate snippet data files from the raw data files, resulting in short snippets of BV and BF data of interest.

Once parameters are configured, starting the software is simply a matter of starting data collection in each of the three main programs: VisAcq (that includes PCP), PBV, and BFA. The user sees a window for visual reference of each program. The combined programs operate continuously without user input indefinitely. The user can return to the computer hours or days later, and snippet files for each sensor for the times when the BioSonics Sonar detected targets (based on the user-defined parameters) will be stored in the user-defined directories.

### 3.5 Archiving Algorithm Description

In this section we describe the algorithm used by PCP to determine the start and end times of snippets, which we refer to as the “archiving algorithm.” Several aspects of the archiving algorithm can be configured by the user:

- **The Region of Interest.** This is the *spatial* part of the BioSonics Sonar data that is used to control the snippet archiving. For each transducer, zero or more intervals in range that should be included in the archiving decision are defined. For example, the user may only be interested in 2 m – 5 m and want to ignore 0 m – 2 m and all data past 5 m. This is easily accomplished during parameter setup.
- **The Interval Length.** This is the *temporal* part of the BioSonics Sonar data that is used to control the snippet archiving. This can be specified in seconds or in number of pings for each BioSonics Sonar transducer.
- **The Interval Criterion.** This is used to decide whether an Interval Length has enough targets to be included in a snippet. There are three possible criteria that users can apply:
  - **Echo integration-based:** The user defines what level of average backscatter (usually referred to as  $S_v$ ) for all targets in the ROI and the Interval Length will trigger snippet archiving. This criterion is for schools and shoals when individual fish are close together.
  - **Echo-based:** Within the user-defined ROI and Interval Length, fish and other single targets spaced apart (i.e., not in a school or shoal) will reflect the sonar transmission and provide an echo signal of varying target strength (TS) in decibels (dB). TS is a relative measure of the size of a target where larger numbers are bigger targets. The user defines how many echoes and the strength of those echoes to trigger snippet archiving. This Interval Criterion is for individual fish that are moving quickly through one or more sonar beams.
  - **Track-based:** Individual fish echoes can be linked together creating tracks, providing confidence that targets in the sonar are fish. The user defines how many tracks, within

the user-defined ROI and Interval Length, are required to trigger snippet archiving. This Interval Criterion is for individual fish that are in one or more transducer beams long enough to be pinged multiple times thus creating a track.

- **The output folders** – one or more folders where PCP should save CSV files with snippet times. The CSV file in each folder is read by one instance of STS to determine the times of the snippets it should create for its secondary sensor.

PCP allows the user to configure multiple instances of the archiving algorithm to run at the same time. This allows flexibility in handling secondary sensors that have different locations, aims, or capabilities.

Suppose your ROI is set, and Interval Length is set to N seconds. When a ping with some timestamp T is received, the algorithm considers all pings with timestamps greater than T-N and less than or equal to T to be the “current interval.” It computes the average  $S_v$ , total number of echoes, or total number of tracks (depending on user-chosen Interval Criterion) over all the pings in the current interval, using only the data in the ROI. The result is compared to the configured threshold in the Interval Criterion. If it exceeds the set threshold, then the interval from T-N to T is included as part of a snippet by STS. Often, there will be multiple pings in a row where each interval has enough targets to be included in a snippet. Those intervals are merged into a single longer snippet.

Because of the Interval Length, and the real-time nature of the algorithm, there can be some lag between when a target is first detected by the transducer and when the start of a snippet is determined. There is a retroactive aspect to the algorithm’s operation—when the algorithm detects that a snippet has started, the start time of the snippet is earlier than the time of the most recent ping. There is a similar effect at the end of a snippet. This ensures the beginning and end of the times of interest when targets are present will be included in the final secondary sensor snippet data file.

### 3.5.1 Algorithm Example

Here is a simple example of how the algorithm operates. For simplicity, this example assumes the following configuration:

- There is only one transducer, pinging once a second.
- The ROI includes all the data for the transducer.
- The Interval Length is 4 seconds.
- The Interval Criterion is Echo-based (as opposed to Echo integration-based or Track-based) and requires that an interval must contain at least 2 echoes, with each echo having a TS of at least  $-50$  dB, to trigger archiving.

Suppose we have the following ping data, (where the ping at 12:00:00 is the first ping after the user starts data collection):

Time of Ping	Number of Echoes with TS $\geq$ -50 dB
12:00:00	0
12:00:01	0
12:00:02	0
12:00:03	0
12:00:04	1
12:00:05	1
12:00:06	0
12:00:07	0
12:00:08	0
12:00:09	0
12:00:10	0
12:00:11	0

When the ping at time 12:00:00 is processed, the current interval consists of all pings with timestamps greater than 11:59:56 and less than or equal to 12:00:00. There is only one such ping since we are at the beginning of the data. The total number of echoes over the current interval is 0, which is not high enough for the interval to be included in a snippet.

When the ping at time 12:00:01 is processed, there are now two pings in the current interval, but the total number of echoes is still 0, so the interval is not added to a snippet. This continues through the processing of the ping at time 12:00:03.

When the ping at time 12:00:04 is processed, the current interval consists of all pings with timestamps greater than 12:00:00 and less than or equal to 12:00:04. Over that set of pings, the total number of echoes is still only 1, so the interval does not get included in a snippet.

When the ping at time 12:00:05 is processed, the current interval consists of all pings with timestamps greater than 12:00:01 and less than or equal to 12:00:05. Over that set of pings, the total number of echoes is 2, which meets our user-defined Interval Criterion. So, the time period from 12:00:01 to 12:00:05 will be included in a snippet. At this point, we have a “pending snippet,” covering 12:00:01 to 12:00:05. We do not yet know what the end time of the snippet will be.

When the ping at time 12:00:06 is processed, the current interval consists of all pings with timestamps greater than 12:00:02 and less than or equal to 12:00:06. Over that set of pings, the total number of echoes is still 2, so the time period from 12:00:02 to 12:00:06 must be included in a snippet. At this point, our pending snippet covers 12:00:01 to 12:00:06.

Similarly, when the ping at time 12:00:07 is processed, the pending snippet gets extended by one more second, so that it now covers 12:00:01 to 12:00:07.

When the ping at time 12:00:08 is processed, the current interval consists of all pings with timestamps greater than 12:00:04 and less than or equal to 12:00:08, so there is only one total echo. So, our pending snippet stays at 12:00:01 to 12:00:07. However, at this point, we still do not yet know when the snippet will end. For example, if a ping were to arrive at 12:00:09 with four echoes in it, then the pending snippet would get extended to 12:00:09.



However, given the data shown in the table, once we process the ping at 12:00:11, we then know that any subsequent ping will come after 12:00:11. Therefore, it will be the end of an interval that won't include 12:00:07, so now we know that our pending snippet ended at 12:00:07. At this point, PCP can write a CSV file in the output folders indicating that a snippet should be created covering the time period 12:00:01 to 12:00:07. When an instance of STS reads that, it will create a file consisting of all the data from its sensor that has a timestamp between 12:00:01 and 12:00:07 and store it in the snippet output directory.

To summarize, note the following:

- The target entered the transducer beam at 12:00:04.
- The algorithm did not detect the start of a snippet until 12:00:05, but it retroactively started the snippet at 12:00:01.
- The target exited the transducer beam at 12:00:06.
- The algorithm did not detect the end of a snippet until 12:00:11, but it retroactively ended the snippet at 12:00:07.
- So, the final snippet is from 12:00:01 to 12:00:07, which includes the two seconds when echoes (fish targets in the water) were detected. This led to a snippet being archived when there were possibly fish passing through the ROI. This snippet is available for human review within 1 hour of the raw data being collected.

## 4 Field Testing and Results

Field testing of the software and sensor suite was conducted at the BioSonics dock site in Seattle, Washington (Figure 5). The site is located on the south shore of Salmon Bay, near the western end of the Lake Washington Ship Canal. The dock is a safe working platform with easy access to the BioSonics office. The BioSonics research vessel was tied to the dock and used as a secondary platform and shelter for the sensor suite electronics. The sensor mount (as described in Section 2.2) was attached to the side of the dock so the sensors were 1.5 m below the water surface. Water depth is approximately 5 m.

We performed the field testing in three phases. For Phase 1, we ran the system overnight on 5/17–5/18 and 5/18–5/19 to test long-term unattended operation. Phases 2 and 3 were done during the day on 5/19, when we performed controlled testing with seven different targets to test whether the archiving software would create snippets at the appropriate times. Phase 2 testing consisted of 32 runs with identical choreography, using the seven targets one at a time. Phase 3 testing consisted of 21 runs with varying choreography, some with multiple targets, varying angles of incidence through multiple transducer beams, and longer ranges than Phase 2.

Our main objectives were to verify that the archiving software can run for extended periods of time without user intervention, and to verify that the archiving software creates snippets when targets of interest are present but does not create snippets when targets of interest are not present.

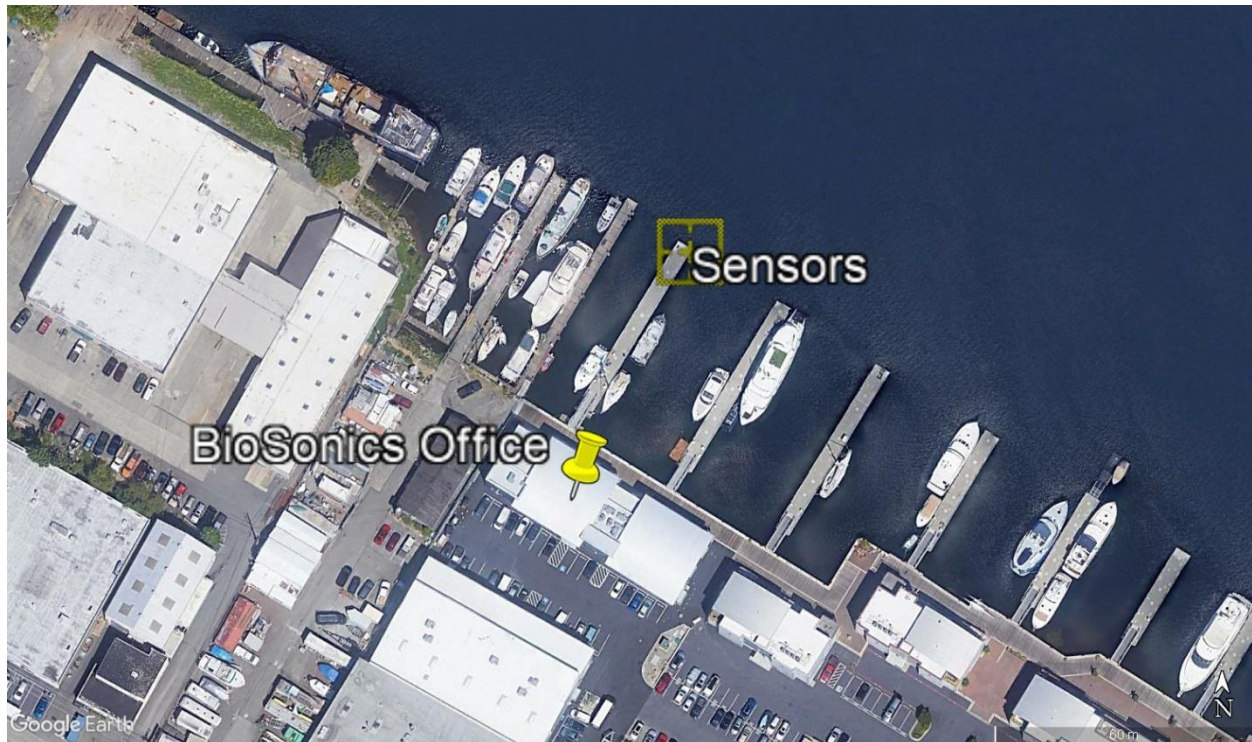


Figure 5. Overview of deployment site showing the location of the sensors.

## 4.1 Phase 1: Overnight Runs

One of the goals of testing was to show that the software can operate unattended for extended periods of time. To demonstrate this, we ran the system unattended overnight twice. The first run was from 5/17 16:48:17 to 5/18 08:53:04, approximately 16 hours, and the second run was from 5/18 16:06:21 to 5/19 09:41:01, approximately 17.5 hours. For these runs, the sensor suite was aimed as shown in Figure 6. The green cones show the area of coverage of each BioSonics Sonar transducer, out to the configured end range of 50 m. The blue area is the configured ROI for archiving BV snippets, which extends from 0–10 m for each BioSonics transducer. The red area is the configured ROI for archiving BF snippets, which extends from 0–5 m for each transducer.

We did not know what to expect in terms of targets swimming through the sensors' FOVs, so for the first overnight run our archiving criteria were arbitrary—we configured the archiving software to archive snippets if 10 echoes of TSs of at least  $-30$  dB were detected in a 10-second period. We used identical criteria for BV and BF archiving, except that the ROIs were different. With these settings, the software did not archive any snippets during the first overnight run. The software ran correctly throughout the run, there simply were not enough targets in the water to trigger any archiving.

To archive snippets for the second overnight run, we reduced the minimum required TS for the echoes to  $-40$  dB, so we were archiving if 10 echoes of TSs of at least  $-40$  dB were detected in a 10-second period. With these settings, the software archived one 12-second BF snippet, and 4 BV snippets totaling 70 seconds. Review of the data indicates that the snippets were created correctly, at the times when the BioSonics Sonar was detecting targets. The BF snippet and one of the BV snippets were created at 08:48:55 on 5/19—this was a time when we were working near the sensors and some cables went into the FOV of the transducers. The cables are visible on both the BF snippet and the BV snippet. The other BV snippets were created at 05:27:08, 07:26:15, and 08:11:26 that day—at these times the sonar did detect targets, but they are weak and diffuse on the echograms, difficult to see in the BV data, and beyond the detection range of the BF. There were few targets of opportunity during these two overnight runs, however, these two demonstrations highlight the stability of the hardware and archiving software at an early TRL.

