



## SONARPOINT · INTRODUCTION

# SonarPoint: the big picture

What a localizing PAM array is, why it matters, what data it delivers, how it works and what it is made of

### 3D

a position for every sound: what was calling, when and exactly where

### ≈ 1%

of mooring spacing: typical position accuracy inside the array

### Up to 800 km<sup>2</sup>

monitored by one 11-mooring array, at up to 1,800 m depth, for up to 14 months

## 1 Adding *where* to *what*

Passive acoustic monitoring (PAM) has become a standard tool of marine science. A recorder on the seafloor can listen for months and tell you **what** was out there and **when**: which species called, how often, at what time of day or season. What a single recorder cannot tell you is **where** the sound came from. It hears a whale 500 m away and one 15 km away in much the same way, and it cannot tell two animals calling at once from one animal calling twice.

**SonarPoint is a localizing PAM (L-PAM) array.** Several recorders are placed on the seafloor kilometers apart, and their clocks are kept synchronized to a fraction of a millisecond. A sound that reaches several recorders arrives at each at a slightly different time, and those time differences reveal where it came from. SonarPoint adds the **where** to the **what** and **when**. The result is a "god's-eye view" of an ocean area: what was calling, when and exactly where, mapped in three dimensions.

|                                | Standard PAM recorder                     | SonarPoint L-PAM array                              |
|--------------------------------|-------------------------------------------|-----------------------------------------------------|
| <b>Answers</b>                 | Was a species present? When did it call?  | Who called, when, and from where (x, y, depth)?     |
| <b>Range to source</b>         | Unknown; detection range must be modeled  | Measured for every localized call                   |
| <b>Several callers at once</b> | Merged into one detection stream          | Separated by position                               |
| <b>Movement</b>                | Not observable                            | Tracks of animals, vessels and other moving sources |
| <b>Density estimation</b>      | Indirect, via assumed detection functions | Based on measured positions within a known area     |
| <b>Data quality check</b>      | Per-detection classifier score            | Plus a geometric residual for every position        |

## 2 Where it came from

SonarPoint grew out of a U.S. Navy need for better whale density estimates near training ranges. Its deep-water configuration was developed and field-validated under the Navy's Living Marine Resources (LMR) program in a series of deployments in Monterey Bay at 500–1,450 m depth. It is designed as a complete, practical system: the moorings deploy from a small boat with a small crew, need no cables or shore power, and the processing runs on a Windows laptop.