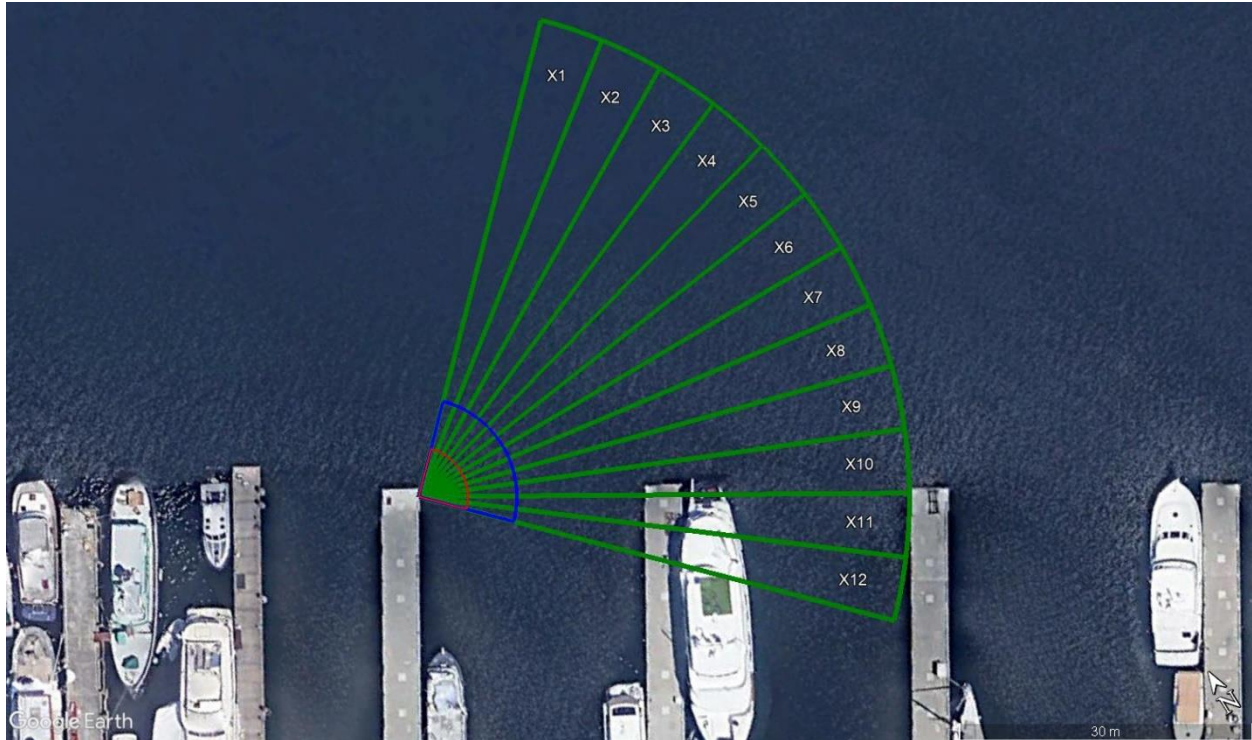


Figure 6. Sensor aims for overnight runs. The red sector represents the Region of Interest (ROI) for Blackfly video camera (BF) archiving (5 m range); the blue sector represents the ROI for BlueView acoustic camera (BV) archiving (10 m range); and the green sector is the BioSonics Sonar range (50 m, with a 90-degree FOV made up of 12 transducer beams). Note that the piers and boat in X10-X12 are outside the ROIs for both secondary sensors, so acoustic backscatter from these objects did not affect archiving. The vertical aim of the sensors was such that acoustic backscatter from the bottom and water surface was not an issue within the ROIs for secondary sensor archiving either.

## 4.2 Phases 2 and 3: Target Testing

After the overnight runs, we aimed the sensors in toward shore, and tested the archiving software by introducing specific targets into the BioSonics Sonar FOV in controlled ways and verifying that the archiving software created secondary sensor snippets at the correct times, i.e., the times when the targets were within the configured ROIs. We performed this testing on 5/19/2022 between 10:30 and 15:00. Phase 2 of the testing was performed by moving single targets toward the sensors parallel to the dock on which the sensors were mounted. Figure 12 shows how the sensors were aimed for Phase 2 testing. Figure 7 shows how we moved the targets, and the approximate path of the targets. Phase 3 of the testing consisted of several types of runs, described in Section 4.2.4.

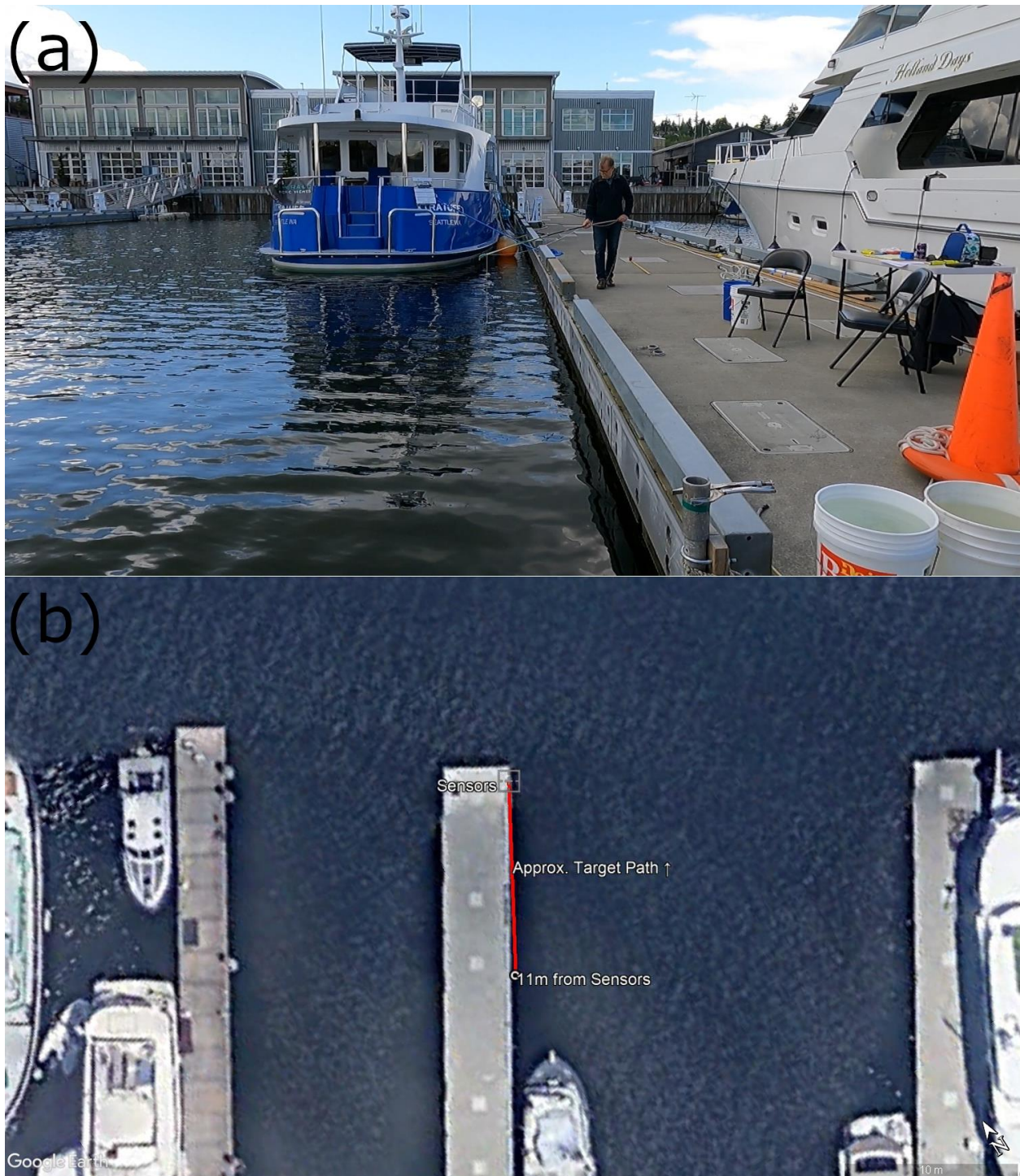


Figure 7. (a) Moving a target suspended from a pole along dock toward the sensors; and (b) the approximate target path.

#### 4.2.1 Target Descriptions

We used seven different targets during Phase 2 and 3 testing (Table 1 and Figure 8).

Table 1. Targets used during Phase 2 and 3 testing.

Name	Description	TS Stability	Approx. TS
RR	Eight-inch diameter aluminum radar reflector	Highly variable	Up to -10 dB
CS	36.4 mm diameter Tungsten carbide sphere <sup>4</sup>	Very stable	-40 dB
5B	Five 1-inch air-filled spheres	Stable	-30 dB
4B	Four 1-inch air-filled spheres	Stable	-33 dB
3B	Three 1-inch air-filled spheres	Stable	-34 dB
5L	Five ½-inch air-filled spheres	Stable	-35 dB
3L	Three ½-inch air-filled spheres	Stable	-37 dB

\* For comparison, a 1.2m long Atlantic salmon has a side-aspect TS of approximately -20 dB, and a head-aspect TS of approximately -38 dB (Lilja et al. 2000)

Target RR has variable acoustic scattering characteristics because it rotates in the water, and at its maximum it provides the highest TS of all targets. The CS target has a stable TS at any orientation and has the lowest TS of all targets. The other five targets have TS values that decrease slightly in the order they are listed. Their TS values are stable but not as stable as CS.

<sup>4</sup> This is a standard sphere for calibrating sonar for fisheries applications using 200 kHz transducers (Demer et al. 2015).

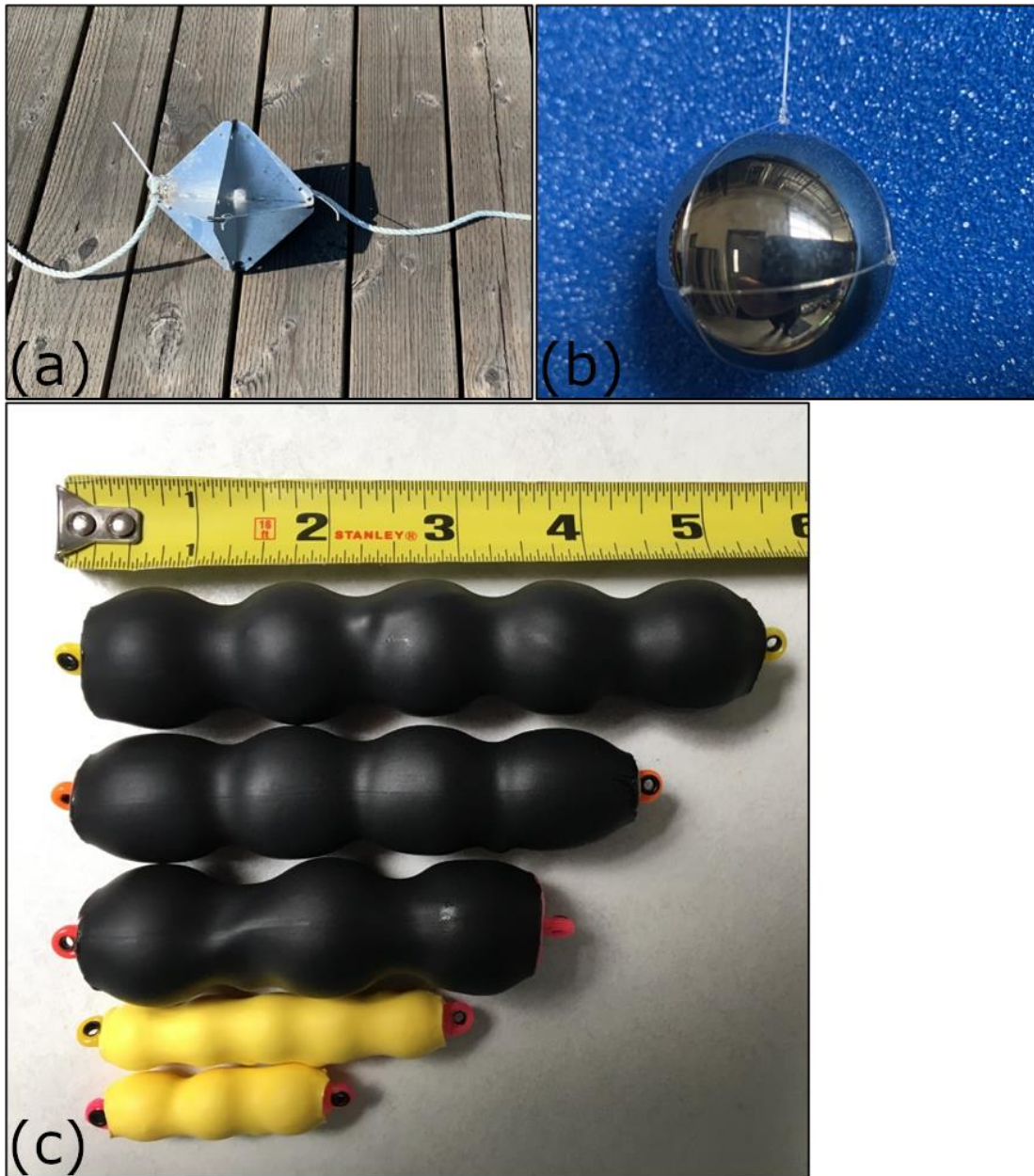


Figure 8. (a) Radar reflector, (b) calibration sphere, and (c) air-filled spheres.

#### 4.2.2 Phase 2 Single Target Test Run Choreography

All tests for Phase 2 were performed as described here. The sensor suite was aimed toward shore so that one of the BioSonics Sonar transducers was parallel to the edge of the dock (Figure 12). We configured the BioSonics Sonar to collect data from the 0 m to 15 m range on all transducers. The archiving software was configured as follows:

- ROI: 0–10 m on all transducers for BV; 0–5 m on all transducers for BF
- Interval Length: 10 seconds for both BV and BF
- Interval Criterion: Echo-based; archive if 10 or more echoes with TSs of at least  $-50$  dB were detected within the Interval Length; same settings for both BV and BF.

Note that the BioSonics Sonar was collecting data to a range that extended beyond both ROI for archiving. This allowed us to start each run with the target outside the ROIs, but to identify the target visually on the echogram to make sure the target was in the appropriate starting position and the sensors were aimed properly. We also enabled VisAcq's Clutter Mapping feature during our testing. This feature maps static objects in each beam and subtracts their regions from the FOV. This allows VisAcq to ignore static dock structures that were strong acoustic targets within the FOV of the BioSonics transducers. The tradeoff is that moving targets through these subtracted regions will not be detected or will be detected intermittently. This tradeoff was worth it for our testing—there were so many static structures in the FOV that without the Clutter Map, VisAcq would have been detecting targets constantly. The Clutter Map did not prevent any of our test targets from being detected. However, we believe the Clutter Map did decrease the maximum range at which some targets were detected.