### 3 What data you get

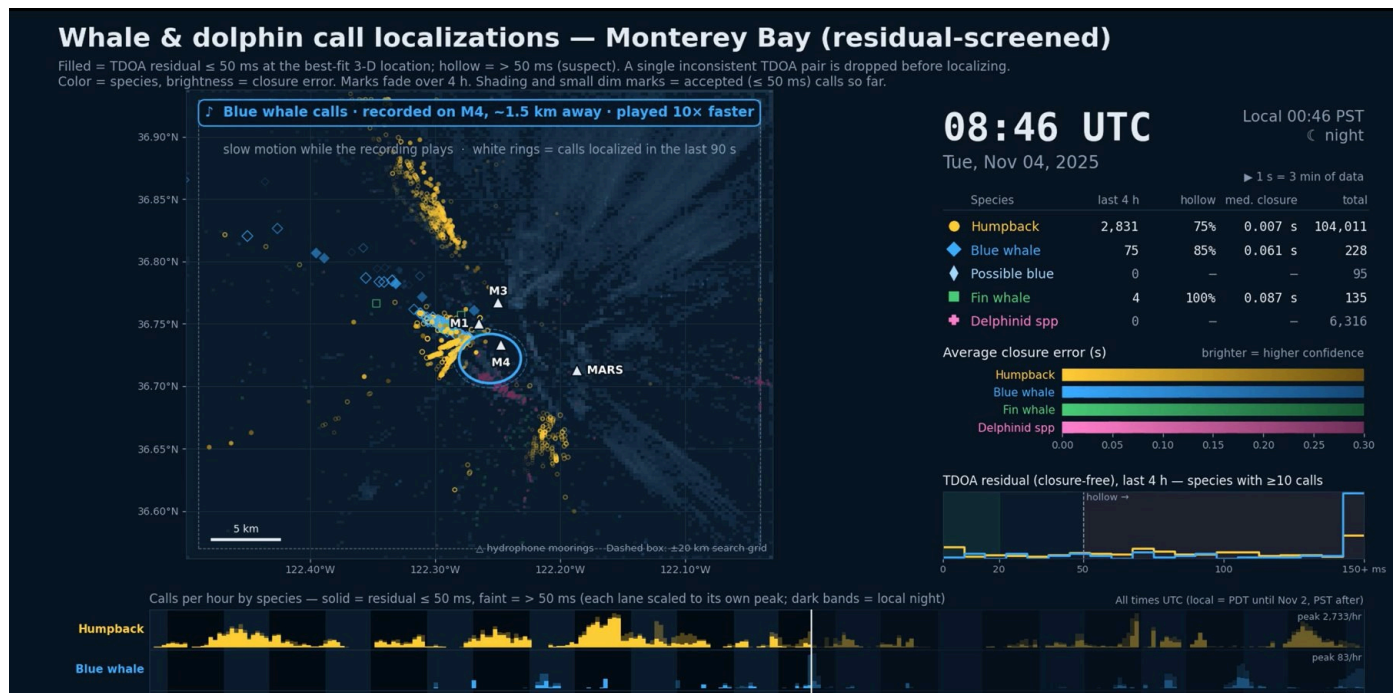


**Figure 1.** Twelve days of LMR1.3 localizations in Monterey Bay, from a frame of the multispecies timelapse video. Each dot is a localized call, colored by species: humpback (yellow), blue whale (blue), fin whale (green), delphinids (pink). Triangles are the moorings. The panels at right and below track call counts and quality by species over time.

#### From every mooring:

- Continuous broadband recordings, as standard WAV files, sampled at up to 416.7 kHz. Everything a conventional PAM recorder delivers, from every mooring.
- A precise, synchronized timestamp on every sample.

#### From the array as a whole:

- A **position for every sound** heard by enough moorings: latitude, longitude and depth, with its time.
- A **quality measure** (residual) for each position, so poor fixes can be screened out automatically.
- **Tracks** of moving sources, built from successive positions.
- Results as CSV and KML files, ready for GIS, Google Earth, PAMGuard or Where's Whaledo.

#### What this enables:

- Density and abundance estimates based on measured positions.
- Behavior: travel, foraging, group interactions, predator and prey.
- Separating individuals calling at the same time by where they are.
- Mapping vessel traffic and other human activity in protected areas.
- Noise exposure at known distances from construction or vessels.
- Detecting and tracking vessels, divers and underwater vehicles for harbor and infrastructure security.
- Portable underwater tracking ranges for testing sound-emitting devices.

SonarPoint can localize any sound heard on enough moorings (four for a full 3D fix): whale and dolphin calls, vessels, sonars, pingers, seismic and geological events.

**Example: tracking a predation event.** In May 2023 a five-mooring SonarPoint array in Monterey Canyon localized humpback whales north of the array in the evening, then killer whales approaching from the southwest the next morning. Around midday the killer whale calls clustered tightly in one spot, a sign of activity below the surface where observers on R/V *Scarlett* saw nothing to explain it. Within the hour the calls moved to the northeast corner of the array, and there the observers saw a gray whale calf carcass come to the surface. The acoustic track matched the visual sightings throughout.