Each run began with a target suspended in the water from a hand-held pole so that the target was 1 m off the edge of the dock and 11 m from the sensor suite, at the same depth as the BioSonics Sonar beams. A weight was attached below the target, out of view of the sensors (causing no visual detection with BF or backscatter with BioSonics Sonar or BV), so that the target would stay at the same depth as it was moved. In this starting position, the target would be visible on the BioSonics Sonar echogram displays for one or more transducers but would not cause any snippet archiving to occur because it was outside the ROI (0 m–10 m). We then walked the suspended target in and lifted it from the water just in front (<0.5 m) of the sensor suite, enabling a visual detection by the BF (Figure 7). While the target was moving in, we observed software displays but did not interact with the software (i.e., the software ran without human intervention). We performed the following tasks during each run:

- We noted whether the return signal from the target was visually detectable on the BioSonics Sonar echogram display (Figure 9) when it was initially placed in the water at 11 m, enabling us to confirm we were in the proper starting configuration for the run.
- As the target was moved toward the sensor suite, we monitored the BioSonics Sonar echogram and noted the time when its range from the sensors reached 10 m ( $T_{10}$ ), indicating that the target was within the ROI for BV archiving.
- As the target continued moving toward the sensor suite, we monitored the BioSonics Sonar echogram and noted the time when its range from the sensors reached 5 m ( $T_5$ ), indicating that the target was within the ROI for BF archiving.
- We noted whether the PCP real-time display (see Section A.1.2 in the appendix) showed echo detections and snippet creation for both BV and BF.
- We noted the time when the target reached the sensor suite and was pulled from the water ( $T_0$ ).
- We noted whether the STS utility created a snippet data file for both the BV and the BF when the target was in the appropriate ROI. For the BV snippet, we noted the start time ( $BV_{start}$ ) and end time ( $BV_{end}$ ) of the BV data in the snippet. For the BF snippet, we noted the start time ( $BF_{start}$ ) and end time ( $BF_{end}$ ) of the BF data in the snippet.
- We noted whether the target could be visually detected in the BV snippet at ranges <10 m (Figure 10) and in the BF snippet at ranges <5 m (Figure 11).

Performing all these tasks in real-time with a single human reviewer was difficult, so we completed them and double-checked our results for several hours after tests by playing back each run.



In Phase 2, targets moved toward the sensors at about 0.3 m/s. This is slow compared to the current speeds at turbine sites but was necessary in order to keep the targets in known, controlled positions in the sensor FOVs. At a turbine site, faster currents would be a reality, but the system would also start detecting targets at a longer range. In particularly challenging environments, it might be necessary to increase the sensitivity of the archiving process (for example, decrease the number of echoes that are required within a certain time bin to cause archiving to be triggered) so that targets moving quickly through the acoustic beam would still trigger archiving. However, the tradeoff could be that the system is more vulnerable to archiving spurious snippets because of noise in the sonar signal. Optimal deployment at a particular site will require consideration of sensor aim and water flow patterns and tuning the archiving parameters appropriately to achieve the best possible reduction in secondary sensor data volume.

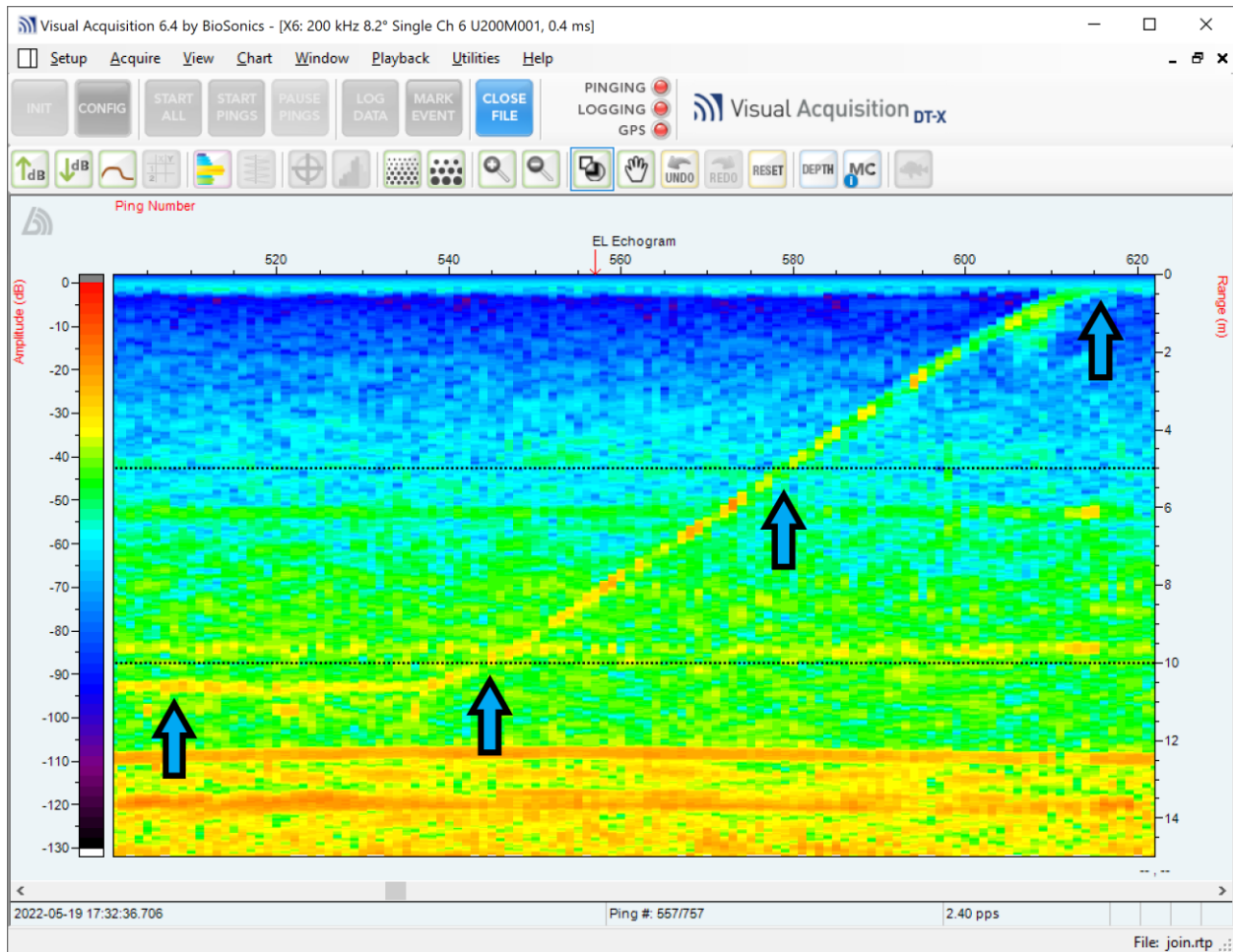


Figure 9. BioSonics Sonar echogram with target strength in color (left side), range in meters (right side), and time in seconds on the horizontal axis. This shows the RR target (amplitude ranging from approximately -40 dB to -20 dB) in the water with arrows showing the target stationary at 11 m, beginning to move toward the sensor suite at 10 m, 5 m, and out of water at 0 m.

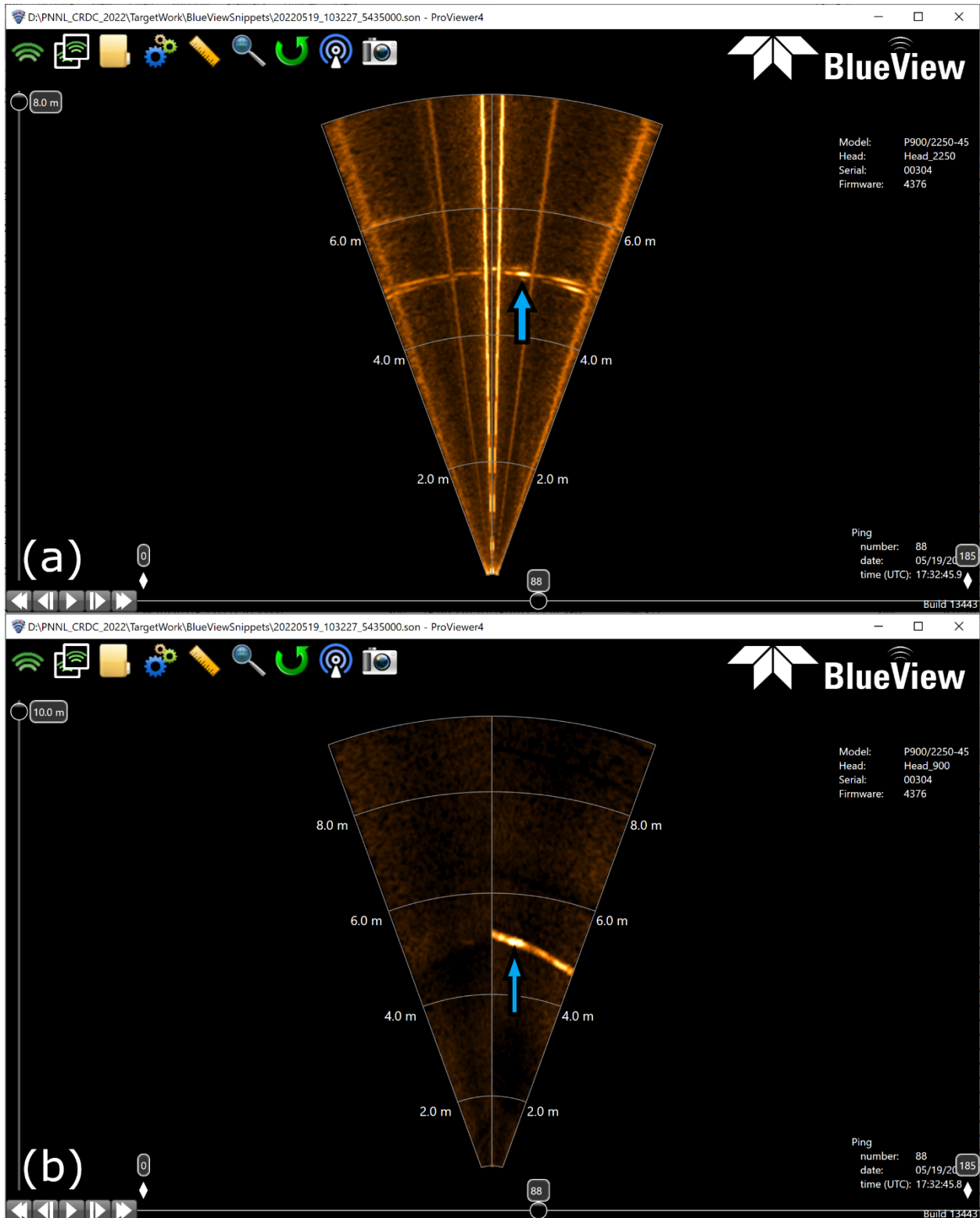


Figure 10. BV display showing RR target at 5 m range in (a) 2,250 kHz data and (b) 900 kHz data.



Figure 11. BF display showing RR target just before it is pulled from the water at the end of the test run.

The sensor suite was aimed in three different directions at various times during Phase 2. In Aim 1, the midline of the BioSonic Sonar FOV ran along the edge of the dock, so the target was detected mostly in X6 and X7 (Figure 12(a)). In Aim 2, the midline of the FOV was 20 degrees out from the dock, so that the target was detected mostly in X9 and X10 (Figure 12(b)). In Aim 3, the midline of the FOV was 20 degrees toward the dock, so that the target was detected mostly in X3 and X4 (Figure 12(c)). Target detection, data logging, and snippet archiving were successful in all three of these configurations, demonstrating that targets anywhere in the FOV of the BioSonic Sonar can successfully trigger snippet archiving.

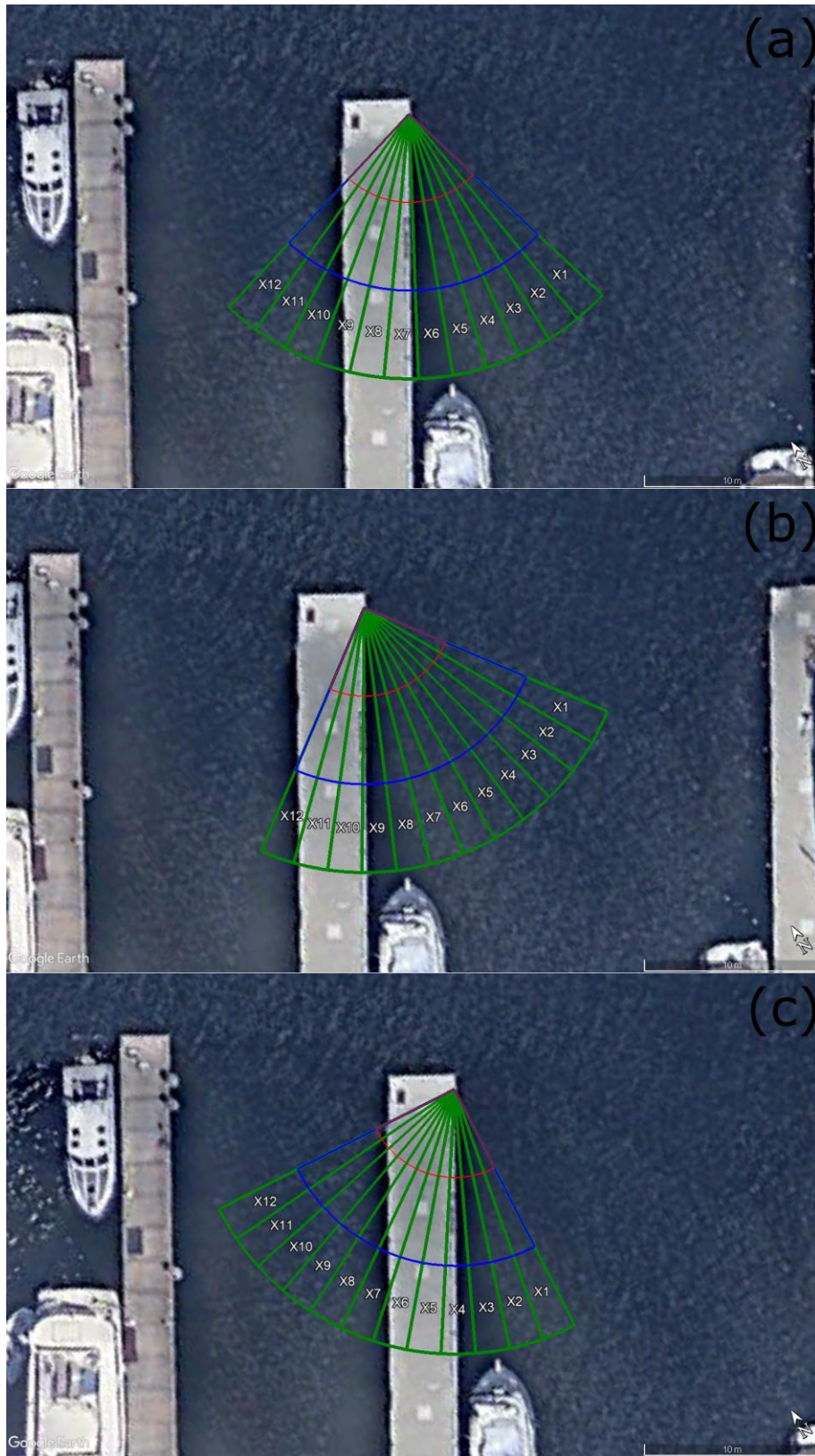


Figure 12. Phase 2 sensor suite aiming: (a) Aim 1; (b) Aim 2; (c) Aim 3.