## 4 How it works: time difference of arrival

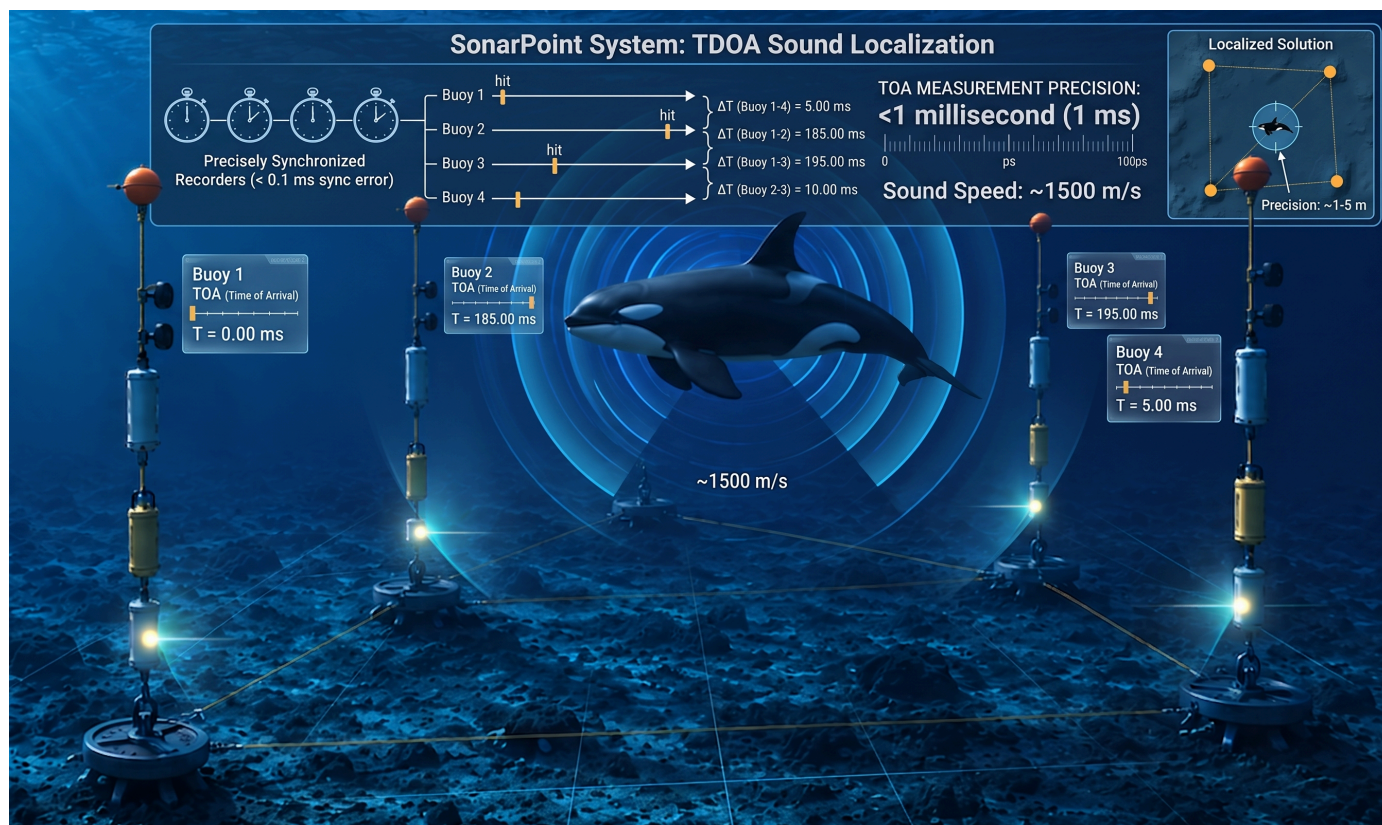


**Figure 2.** Time difference of arrival (TDOA), illustrated. A call reaches the nearest mooring first and the farthest last. With synchronized clocks, the differences in arrival time fix the position of the source.

**Sound travels at about 1,500 m/s in seawater.** A call reaches each mooring after a delay proportional to its distance. We never know exactly when the animal called, but we can measure precisely how much later the sound reached one mooring than another. Each such time difference places the source on a curved surface (a hyperboloid) between the two moorings; where the surfaces from several mooring pairs intersect, the source is.

**How many moorings?** A position in 3D has three unknowns, plus the unknown time of the call: four in all. Four moorings that hear a sound give three independent time differences, just enough to solve for its position. A fifth mooring adds a redundant measurement, and with it a check: if all the time differences agree on one point, the **residual** is small and the fix can be trusted; if they disagree, the fix is flagged.