### 4.2.3 Phase 2 Test Run Results

We performed 32 target runs during Phase 2. Table 2 shows the times when the target was within the ROIs, and the start and end times of the created snippets.

Table 2. Target progress and snippet times for single target Phase 2 runs.

Run	Target	Aim	Time Target at 10 m on Echogram (T <sub>10</sub> )	Time Target at 5 m on Echogram (T <sub>5</sub> )	Time Target Out of Water (T <sub>0</sub> )	BV Snippet Start Time (BV <sub>start</sub> )	BF Snippet Start Time (BF <sub>start</sub> )	BV Snippet End Time (BV <sub>end</sub> )	BF Snippet End Time (BF <sub>end</sub> )
1			10:30:50	10:31:05	10:31:19	10:30:47	10:30:57	10:31:36	10:31:25
2		1	10:32:31	10:32:45	10:33:00	10:32:27	10:32:37	10:33:06	10:33:05
3	RR	2	10:38:54	10:39:09	10:39:23	10:38:55	10:39:01	10:39:31	10:39:31
4			10:42:59	10:43:14	10:43:27	10:42:57	10:43:07	10:43:34	10:43:34
5		3	10:48:52	10:49:06	10:49:19	10:48:47	10:48:57	10:49:27	10:49:27
6			10:50:16	10:50:29	10:50:44	10:50:15	10:50:21	10:50:52	10:50:52
7			11:02:12	11:02:30	11:02:43	11:02:26	11:02:26	11:02:48	11:02:48
8		1	11:05:35	11:05:50	11:06:03	11:05:49	11:05:49	11:06:05	11:06:05
9	CS		11:07:08	11:07:24	11:07:38	11:07:20	11:07:20	11:07:42	11:07:42
10			11:10:07	11:11:43	11:11:55	11:11:35	11:11:38	11:12:01	11:12:01
11		2	11:16:17	11:16:35	11:16:53	11:16:31	11:16:31	11:16:58	11:16:58
12			11:18:51	11:19:09	11:19:27	11:19:05	11:19:06	11:19:30	11:19:30
13		1	11:45:24	11:45:48	11:46:11	11:45:40	11:45:44	11:46:14	11:46:14
14	5B		11:47:37	11:47:59	11:48:19	11:47:52	11:47:53	11:48:23	11:48:23
15		2	11:50:43	11:51:02	11:51:22	11:50:56	11:50:58	11:51:25	11:51:25
16			11:53:10	11:53:30	11:53:48	11:53:16	11:53:22	11:53:54	11:53:54
17		1	11:57:43	11:58:04	11:58:21	11:57:57	11:57:59	11:58:26	11:58:26
18	4B		11:59:02	11:59:24	11:59:44	11:59:13	11:59:18	11:59:44	11:59:44
19		2	12:01:54	12:02:14	12:02:34	12:02:06	12:02:09	12:02:39	12:02:39
20			12:03:51	12:04:10	12:04:31	12:04:04	12:04:05	12:04:33	12:04:33
21		1	12:07:02	12:07:24	12:07:42	12:07:17	12:07:19	12:07:43	12:07:43
22	3B		12:08:54	12:09:13	12:09:33	12:09:08	12:09:10	12:09:33	12:09:33
23		2	12:12:06	12:12:27	12:12:48	12:12:26	12:12:26	12:12:49	12:12:49
24			12:13:36	12:13:57	12:14:18	12:13:54	12:13:54	12:14:16	12:14:16
25		1	13:04:34	13:04:56	13:05:18	13:04:38	13:04:50	13:05:20	13:05:20
26	5L		13:08:35	13:08:54	13:09:09	13:08:38	13:08:47	13:09:11	13:09:11
27		2	13:11:26	13:11:43	13:12:04	13:11:33	13:11:36	13:12:03	13:12:03
28			13:13:21	13:13:38	13:13:55	13:13:30	13:13:32	13:13:56	13:13:56
29		1	13:16:55	13:17:18	13:17:41	13:17:12	13:17:15	13:17:44	13:17:44
30	3L		13:18:50	13:19:08	13:19:26	13:18:59	13:19:04	13:19:26	13:19:26
31		2	13:21:35	13:21:52	13:22:09	13:21:47	13:21:47	13:22:11	13:22:11
32			13:22:49	13:23:07	13:23:30	13:23:02	13:23:02	13:23:30	13:23:30

The success of the archiving software is defined as when a snippet data file is created for the secondary BV and BF sensors for the times when each target is within the ROIs. For the BV, the ROI was 10 m or less and for the BF it was 5 m or less. To quantify this success, it is important to be consistent when determining if a created snippet covers the appropriate times when the target was in the ROI for both the BV and the BF (Table 3). For the beginning of a snippet time, this was accomplished for the BV by subtracting the  $BV_{start}$  (the start time of a particular BV snippet) from  $T_{10}$  (the start time when a particular target was at range 10 m in the BioSonics Sonar). For the end of the snippet time,  $T_0$  was subtracted from  $BV_{end}$ . Both of these differences, if the archiving software was successful, will be positive. The same calculations were done when determining the success of the beginning and end times of BF snippets, except we used  $BF_{start}$ ,  $BF_{end}$ ,  $T_5$ , and  $T_0$ . Furthermore, we use the  $Range_{1stEcho}$  value to show where the BioSonics Sonar first algorithmically detected the target. Ideally, this would be 10 m, but it varied depending on target size and target movement related to operator variability (i.e., speed and exact location of target in water column, including position relative to acoustic reflections from dock structures). Lastly, we qualitatively addressed the success of the archiving software by documenting target detection in both BV operating frequencies and the BF with a human reviewer in post-processing. This assumes that if a human reviewer saw the target in the BV or BF during target testing, then a snippet should have been archived. We highlight deviations or failures in yellow (Table 3).

Table 3. Target progress vs. snippet times and detectability in snippets.

Run	Target	Aim	T <sub>10</sub> - BV <sub>start</sub> (s)	T <sub>5</sub> - BF <sub>start</sub> (s)	BV <sub>end</sub> -T <sub>0</sub> (s)	BF <sub>end</sub> -T <sub>0</sub> (s)	Range <sub>1stEcho</sub> (m)	BV900 Visual (Y/N)	BV2250 Visual (Y/N)	BF Visual (Y/N)
1			3	8	17	6	9.8	Y	Y	Y
2		1	4	8	6	5	9.8	Y	Y	Y
3	RR	2	-1	8	8	8	9.9	N	Y	Y
4		2	2	7	7	7	8.9	N	Y	Y
5		3	5	9	8	8	9.7	Y	Y	Y
6			1	8	8	8	9.9	Y	Y	Y
7			-14	4	5	5	4.2	Y	Y	Y
8		1	-14	1	2	2	3.1	Y	Y	Y
9	CS		-12	4	4	4	4.5	Y	Y	Y
10			-88	5	6	6	6.5	Y	Y	Y
11		2	-14	4	5	5	4.4	Y	Y	Y
12			-14	3	3	3	5.7	Y	Y	Y
13		1	-16	4	3	3	7.2	Y	Y	Y
14	5B		-15	6	4	4	5.3	Y	Y	Y
15			-13	4	3	3	6.6	N	Y	Y
16		2	-6	8	6	6	7.2	N	Y	Y
17		1	-14	5	5	5	6.6	Y	Y	Y
18	4B		-11	6	0	0	6.9	Y	Y	Y
19			-12	5	5	5	6.8	N	Y	Y
20		2	-13	5	2	2	6.5	N	Y	Y
21		1	-15	5	1	1	5.7	Y	Y	Y
22	3B		-14	3	0	0	5.3	Y	Y	Y
23			-20	1	1	1	3.8	N	Y	Y
24		2	-18	3	-2	-2	4.7	Y	Y	Y
25		1	-4	6	2	2	8.2	Y	Y	Y
26	5L		-3	7	2	2	7.5	Y	Y	Y
27			-7	7	-1	-1	6.2	N	Y	Y
28		2	-9	6	1	1	6.4	Y	Y	Y
29		1	-17	3	3	3	5.6	Y	Y	Y
30	3L		-9	4	0	0	6	Y	Y	Y
31			-12	5	2	2	4.8	N	Y	Y
32		2	-13	5	0	0	4.7	N	Y	Y

All runs except 1, 2, 4, 5, and 6 have negative values for T<sub>10</sub> - BV<sub>start</sub>. This indicates that the remainder of the runs in Phase 2 have BV snippets that do not cover the entire time the target was within the 10 m range. The snippet begin time is too late. Review of the data indicates that this is due to the BioSonics Sonar not detecting the targets as echoes immediately after they come within the 10 m range. The range at which the target was first detected as an echo is included in Table 3 as Range<sub>1stEcho</sub>. For a target to be detected as an echo, the TS had to be >-50 dB, based on what our Interval Criterion was set to. All targets met this threshold, so in clear open water, away from static structures like dock pilings, they would likely have been detected at the 10 m range. Because of the dock structures present, we had the Clutter Map

feature in VisAcq operating—otherwise, VisAcq would have been constantly detecting the dock structures as targets. The Clutter Map was configured to ignore a target unless its TS was at least 10 dB larger than the level of background signal at its range. There was significant background signal level present. For example, in Figure 9 you can see that starting at around 6 m range, the background signal level is green, which is somewhere between -50 and -40 dB. This effectively raised the target detection threshold in that Clutter Mapped region to somewhere between -40 and -30 dB, which meant that many of the targets were harder to detect when they were in this region. In other words, the -50 dB TS Interval Criterion became -40 dB or higher in the Clutter Mapped regions. This was less of an issue with the RR target because it is such a strong reflector and easily exceeded even a -30 dB threshold.

When the system is deployed at an actual turbine site, having structures in the sonar FOV, e.g., parts of the turbine, may be unavoidable, so the Clutter Map may be an important tool to use to reduce spurious detections caused by these structures. The Clutter Map in VisAcq has several configuration parameters, such as the amount by which a target must exceed the level of background signal (which we had set to 10dB). In this work, we did not focus on optimizing these settings in the field. However, the interactions we observed between the Clutter Map and the detectability of targets at various ranges makes clear the importance of carefully tuning these parameters when optimizing the system for a particular site.

One way to mitigate snippets starting too late would be to use a positive value for the padding parameter (see Section A.1.1 in the appendix) to extend the beginning of snippets. A value of 20 seconds would have fixed this issue for all runs except Run 10. We were using a value of 0 in our testing. Another way of handling significant background noise would be to configure a more complex ROI for the archiving software, excluding regions where strong background noise exists. This would have been difficult to do during our testing because we were changing the sensor suite's aim so frequently. However, for a long, fixed deployment, doing so might be better than using the Clutter Map. For example, if we wanted our ROI to be from 0–10 m on all transducers, but on X2 there was a dock piling that showed up as a strong fixed target at a range of 5.25 to 5.75 m, then we could configure the ROI to go from 0–5 m and 6–10 m on X2, so the dock piling would not be counted as a target for archiving purposes.

For Run 10, the value for  $T_{10} - BV_{\text{start}}$  is -88 seconds. This is due to a mistake in the choreography of that run. Instead of starting the run with the target beyond the 10 m range, it was started with the target holding in place at less than the 10 m range. So, the -88 second gap shown in the first column includes the time when we were holding the target in place, just inside the 10 m range, waiting to move it toward the sensor suite. The target was first placed in this position at 11:10:07, and we started moving it in at 11:11:30. The BV snippet started at 11:11:35, which was only 5 seconds after we started moving the target in.

The BF archiving was successful—all the BF snippets started before the target reached 5 m.

There are two runs, 24 and 27, where the snippets (both BV and BF) ended slightly before the target was pulled out of the water. This is because on those two runs we did not keep the target well centered in the transducer beams as we got very close to the transducers, where the beams are very narrow. Because of this, the targets stopped being detected as echoes farther from the transducers than on the other runs. This was minor operator error but important to note for targets at close range in an actual field setting. Transducers with wider angle beams are available and they might be a good choice if targets of interest are known to only be at short ranges from the transducers. Additionally, multiple narrow-angle transducers like the ones used in this test can also be configured in a stacked array, increasing the FOV vertically if needed.



There were 10 runs when the sensor suite was oriented in Aim 2 where the targets were not visible in the BV 900 kHz snippet data. They were always visible in the BV 2,250 kHz snippet data, so we know that the snippets covered times when the target was in the FOV. However, in Aim 2, the targets were very close to the right edge of the BV FOV, and in general, the targets we used showed up less strongly in the BV 900 kHz data than in the BV 2,250 kHz data. In a real field setting, the user would likely pan the whole sensor suite a few degrees if collocated or reorient the BV by itself if mounted separately from the BioSonics Sonar. The visual failures on these runs are not of concern and are not indicative of either sensor or software limitation.

After Phase 2 target testing, from 13:47:40 to 13:53:30, we ran the archiving software without placing any targets in the water. During this time, the archiving software did not create any snippets, as intended.

#### **4.2.4 Phase 3 Exploratory Target Runs**

Between 14:00 and 14:25, we performed other target runs from the dock with the sensor suite in Aim 1. These runs were ad hoc, exploring the capabilities of the system, so we are describing them informally, and separately from the formal runs of Phase 1 that achieved our primary objectives.

##### **4.2.4.1 Two Simultaneous Targets at Different Ranges**

We performed three runs in Aim 1 using two different targets (3S & 5S), moved simultaneously toward the sensors from the same direction (so they were detected by the same transducer like in all Phase 2 runs), but at different ranges. During the first of these runs we moved the targets at the same speed as in the Phase 2 runs. During the second and third run we moved the targets much faster. In the first run, snippets were created as expected. In the second run, where the targets were being moved much faster, no snippets were created. The target signatures observed on the echogram were much weaker than expected. The likely explanation is that the quicker movement caused the targets to rise in the water column, because the line suspending them was pushed off vertical by the increased water drag. In the third run, the target signatures were still weaker than expected. They were strong enough to be detected as echoes and cause snippets to be created, but the snippets started when the targets were fairly close to the transducers. We did not change the archiving configuration before we did the faster runs. In an actual deployment, the speed of targets will generally be expected to fall into a certain range near the speed of the water current, and that should be considered when deciding on the size of the time bins for archiving, and the number of echoes required within a time bin for archiving to be triggered. This is a good example of the need to tune the parameters such as ROI, Interval Length, and Interval Criterion to achieve meaningful results.

##### **4.2.4.2 Two Simultaneous Targets at Same Range**

Two runs were conducted in Aim 1 with targets 3S & 5S approaching the sensors from different directions, so one target was visible in transducer X5, and one target was visible in transducer X6. We performed these runs with the targets moving at the same speed as in the Phase 2 runs and in both runs snippets were created as expected. Because the configured ROIs for archiving included all the transducers, echoes from both targets were included in the count regardless of which transducer the target was visible in.

#### 4.2.4.3 Single Target Through Multiple Transducers

We performed five runs moving one target (3S) through multiple transducer beams at ranges <5 m. In all of these runs, snippets were created as expected. Again, because the ROI was configured to include all transducers, it did not matter which transducer a target was visible in, as long as the signal was strong enough to be detected as an echo based on the Interval Criterion. Figure 13 shows the echoes detected by the BioSonics Sonar during one of these runs as the target was moved from transducer X7 to transducer X1, slightly decreasing the range from the sensor suite. The archiving software works if a target is detected in one or more beams and this example makes this clear.

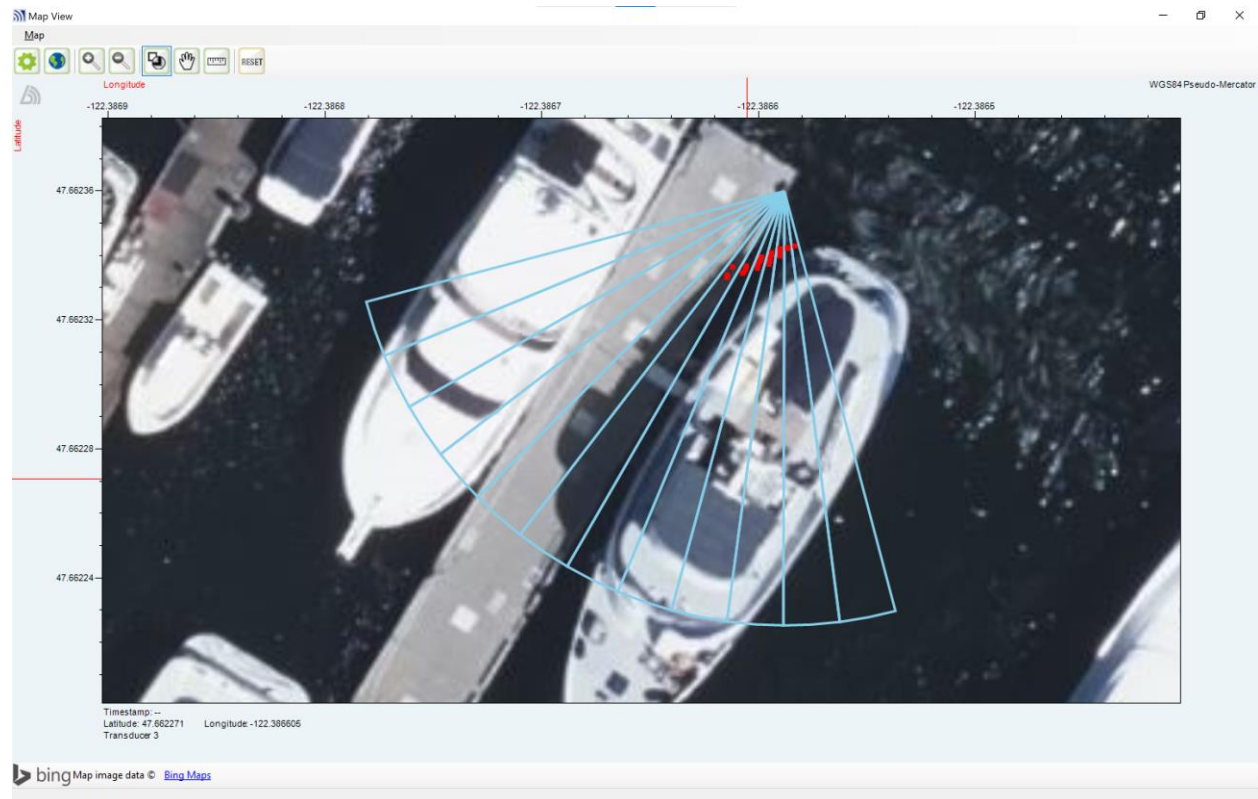


Figure 13. Target being moved from X7 to X1. Note that the boat on the right side of the dock was not present at the time of testing; it was present when the satellite image used by Bing Maps was captured.

#### 4.2.4.4 Longer-Range Detection

For the last component of Phase 3, we changed the aim of the sensor suite to point toward the adjacent dock to the east, termed “Aim 4” (Figure 14). We increased the collection range for the BioSonics Sonar to 30 m and increased the ROI for BV archiving to 22 m, so it reached the adjacent dock. The ROI for the BF remained 0 m–5 m due to visibility limitations in the water. We started the archiving software with no target in the water, verified that the sonar was not detecting any targets, then introduced target 3S at 2 m in front of the adjacent dock so it was approximately 20 m from the sensor suite. The archiving software successfully detected the target in transducer X6 and created a BV snippet (14:35:46–14:36:32) for the time the target was in the water (14:35:50–14:36:30). This demonstrates snippet archiving being triggered by a

target 20 m away from the transducers. No BF snippet was created because the target was not within the 0 m–5 m ROI for BF archiving.

During the second run, target 3S was in the water from 14:36:57 to 14:39:10. The archiving software created BV snippets covering 14:36:54 to 14:39:12. These snippets covered the beginning with 3 seconds prior to target detection (i.e., a three-second margin) and covered the end with a two-second margin. However, during the whole run, there was a gap in the snippets of 9 seconds and one of 6 seconds. These gaps occurred because the target was not reflecting strongly enough to make it through the Clutter Map and be detected as an echo at these times. Additionally, we had increased the collection range on the BioSonics Sonar for these runs from 15 to 30 m compared to the Phase 2 runs and the transducers were not able to ping as fast due to increased sound travel time (out to 30 m and back instead of out to 15 m and back). In Phase 2 runs, the BioSonics Sonar had 2.4 pings per second per transducer, but for this set of runs it was 1.5 pings per second per transducer. Furthermore, our Interval Criterion was still set to require 10 echoes to be detected within the 10-second Interval Length for archiving to occur. This effectively required the target to be detected 10 times out of every 15 pings (67% of the time) for archiving to occur, whereas in the Phase 2 runs we were requiring the target to be detected 10 times out of every 24 pings (only 42% of the time). So, in these runs we unintentionally increased the percentage of pings in which the target was required to be detected for archiving to occur. This is a dependency between configuration parameters that we did not calculate prior to collecting data and exemplifies the necessity for properly tuning the archiving parameters to collect meaningful data. This example also makes clear the need for early testing of data collection at a new site. Time should be budgeted to allow for example data sets for post-processing to check for dependencies like the one we encountered here, and we propose at the end of this report that beta testing in a field setting is the logical next step to addressing this.

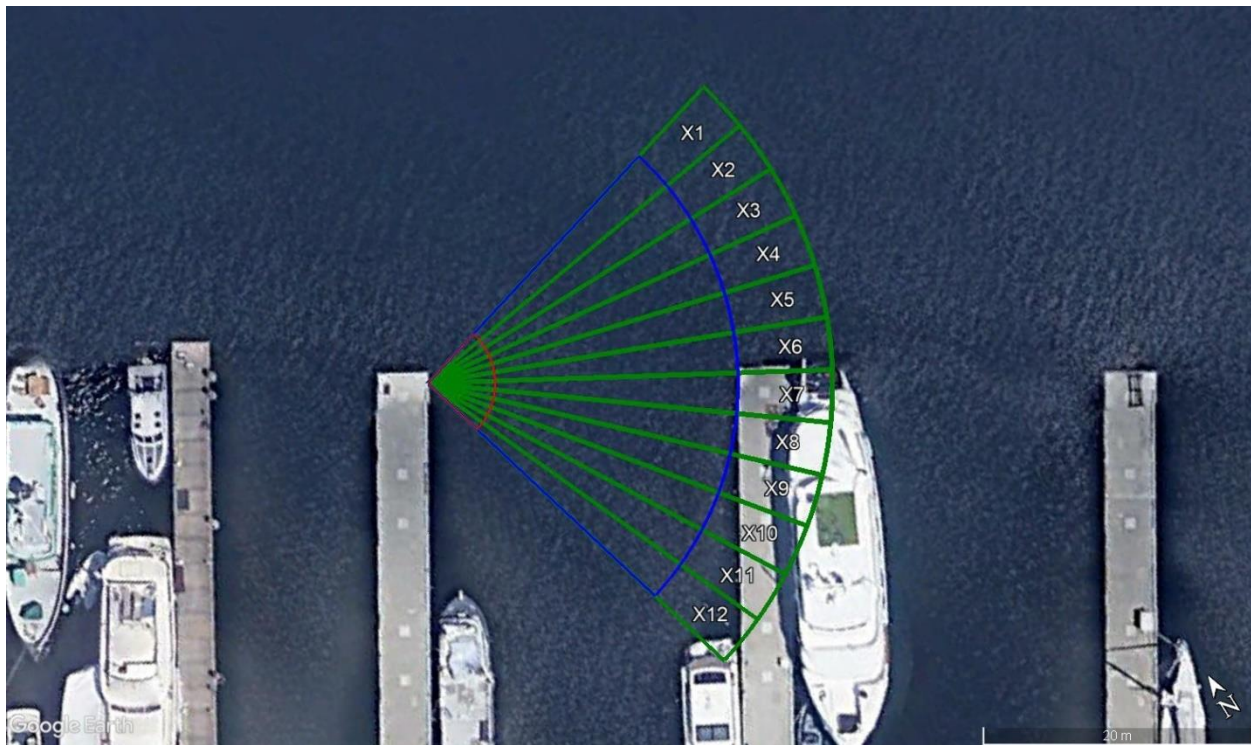


Figure 14. Aim 4 for target testing from adjacent dock.

#### 4.2.4.5 Single Target through Multiple Transducers

Still maintaining Aim 4, we decreased the BioSonics Sonar collection range to 10 m and changed the BV archiving ROI to 0–10 m. Our final two tests involved putting target 3S in the water and moving it through (almost) all the transducers—we managed to cover every transducer except X12, which was out of reach of the person manually moving the target. Figure 15 shows the BioSonics Sonar-detected echoes for one of these tests, where we moved the target from transducer X1 through to transducer X11, and then back to X1. During this test other targets were detected around the 7 m range in X5, which likely correspond to fish or debris. In both of these tests, BV and BF snippets were created as expected, thereby demonstrating snippet archiving being triggered by targets detected in any of the transducers in the ROI.

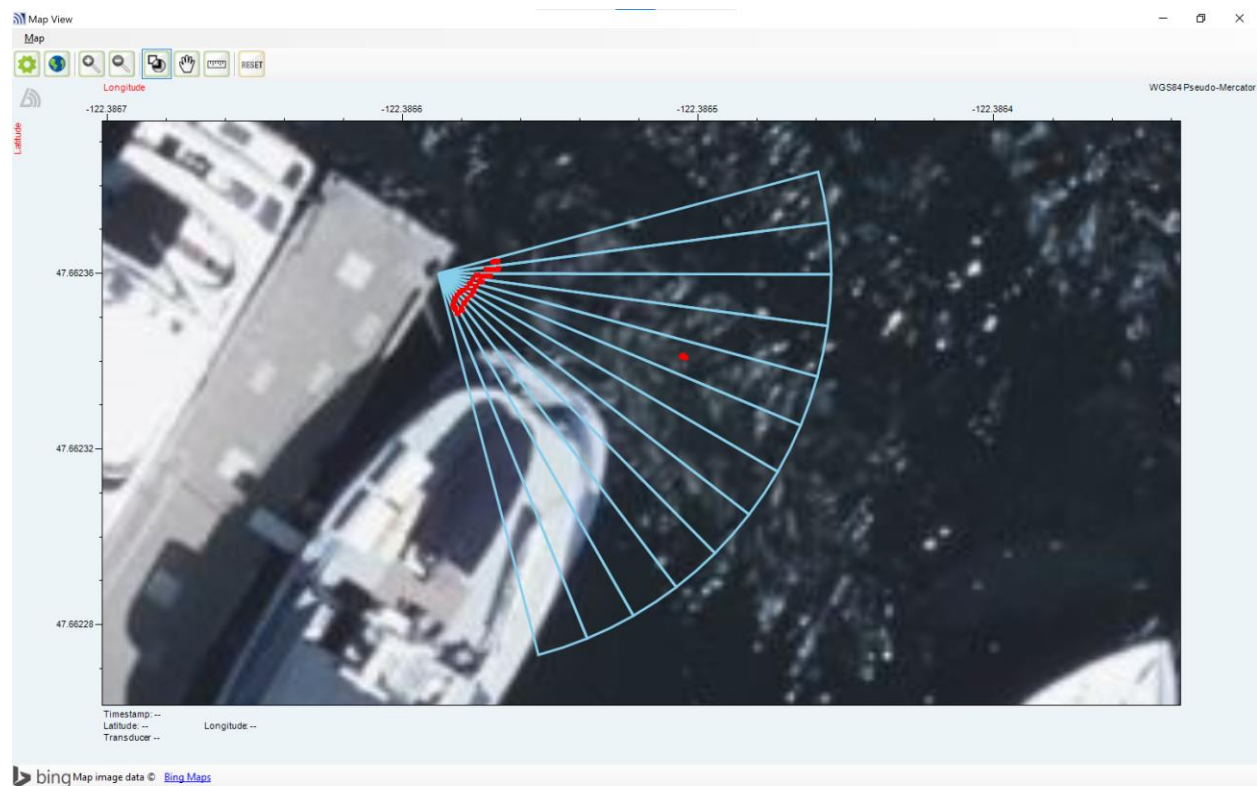


Figure 15. Target 3S going through beams X1 to X11 and back to X1. Note that the boat on the right side of the dock was not present at the time of testing; it was present when the satellite image used by Bing Maps was captured.