**How the position is found.** SonarPoint's localizer searches a 3D grid over the monitored volume and picks the point whose predicted arrival-time differences best match the measured ones. The quality of that match is the residual reported with every position.

### Timing is everything

1 ms of timing error  $\approx$  1.5 m of range error.

Each recorder's clock is stable to 50 parts per billion, which on its own would drift by only about 0.2 ms per hour. Two independent synchronization methods correct even that: a sync pinger in the array, and GPS-timed pings before deployment and after recovery.

### Geometry matters too

Accuracy is best inside the array and falls off outside it. In GPS-checked tests, sounds inside an 8 km array were placed within about 1% of the mooring spacing (62–75 m).

Two practical consequences follow. First, the array must know where its own moorings are: they drift up to a few hundred meters while sinking, so their seafloor positions are measured after deployment (phase 2, below). Second, array layout is a design choice. Moorings spread in two dimensions, with the area of interest inside, give the best accuracy. These topics are covered in detail in the companion application notes.

## 5 System components

SonarPoint is a complete system from seafloor to software. Each mooring is a short string, about 10 m (33 ft) tall, so it stays close to the seafloor and clear of fishing gear and vessel traffic.

| Component                                           | Role                                                                                                                                                           |
|-----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Recorder</b><br>SP300-2, SP1000-8, SP1800-8      | Records continuously to removable SD cards (up to 8 TB) at up to 416.7 kHz, with a 50 ppb precision clock and GPS calibration. Rated to 300, 1,000 or 1,800 m. |
| <b>Hydrophone</b>                                   | Endcap-integrated (shallow models) or calibrated free-field HTI-99-UHF.                                                                                        |
| <b>External battery</b><br>SPB1800-175Ah            | Extends continuous recording at 100 kHz from 89 days to about 14 months (433 days).                                                                            |
| <b>Sync pinger</b><br>SPP series                    | Mounted on one mooring; emits a short timing ping every recording segment to keep the array synchronized throughout the deployment.                            |
| <b>Acoustic releases</b><br>ARC series              | Release the mooring from its anchor on acoustic command; deep systems use two releases for redundancy.                                                         |
| <b>Floats</b>                                       | Syntactic foam, rated to 1,800 m, with reserve buoyancy.                                                                                                       |
| <b>SeaTag satellite transmitter</b>                 | On the top float: silent at depth, reports by satellite as soon as the mooring surfaces, and guides the recovery boat.                                         |
| <b>Anchor</b>                                       | Sacrificial steel weight, left on the seafloor at recovery.                                                                                                    |
| <b>Deck gear</b><br>STM-5 deck box, GPS pinger pole | Communicates with the releases, emits GPS-timed pings for synchronization, and surveys the seafloor positions of the moorings.                                 |
| <b>Software</b><br>Pipeline Manager                 | Turns the raw recordings into synchronized files, detections and 3D positions (section 7).                                                                     |



**Figure 3.** An 1,800 m SonarPoint mooring string.



**SonarPoint™**

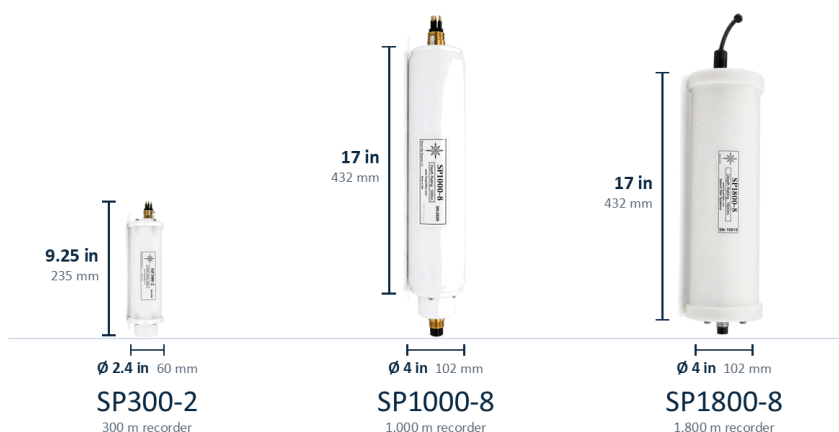
TIME-SYNCHRONIZED UNDERWATER ACOUSTIC RECORDERS