#### 4.2.5 Spurious and False-Positive Snippets

Between about 13:12 and 14:42, we had an intermittent issue with BioSonics Sonar transducer X3. At random times it would stop transmitting and receiving due to a bad cable connection. When this occurred, it caused the acoustic data for the X3 transducer to be much weaker than normal (Figure 16).

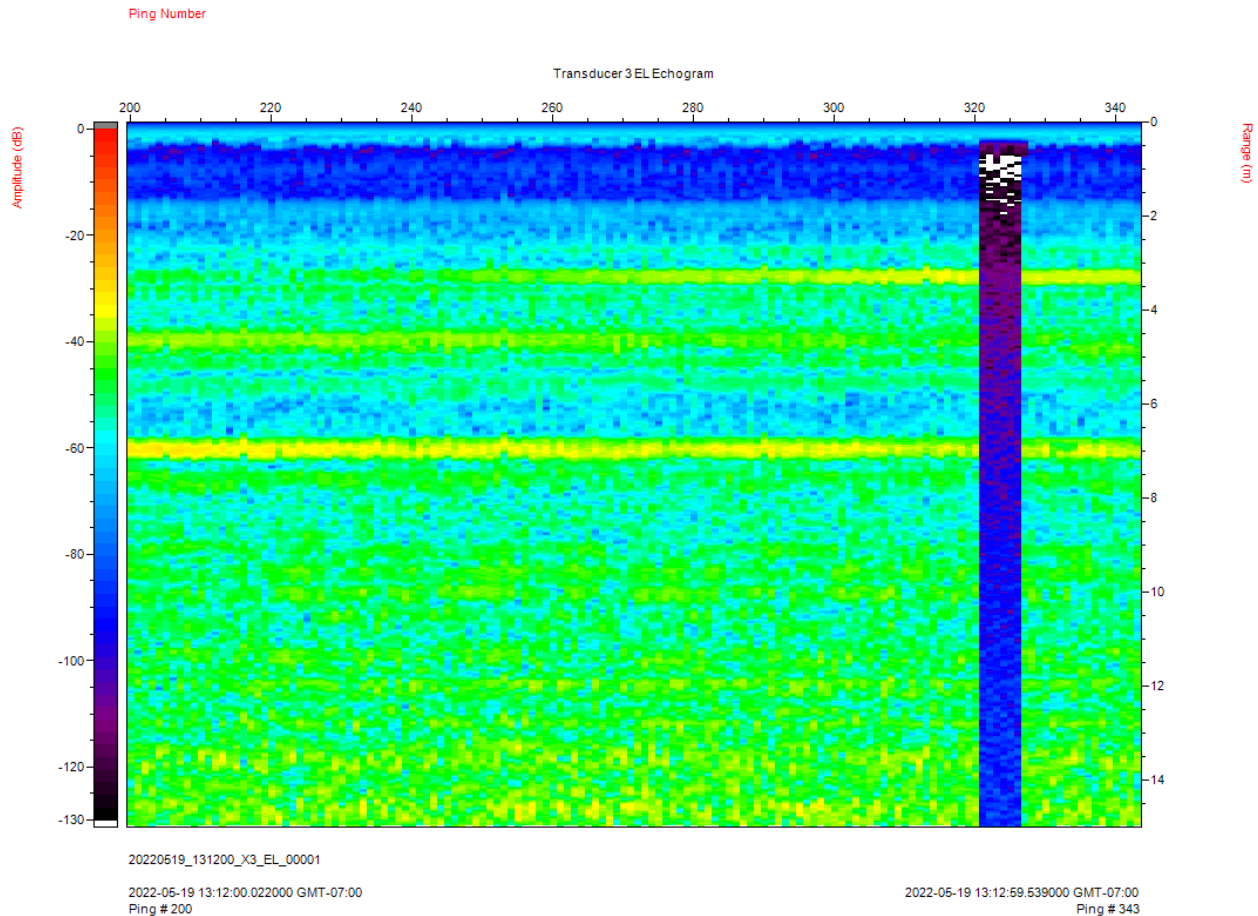


Figure 16. BioSonics Sonar echogram showing X3 not transmitting properly for pings 321–326.

When this occurred, we were not able to properly detect targets within X3’s beam. This was a minor issue because we rarely had targets in this transducer beam. The more significant issue was when this loss of transmission happened at the start of a run, when we were initializing the Clutter Map feature of the BioSonics Sonar. During this phase, at startup, VisAcq references the first 100 pings on each transducer to build the Clutter Map “baseline” of the static targets present in the environment at each range from each transducer. After that, it ignores signals unless they are stronger than the baseline. When X3 was not transmitting during the initialization, the Clutter Map baseline for X3 was artificially low and when it began transmitting after Clutter Map initialization was complete, the level of detected targets was artificially high because static targets such as the dock structure were not properly ignored by the Clutter Map. This caused “spurious snippets” during the 90-minute testing window during which this issue occurred. This created a set of false-positive target detections and associated snippets. Except for this issue, the archiving software did not create any snippets at times when targets were not in the water (i.e., false positives).

## 5 Conclusions

In the first stage of this project (previous effort), we successfully demonstrated the proof-of-concept of using BioSonics Sonar data to determine when targets of interest, like the targets one would be interested in monitoring near a turbine, were present in the FOV (one or more transducer beams). We showed that we could use the results of that analysis to create data files from secondary sensors, including just the time periods when targets of interest were present. At the conclusion of BP1, our system was at Technology Readiness Level (TRL) 3. The analysis of the BioSonics Sonar data and the creation of data files from secondary sensors were not fully automated and had to be done manually in post-processing in the first stage. Testing of the system was limited to a few target types, short ranges (<4 m), and with the BioSonics Sonar only covering a 30-degree FOV.

In this stage of the project (this report), we developed and tested software that automated the process of analyzing the BioSonics Sonar data for target detection and creating secondary sensor data files for time periods when targets of interest were present. The present version of the archiving software runs without user intervention and creates the secondary sensor data files in near-real-time. It is agile and highly configurable to allow optimization of performance at sites that have different physical characteristics and different types of targets of interest. We tested the full system in a controlled but realistic environment with seven types of targets, and successfully triggered archiving of secondary sensor data when targets were at up to 10 m range in Phase 2 and up to 20 m range in Phase 3, over the full 90-degree FOV of the BioSonics Sonar, thereby satisfying the objectives of expanding the region of archiving over BP1 (>4 m range and >30-degree FOV). The system operated continuously, without user intervention, for 16 hours on one occasion, and for 17.5 hours on another occasion. At the conclusion of this project, the system is at TRL 4. All components are operating as an integrated system that is ready to be tested near an actual turbine or configured in a new orientation depending on the site chosen for beta testing.

During our testing, the software performed as intended. Archiving of secondary sensor data was successful in every formal target run. In the cases where the archived BV data did not cover the entire time the target was in the ROI, this was due to the difficulties of detecting targets in a complex environment when Clutter Mapping is being used. This issue could likely have been improved by making the Clutter Map parameters slightly less aggressive (allowing more targets through the Clutter Map), or by defining the ROIs for the archiving software more carefully, reducing the need for Clutter Mapping.

The testing we performed in this project was carefully controlled. It was performed in an environment that, while it had a lot of boats and dock structures that complicated the acoustic environment, did not have significant water current, debris, or entrained air. All these factors are likely to be present at a site with an operational turbine and can make sonar target detection more difficult. Further testing at such sites will be needed to optimize sonar target detection in such environments. This testing will also be needed to examine the best ways to locate and aim the various sensors in the system to make optimal use of their capabilities and work around their limitations. The configurability of this system allows for multiple types of sensors that can be collocated or separated in space. For example, the BV and acoustic cameras in general have longer effective ranges than video cameras and can give range information about targets, but are quite expensive, often have smaller FOVs, and can have a harder time detecting targets that are in certain orientations. Conversely, video cameras are much cheaper and can have

quite wide FOVs, but they do not perform well under conditions of limited visibility and do not provide range information for targets.

We believe that this system has the potential to significantly reduce the volume of acoustic camera or video camera data that must be reviewed in order to provide sufficient monitoring of fish interactions with current energy converter turbines, thereby significantly reducing the cost of such monitoring. This system also provides data on targets approaching a turbine at different ranges and are good candidates for encounter risk model inputs.

Beta testing the system in an energetic location or at a turbine deployment site, perhaps even alongside an existing operational turbine, is the exciting next step!

## 6 Next Steps

The project team successfully developed specialized archiving software that has the potential to reduce the time and effort needed to collect data in the vicinity of operational current energy converters to assess animal interactions. The utility of this software was demonstrated using an integrated sensor suite. Field testing was conducted dockside using a variety of simulated “fish sized” targets.

The project team believes that the next steps should be focused on beta field testing various configurations of the sensor suite and archiving software at a site where a current energy converter turbine is deployed or at a potential deployment site. The goal of this field testing would be to advance the TRL of the integrated system from its current TRL 4 state up to a TRL 6 state and demonstrate a prototype system that is capable of efficiently collecting data.

A logical site at which to conduct these field tests would be the Igiugig Village Council and Ocean Renewable Power Company (IVC/OPRC) RivGen® Project in the Kvichak River, Alaska (Federal Energy Regulatory Commission Docket P-13511). The project has a current energy converter turbine deployed, and a second device deployment is pending. Additionally, the site has a significant migratory salmon population. So, while beta field testing various configurations of the sensor suite and archiving software for functional optimization, the project would, at the same time, provide valuable data about smolt passage and device interaction, which is of great interest to project stakeholders, resource managers, and regulators.

Many communities in Alaska that are targeted for renewable energy additions, such as river current-based electrical power solutions, are located along river systems that have salmon migration runs that are critical to the economy and cultural heritage. There is regulator and other stakeholder concern that turbines may interfere with migrating salmon. This concern is a barrier to project permitting and slows industry technology testing. Some research questions that need to be addressed to address these concerns and reduce or remove the monitoring barrier include the following:

1. What proportion of out-migrating salmon smolts pass through the zone of risk of candidate current energy converter turbines?
2. How are fish that pass through the zone of risk affected?
3. Does fish behavior related to upstream turbines affect interaction probability with a downstream turbine?

The project team believes answers to these questions will critically inform decisions about directions taken in system design and can function as a guide for field testing and prototype development, with the goal of answering these questions in a way that reduces risk.

Furthermore, the project team recommends designing a Next Steps project that proceeds quickly and efficiently toward a prototype system that, by design, would be useful for a variety of applications, but in its first iteration would be focused on a site like the IVC/ORPC RivGen® Project (or similar pending collaboration agreements). Such a project design will best support the following key opportunities and program goals outlined in the Water Power Technologies Office Multi-Year Program Plan for Marine Energy:

- Power underserved communities and enhance coastal resilience. Marine energy can power electric microgrids in coastal, remote, and islanded communities, enhancing energy and coastal resilience and sustaining marine ecosystems.



- Complete resource measurements and assessments in support of marine energy projects to enhance the resilience of specific remote communities.
- Complete initial field-testing for modular current energy converter systems that capture hydrokinetic river energy in low-flow environments (less than 2 m/sec) and can incorporate and advance IO&M techniques, which require only limited use of port and deployment vessel infrastructure.
- Demonstrate the improved technical performance of environmental monitoring technologies in relevant marine energy environments while opportunistically collecting data about animal interactions.

## 7 References

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## Appendix A. Software Configuration Reference

### A.1 PnnlCrdcPlugin

#### A.1.1 Configuration Dialog

The PnnlCrdcPlugin (PCP) module adds a new section of configuration options to the standard commercially available BioSonics Visual Acquisition software (VisAcq) configuration dialog. This new section is called “Snippets” and is highlighted in blue in Figure 17. In this window the user manages the list of “snippet configurations,” which are the settings for each desired instance of the archiving algorithm. Normally there will be one instance of the algorithm for each secondary sensor, but if multiple secondary sensors have identical criteria for archiving, one instance of the algorithm can manage all those sensors. In this example, we have one snippet configuration for Blackfly video camera (BF) archiving and one for BlueView acoustic camera (BV) archiving. The “Edit...” button opens a dialog box for the user to define the parameters for a specific snippet configuration.

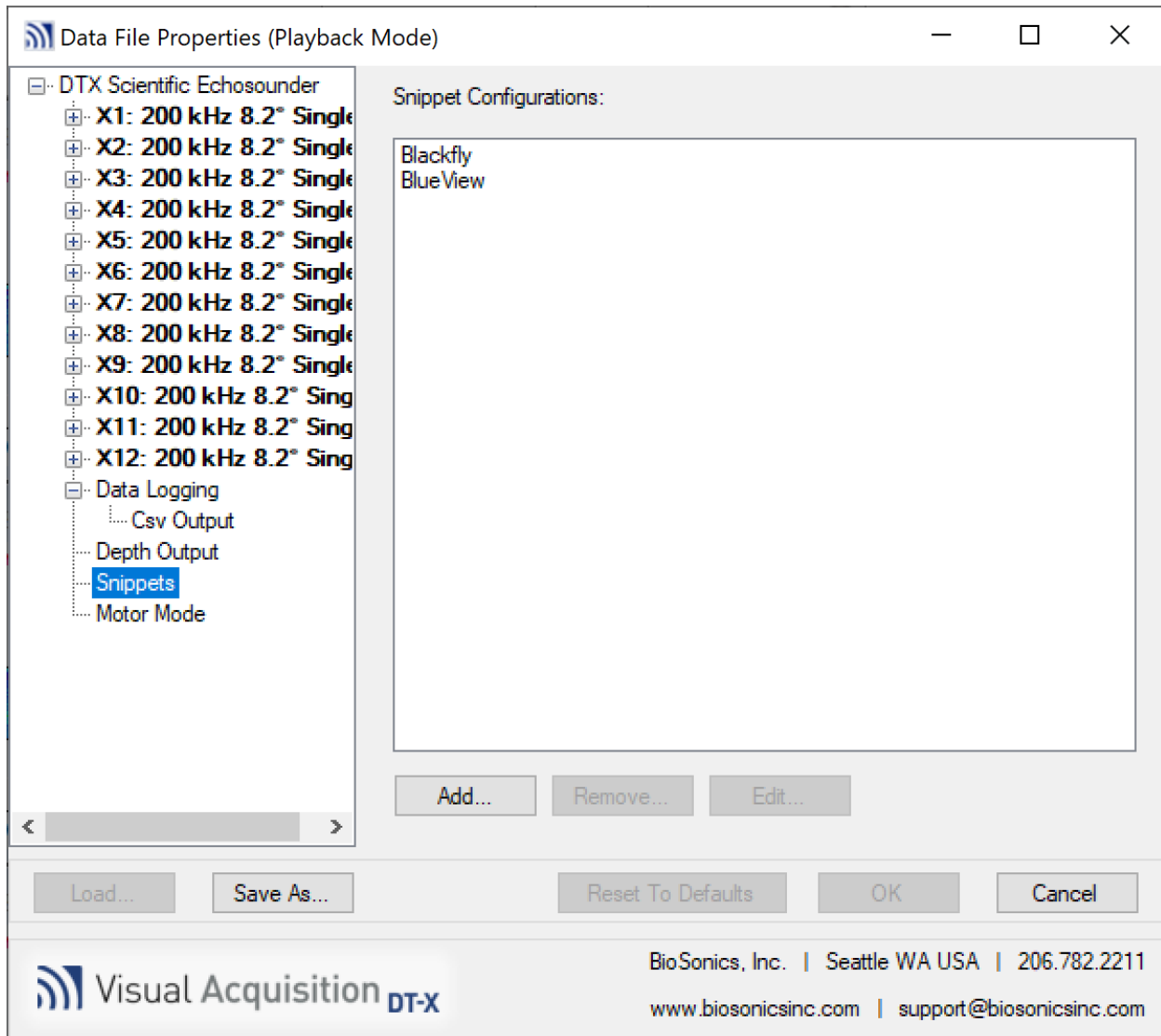


Figure 17. PnnlCrdcPlugin top-level configuration to manage instances of the archiving algorithm.

Figure 18 shows the detailed settings for one instance of the archiving algorithm. In the “Interval Length” section, you can set the Interval Length in seconds, or as a fixed number of pings per transducer.

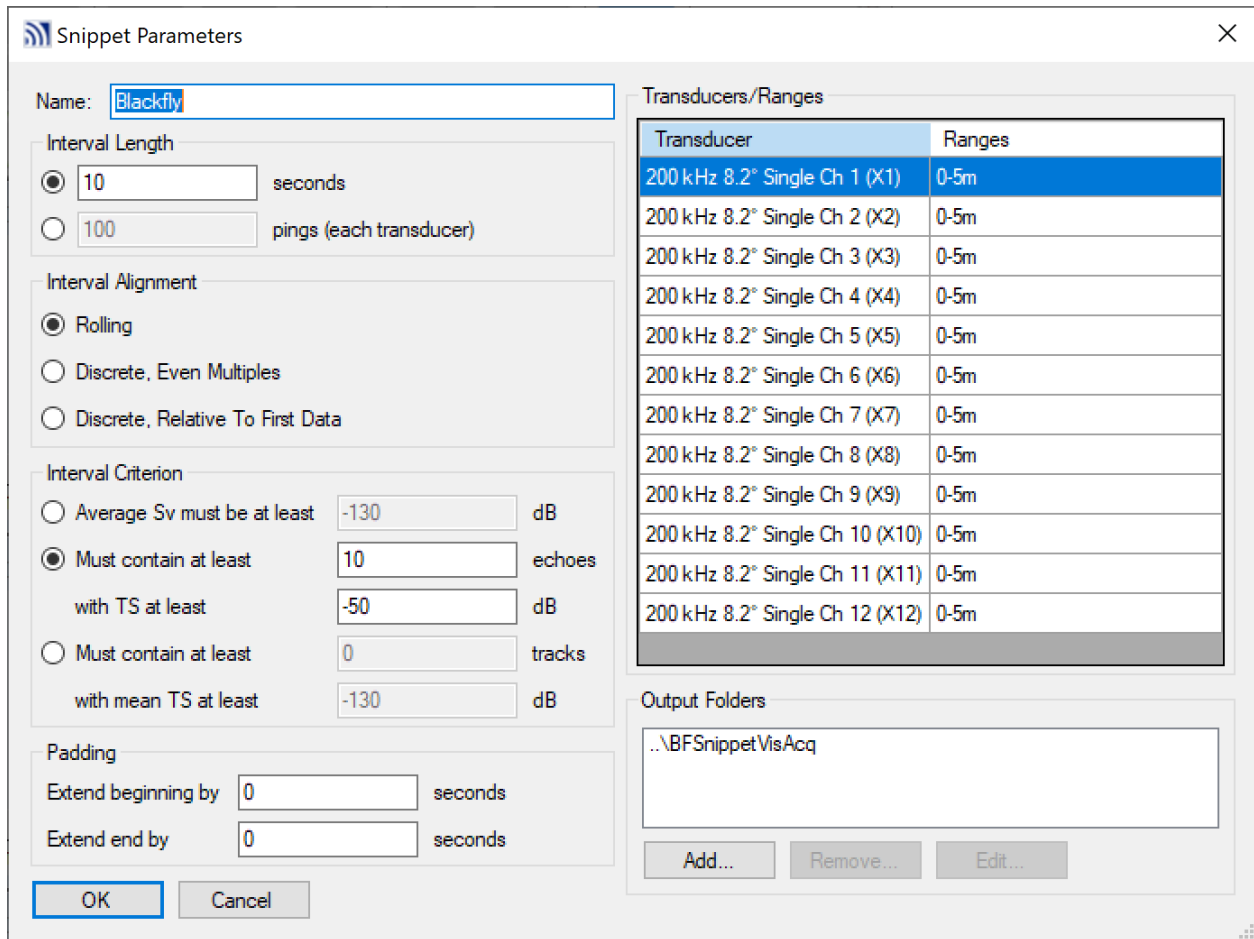


Figure 18. PnnlCrdcPlugin configuration settings window.

In the “Interval Alignment” section, you can set the Interval Alignment mode, which is the way this instance of the algorithm selects intervals of data to be compared with the Interval Criterion. For this project, we used the “Rolling” interval mode, and this is what the example in Section 3.5.1 illustrates. In rolling interval mode, every time a new ping is logged, the software forms a “current interval” of data based on that ping and examines whether the data in the current interval satisfy the Interval Criterion. For example, suppose you are using Rolling Interval Alignment mode, and you have set your interval length to be 10 seconds. Then, each time a new ping with some timestamp  $T$  is logged, the software considers all pings with timestamps greater than  $T-10$ , and less than or equal to  $T$ , to be the “current interval.” Now suppose you have instead set your interval length to be 10 pings per transducer. In that case, every time a new ping arrives, the software considers the current interval to consist of the most recent 10 pings on each transducer. Because VisAcq always pings the transducers in strict round-robin order, this set of pings forms a contiguous interval of data. In Rolling Interval Alignment mode, specifying the interval length by time or by number of pings is roughly equivalent. For example, if you are pinging 10 times per second per transducer, using an interval length of 10 seconds is very similar to using an interval length of 100 pings per transducer. However, for very short intervals, specifying the interval length in terms of number of pings will give more even weight to each transducer. For example, if you are pinging 10 times per second per transducer, and you use an interval length of 0.1 seconds, then on average your intervals will contain 1 ping for each transducer, but because of slight variability in the ping rate you might have intervals in which a

certain transducer has no ping present, or intervals in which a certain transducer has two pings present.

In the “Discrete” Interval Alignment modes, the software does not form an interval each time a new ping arrives. Here is a description of the Discrete Interval Alignment modes:

- **“Discrete, Even Multiples” mode with interval length specified to be N seconds:** the software breaks each day up into time intervals of N seconds, with one interval starting at midnight. Whenever a ping arrives that goes into a new time interval, the software knows that the previous time interval will receive no more pings, so it checks that interval against the Interval Criterion.
- **“Discrete, Relative to First Data” mode with interval length specified to be N seconds:** if the time of the first ping logged is T, the software uses time intervals of the form “T to T+N”, “T+N to T+2\*N”, “T+2\*N to T+3\*N”, etc. Whenever a ping arrives that goes into a new time interval, the software knows that the previous time interval will receive no more pings, so it checks that interval against the Interval Criterion.
- **Either discrete mode, with interval length specified to be N pings per transducer:** pings 1 through N on each transducer form one interval, pings N+1 through 2\*N on each transducer form another interval, pings 2\*N+1 through 3\*N on each transducer form another interval, etc. Whenever a ping arrives that goes into a new interval, the software knows that the previous interval will receive no more pings, so it checks that interval against the Interval Criterion.

The Discrete modes were included because they more closely emulate the manual processing we did during Billing Period 1 (BP1) of this project. However, during BP2 we chose to use Rolling mode because it is more responsive.

In the “Interval Criterion” section, you can decide whether you want this instance of the archiving algorithm to base snippet creation on echo integration, echo count, or track count. For echo and track count, you can specify the minimum TS that a target must have to be counted.

In the “Padding” section, you can configure this instance of the algorithm to apply fixed offsets to the snippet start and end times relative to the times of the intervals where the BioSonics Sonar detected enough targets to pass the Interval Criterion. If the BioSonics Sonar is not collocated with secondary sensors padding might be needed. For example, if the BioSonics Sonar is 5 seconds upstream of the secondary sensor, you might want the snippets to cover the times 5 seconds after the BioSonics Sonar sees targets. This could be accomplished by setting the beginning padding to -5 seconds, and the ending padding to 5 seconds. Another use for these parameters would be if the BioSonics Sonar does not reliably detect targets until they are partially through the secondary sensor field of view (FOV)—you could add beginning padding to make sure that snippets start before targets are in the secondary sensor FOV. If the BioSonics Sonar does not reliably detect targets all the way through the secondary sensor FOV, you could add ending padding to make sure that snippets end after targets have left the secondary sensor FOV. Site characteristics like current speed and noise level will drive the tuning of this parameter.

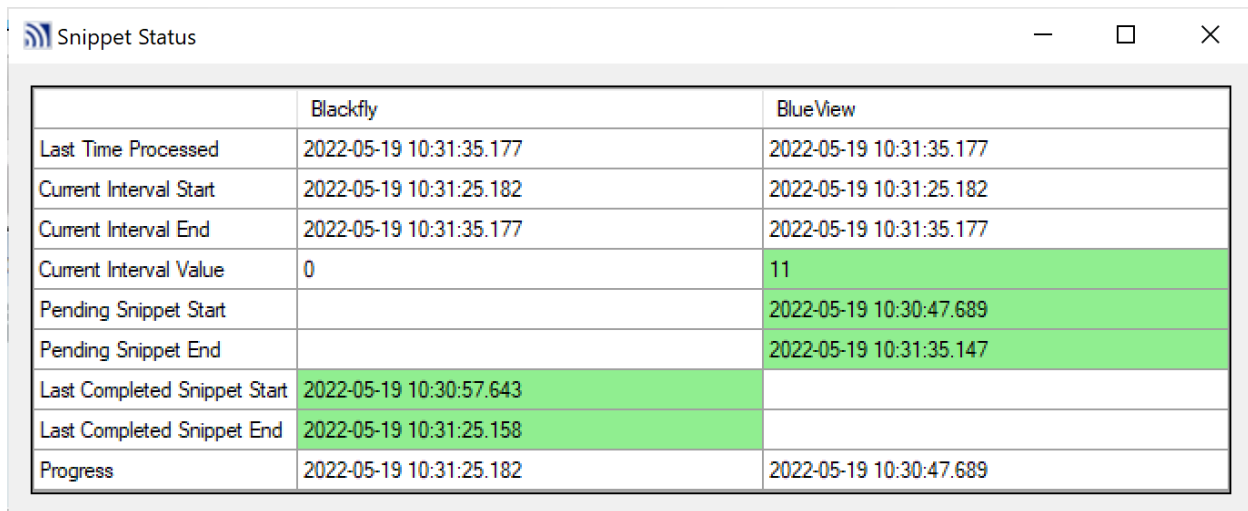
In the “Transducers/Ranges” section, you define the ROI for this instance of the algorithm. For each transducer, you can set any number of range intervals to be included in the ROI. So, you can have a very complex ROI, for example if you want to exclude ranges where physical structures in the environment (e.g., rocks on the bottom) show up as strong fixed targets. This

could prevent archiving being triggered by those targets that are not of interest. You can even have no range intervals defined for a particular transducer if targets in that transducer’s FOV are not expected to enter the FOVs of the secondary sensors being archived by this instance of the algorithm (perhaps they are only expected to enter the FOV of other secondary sensors).

In the “Output Folders” section, you specify the list of folders where this instance of the algorithm should store its output. Each folder will be read by the instance of STS for one secondary sensor. So, one instance of the algorithm can control multiple secondary sensors if you want them archived under the same conditions.

### A.1.2 Real-Time Display

While VisAcq is collecting data, PCP makes an additional real-time display window available to the user, which shows the current snippet creation status, updated as each ping from the BioSonics Sonar is completed (Figure 19).



	Blackfly	BlueView
Last Time Processed	2022-05-19 10:31:35.177	2022-05-19 10:31:35.177
Current Interval Start	2022-05-19 10:31:25.182	2022-05-19 10:31:25.182
Current Interval End	2022-05-19 10:31:35.177	2022-05-19 10:31:35.177
Current Interval Value	0	11
Pending Snippet Start		2022-05-19 10:30:47.689
Pending Snippet End		2022-05-19 10:31:35.147
Last Completed Snippet Start	2022-05-19 10:30:57.643	
Last Completed Snippet End	2022-05-19 10:31:25.158	
Progress	2022-05-19 10:31:25.182	2022-05-19 10:30:47.689

Figure 19. PCP real-time display providing the user with a visual reference of when times of interest are being processed and eventually archived as snippets for each secondary sensor.