### COMMON TO ALL SONARPOINT RECORDERS

- Sampling up to 416.7 kHz
- WAV files on removable SD
- 50 ppb precision clock
- GPS calibration & sync

Recorders and battery shown to the same scale

Scale: 6 in 152 mm



|                           |                         |                         |                         |
|---------------------------|-------------------------|-------------------------|-------------------------|
| <b>DEPTH RATING</b>       | 300 m                   | 1,000 m                 | 1,800 m                 |
| <b>ACOUSTIC BANDWIDTH</b> | Up to 156.25 kHz        | Up to 60 kHz            | Up to 60 kHz            |
| <b>STORAGE</b>            | 2 SD slots · up to 2 TB | 8 SD slots · up to 8 TB | 8 SD slots · up to 8 TB |
| <b>RECORDING</b>          | 20 days / —             | 89 / 433 days           | 89 / 433 days           |
| <b>ENDURANCE*</b>         |                         |                         |                         |

\* Continuous recording at 100 kHz. Internal battery / with the SPB1800-175Ah external battery.

**EXTERNAL BATTERY OPTION**

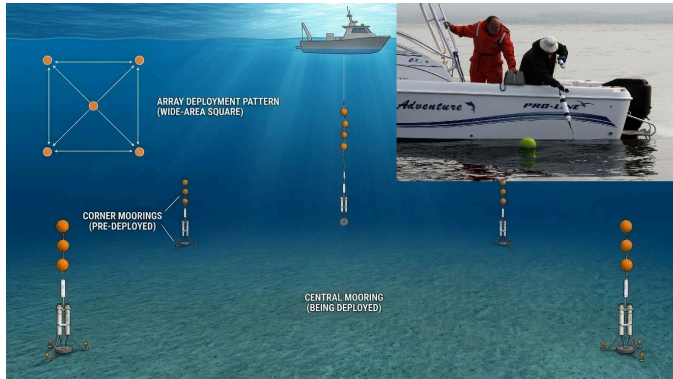
**SPB1800-175Ah**  
175 Ah rechargeable lithium battery