This display shows one column for each instance of the archiving algorithm that you have configured. In each column, it shows the following information:

- **“Last Time Processed”**: This is the timestamp of the most recent ping.
- **“Current Interval Start”**: This is the timestamp of the first ping in the current time interval.
- **“Current Interval End”**: This is the timestamp of the last ping in the current interval. In Rolling Interval Alignment mode, this is the same as “Last Time Processed.”
- **“Current Interval Value”**: This is the value that determines whether the current interval should be included in a snippet.
  - If you have configured archiving to be based on the number of echoes detected, this number is the total number of echoes of sufficiently large TSs that were detected in the ROI in all pings in the current interval.

- If you have configured archiving to be based on the number of tracks detected, this number is the total number of tracks of sufficiently large mean TSs that were detected in the ROI in all pings in the current interval.
- If you have configured archiving to be based on echo integration, this number is the average  $S_v$  (acoustic volume backscattering) over the ROI in all pings in the current interval.
- If the Current Interval Value is equal to or greater than the configured threshold value, then the cell will be highlighted in green
- **“Pending Snippet Start” and “Pending Snippet End”**: If there is a pending snippet, the start and end times of the snippet so far will be in these cells and the cells will be highlighted in green.
- **“Last Completed Snippet Start” and “Last Completed Snippet End”**: Once the end of a snippet is detected, the start and end times will be removed from the “Pending Snippet” cells and put in these cells.
- **“Progress”**: This is the time up to which snippet processing has been completed. If there is no pending snippet, it is equivalent to “Current Interval Start.” If there is a pending snippet, it is equivalent to “Pending Snippet Start.”

## A.2 Blackfly Acquisition

The Blackfly Acquisition (BFA) program has a simple interface (Figure 20). The user clicks “Configure” to bring up the configuration dialog. The Start and Stop buttons control whether video data are being collected. The Video section shows the live video display when data are being collected. The Messages section shows status messages from the program during operation.



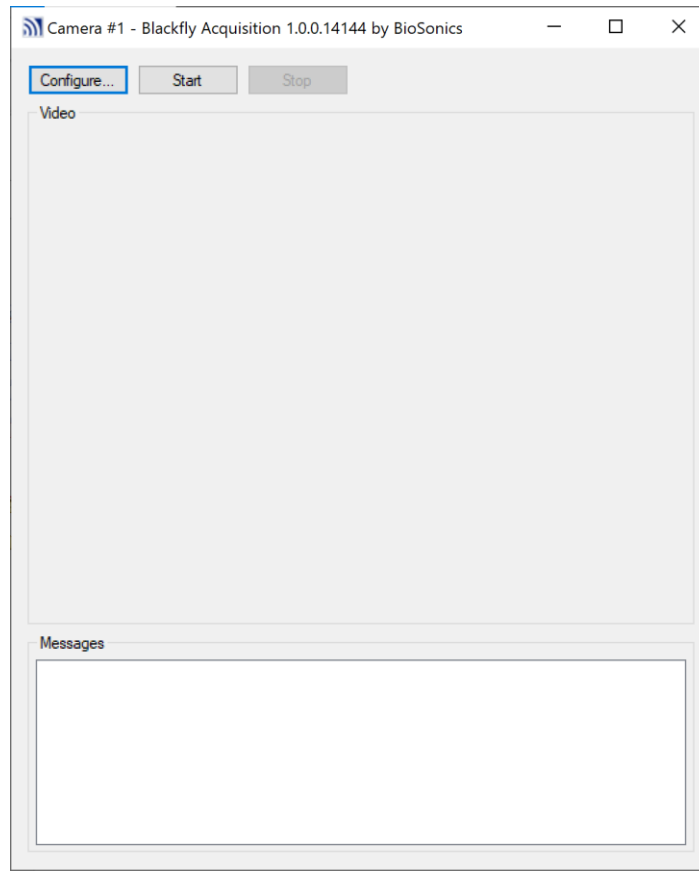


Figure 20. BFA main window.

Figure 21 shows the configuration dialog. You can set the serial number of the camera that this instance of BFA should control; this is particularly useful if you have multiple cameras attached to the computer. You can control the video frame rate that is logged to disk, and the video quality, to manage the disk usage of your video data. You can specify the file duration in minutes of the raw video files, and the folder in which they should be saved. The raw video files will have names derived from the start timestamp of the video data they contain; for example, “20220718\_120500.avi” for data starting at 12:05:00 on 2022-07-18. You can also add a prefix and suffix before and after the timestamp part of the filename. You can select whether the video data timestamps should be based on local time or Coordinated Universal Time (UTC). You can configure the software to draw a timestamp string on each frame of the video itself, and control the timestamp’s location in the frame, size, and time format. The timestamp text is drawn either in white or black depending on which contrasts better with the background of the video frame. The hysteresis parameter keeps the color from jumping back and forth too much from frame to frame when the background is near 50% gray.

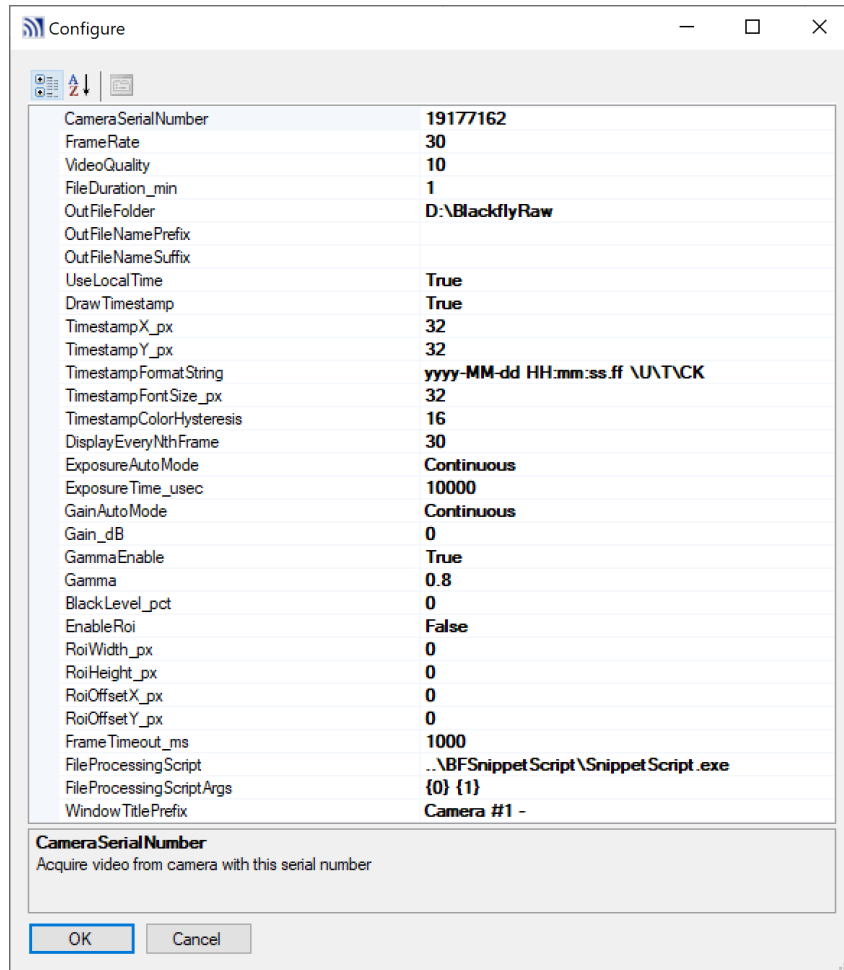


Figure 21. BFA configuration dialog.

The `DisplayEveryNthFrame` parameter allows you to control how often the display should be updated. Here we are collecting video data at 30 frames per second but only updating the display every 30 frames, or once a second, to minimize load on the computer.

The `Exposure`, `Gain`, `Gamma`, and `BlackLevel` parameters directly control the settings of the camera itself. The ROI-related parameters allow you to specify a rectangle of interest in the camera's FOV and ignore everything outside of that rectangle. This can allow you to save disk space if, for example, part of the camera's FOV is blocked, and you know that you will never see targets appear in that part of the video frames.

The file processing script parameters allow you to specify a script that runs after each raw data file is finished—we use this to run STS, which reads the CSV files output by PCP and creates video snippet files from the raw video files.

The `WindowTitlePrefix` parameter allows you to change the title bar of this instance of the program, so if you are running multiple instances, you can distinguish them at runtime.

### A.3 Ping BlueView

The Ping BlueView (PBV) program also has a simple interface (Figure 22). The user clicks “Configure” to bring up the configuration dialog. The Start and Stop buttons control whether BV data are being collected. The main area of the window shows the live data display when data are being collected. The Pings Per Second Per Head and Sonar Temperature fields are also updated when data are being collected.

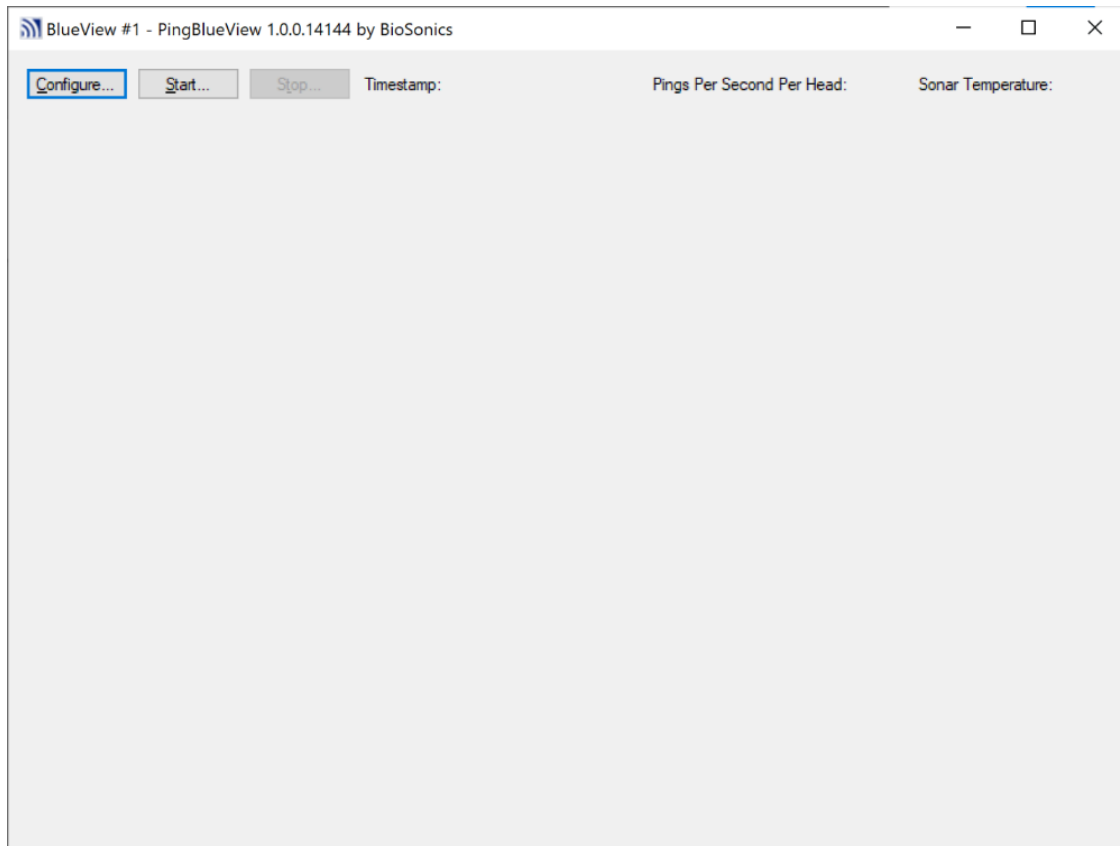


Figure 22. PBV main window.

Figure 23 shows the configuration dialog. You can set the Internet Protocol address and port of the BV that this instance of PBV should control—this is useful if you have multiple BVs attached to the computer.

PingBlueView Configuration

Sonar IP Address:  Port:

**Triggering**

Self Triggered

Delay Between Pings (ms):

Enable External Trigger Output

Output Timing:

Externally Triggered

Delay (ms):

**Source Level**

Automatic Percent of Maximum:

**Display**

Color Map File:  ...

**Data Logging**

File Length (min):

Logging Folder:  ...

Min Free Space (GiB):

**Environment**

Sound Speed (m/s):

Fluid Type:

**Head 0**

Enabled

Start Range (m):  Base Gain (dB):

Stop Range (m):  TVG (dB/m):

Enable Alt Ping  Enable Transmit

**Head 1**

Enabled

Start Range (m):  Base Gain (dB):

Stop Range (m):  TVG (dB/m):

Enable Alt Ping  Enable Transmit

Figure 23. PBV configuration dialog.

In the “Triggering” section, you can control the timing of BV pings. Pinging can be self-triggered, where the unit pings according to its own internal timing, with a specified delay between pings. In this mode, the unit can produce a trigger output signal. If your cable has a trigger line, this signal can be used to synchronize another sonar’s pinging to that of the BV. You can select whether the trigger output signal should be synchronized to the beginning of the transmit pulse, the end of the transmit pulse, or the end of data collection for each ping. Alternatively, you can set the BV to be externally triggered, in which case it pings a specified amount of time after it receives a trigger signal from another sonar. This also requires your cable to have a trigger line.

In the “Source Level” section, you can set the transmit source level, as a percentage of the maximum, or set it to be managed by the unit automatically based on the end range.

In the “Head 0” and “Head 1” sections, you can set whether each of the heads of a dual-frequency BV is enabled (i.e., whether any data should be collected with that head). If a head is enabled, you can set other data collection parameters for that head. You can set the start and end ranges of data collection. You can set the base gain and time-varied-gain on the receiver amplifiers. The “Enable Alt Ping” checkbox switches between higher ping rate (alt ping disabled) mode and an improved imaging mode (alt ping enabled). The “Enable Transmit” checkbox should be checked for normal operation. If it is unchecked, then no transmit pulse is produced. This can be useful for testing when the unit is out of water, or for investigating system noise.

In the “Display” section, you can select a BlueView color map file that should be used for generating the live images of ping data.

In the “Data Logging” section, you can select how long each logged data file should be, in minutes, and the folder to which data should be logged. You can also set a minimum amount of free space that must be present on the drive to which you are logging, or logging will be stopped. This prevents you from filling up a drive so much that it interferes with the operation of your computer.

In the “Environment” section, you can specify the speed of sound, and whether you are operating in freshwater or saltwater. This information is necessary for proper generation of images from the ping data.

# **Pacific Northwest National Laboratory**

902 Battelle Boulevard  
P.O. Box 999  
Richland, WA 99354

1-888-375-PNNL (7665)

***[www.pnnl.gov](http://www.pnnl.gov)***