**FULL TECHNICAL SPECIFICATIONS**  
Dimensions, weights and deployment details

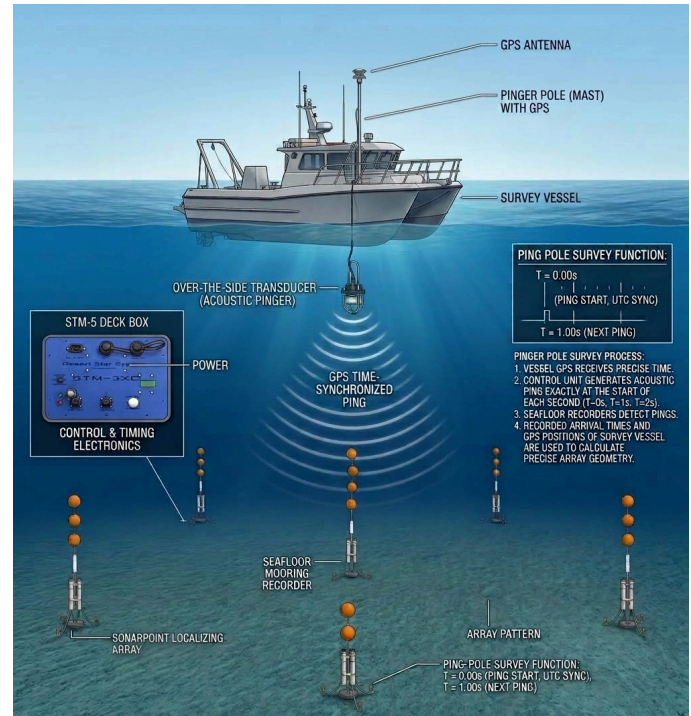
**SCAN TO VIEW**

**Figure 4.** SonarPoint recorders for 300, 1,000 and 1,800 m, and the external battery, shown to the same scale.

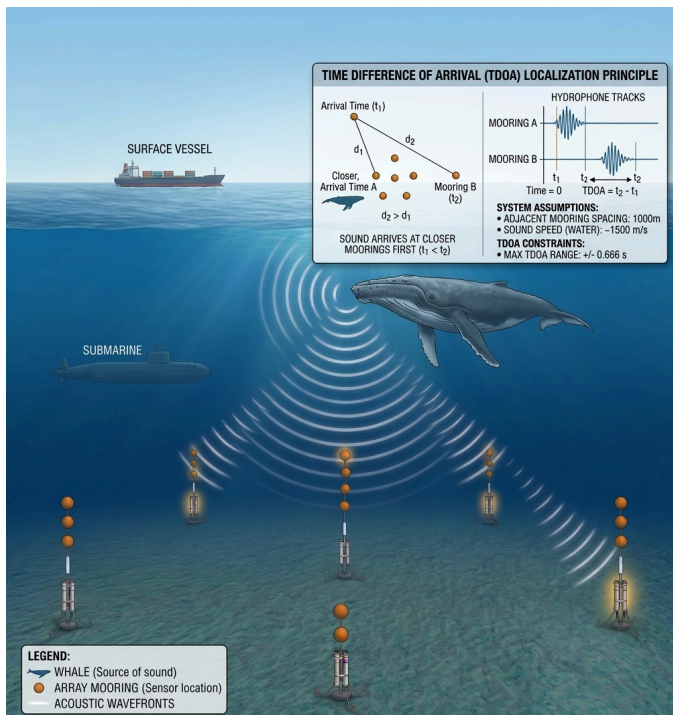
## 6 The four phases of a deployment



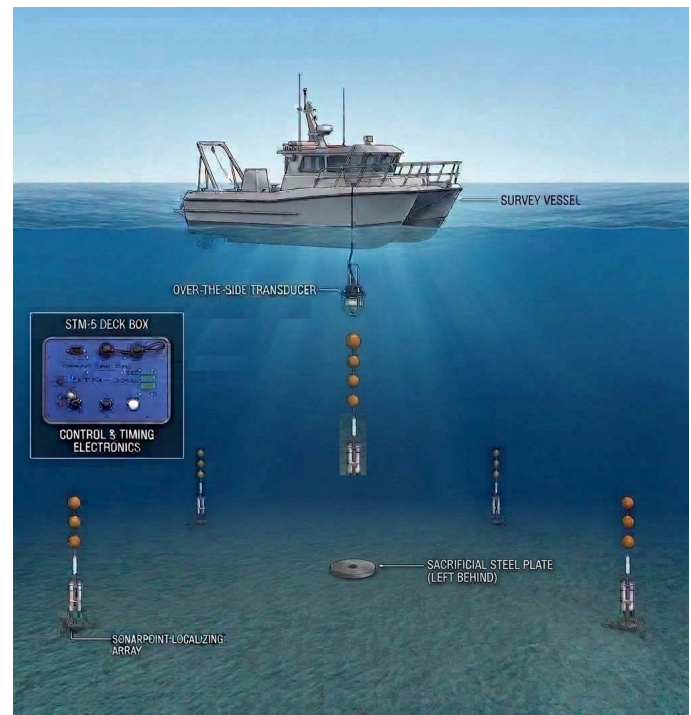
**Phase 1: Deploy.** From a small boat, each mooring is lowered over the side and sinks to the seafloor on its anchor. The drop position is logged by GPS. Before deployment, GPS-timed pings are recorded at every recorder to set its clock.



**Phase 2: Survey.** Moorings drift as they sink, so their seafloor positions are measured: the boat runs a pattern with the GPS pinger pole, sending pings at precisely known times and places, and the moorings record their arrival times.

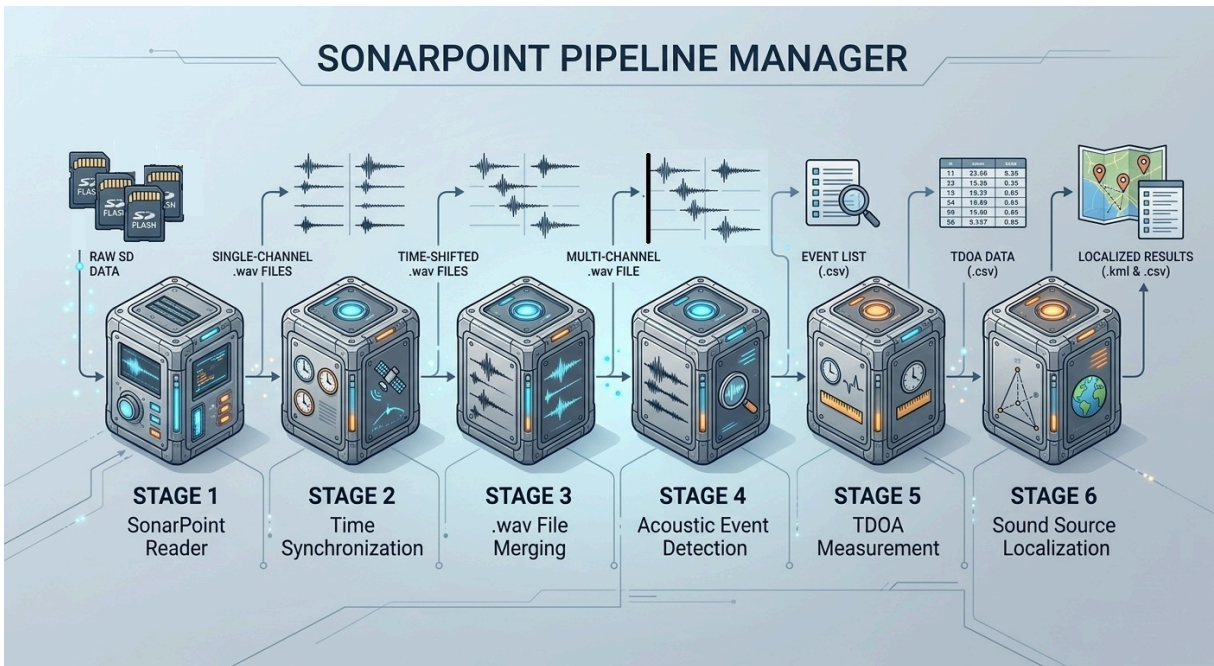


**Phase 3: Listen.** The array records continuously for weeks to months. The sync pinger keeps the clocks aligned, and every sound heard on several moorings can later be localized.



**Phase 4: Recover.** The boat commands each mooring's acoustic releases. The mooring drops its anchor and floats to the surface, where it is picked up. GPS-timed pings recorded right after recovery close the timing record.

## 7 From raw recordings to 3D positions: Pipeline Manager



SonarPoint Pipeline Manager runs the processing in six stages: **(1)** read the raw SD card data; **(2)** apply the time synchronization; **(3)** merge the recordings of all moorings into multichannel WAV files; **(4)** detect acoustic events; **(5)** measure the time differences of arrival; and **(6)** localize each sound in 3D. Every stage writes standard files, so you can bring in your own detectors or hand off to PAMGuard or Where's Whaledo at any point.

## 8 Scaling to your area

An array can be as small as a few hundred meters across, for detailed tracking of dolphins or a test range, or as large as tens of kilometers for baleen whales, whose low-frequency calls travel far.

The largest configuration validated so far combines a compact inner array of 5 moorings with 6 moorings on an 8 km ring, plus a spare. A geometry model predicts errors of 25 m or less over about 200 km<sup>2</sup> inside the ring, and LMR detection ranges support monitoring of baleen whale calls over **up to about 800 km<sup>2</sup>**.

| Starter system | Depth   | Moorings     | Endurance* |
|----------------|---------|--------------|------------|
| SPA-300        | 300 m   | 5            | 20 days    |
| SPA-300XD      | 300 m   | 5            | 89 days    |
| SPA-1000XD     | 1,000 m | 5            | 89 days    |
| SPA-1800XD     | 1,800 m | 5            | 89 days    |
| SPA-1800WA     | 1,800 m | 11 + 1 spare | 433 days   |

\* Continuous recording at 100 kHz. See the System Selector Guide for full configurations.

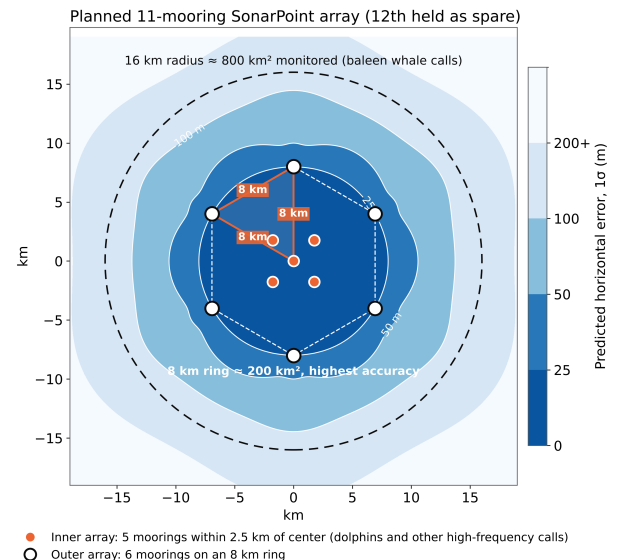


**Figure 5.** The 11-moorings wide-area layout: 5 inner moorings and 6 on an 8 km ring. Shading shows predicted position error; the dashed circle marks about 800 km<sup>2</sup>.

## 9 What to expect in the workshop

This note gives the big picture. The rest of the day goes into the details, and each topic has its own application note:

| Topic                                                             | Application note                                              |
|-------------------------------------------------------------------|---------------------------------------------------------------|
| How accurate positions are, and how array geometry sets the limit | <i>How accurate is a sparse SonarPoint array?</i>             |
| How the system protects your data and your gear                   | <i>Built to come back: redundancy in SonarPoint arrays</i>    |
| Keeping recorder clocks in step                                   | <i>Clock Drift Compensation in SonarPoint Acoustic Arrays</i> |
| Finding and recovering a surfaced mooring                         | <i>Satellite Tracking of SonarPoint Mooring Strings</i>       |

## 10 In the field



**Figure 6.** Deploying a SonarPoint mooring from a small boat.

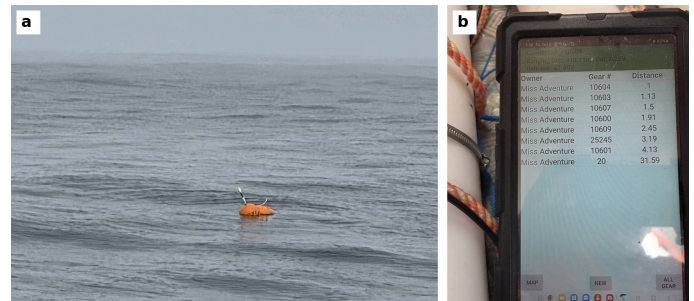


**Figure 7.** (a) An LMR2 mooring at the surface after release, satellite tag antenna up. (b) The release deck unit during recovery.

### In one paragraph

SonarPoint adds *where* to the *what* and *when* of passive acoustic monitoring. A set of time-synchronized seafloor recorders, deployed from a small boat, records an ocean area continuously for weeks to months. Afterwards, Pipeline Manager uses the tiny differences in arrival time between moorings to place each sound in 3D, with a built-in quality check on every position. The result is a map of what was calling, when and where, for whales, dolphins, vessels and any other sound source.

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