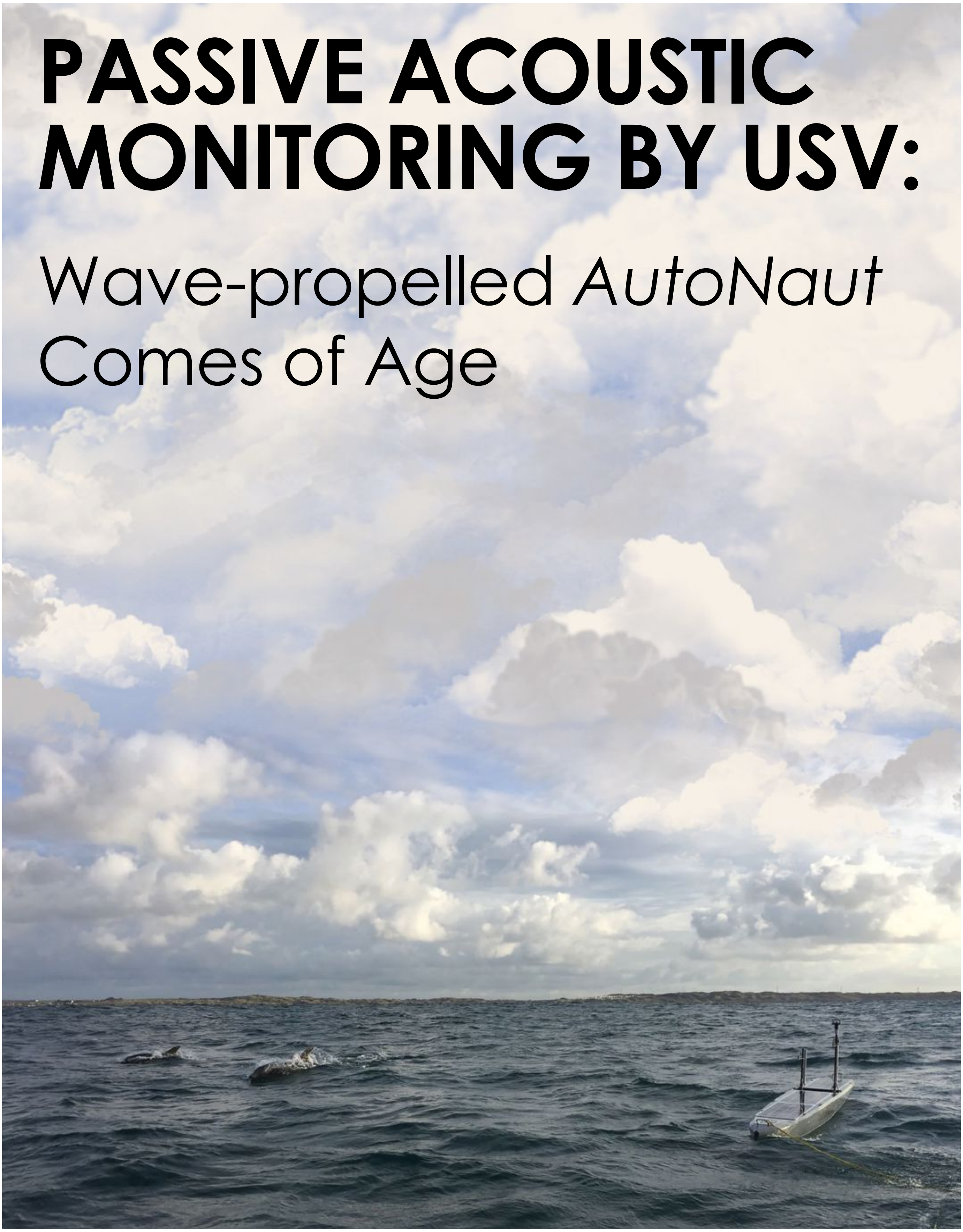
PASSIVE ACOUSTIC MONITORING BY USV:

Wave-propelled *AutoNaut* Comes of Age



Welcoming party for AutoNaut Islay while towing in for slipway recovery after a successful mission monitoring water pollution. The mission also involved ground-truthing satellite Synthetic Aperture Radar (SAR) images off the south coast of England.

By: Phil Johnston, AutoNaut Ltd.

Recent years have seen an explosion in the number of applications for unmanned surface vessels (USVs), including a game-changing solution for Passive Acoustic Monitoring (PAM) detection of whales or submarines, the *AutoNaut.*

Low noise, high mobility, and long mission duration are key requirements for acoustic surveys. These are areas where *AutoNaut* is particularly capable, enabling the measurement of underwater sound and monitoring of marine mammals, which are two tasks in high demand from both the commercial and academic sectors. For defence purposes, the same capabilities mean proficiency in listening for submarines.

Advantages of USVs for PAM

The *AutoNaut's* wave-propulsion system has an elegant design involving only four moving parts—for near-silent operation. This is a vital asset for persistent, unobtrusive monitoring. As with Liquid Robotics' Wave Glider, being powered wholly by renewable energy has the additional benefit of requiring no carbon fuel. Also, with a role to play in PAM, conventionally powered USVs such as the ASV *C-Worker* can offer quicker survey speeds for shorter duration missions.

Fieldwork for acoustic surveys at sea commonly involves hydrophone arrays towed from conventional vessels or moored data loggers. Vessel-towed PAM provides mobility, but all too frequently suffers from self-noise. With acoustic data loggers, these issues are reversed. Both methods require personnel heading out to sea for deployment and retrieval, and the associated cost and risks are often major limiting factors. By providing both mobility and high signal-to-noise ratio, the *AutoNaut* can overcome these challenges.

Higher mobility surveys are brought into play by the 5M model, which has a top speed of 4 knots, but it is the *AutoNaut's* ability to hold position that allows for both spot measurement sampling as well as transects. Station-keeping within 50 m of a given way-point is readily attainable, even in harsh sea conditions. As a complement to conventional surveys, smaller USVs can be launched from a principal research vessel to provide additional data. Alternatively, USVs can operate independently to gain data that might not otherwise be acquired. In addition, *AutoNaut* has a unique ability in that it is simple to launch from a slipway by two personnel before transiting to the survey area, including shallower coastal regions as well as the oceanic depths.

AutoNaut Islay taking part in the anti-submarine warfare (ASW) section of the Royal Navy's Unmanned Warrior exercise off Stornoway, October 2016. Sensors include a Seiche digital thin-line Passive Acoustic Array, which detected the submarine target, 360° camera, 360° Radar Electronic Support Measures (RESM) Teledyne radar threat warning system, YSI EXO2 Sonde measuring six water properties, and Gill Windsonic weather station. AIS autonomous collision avoidance is fitted together with a radar transponder and all-round white light.

Developing PAM for *AutoNaut*

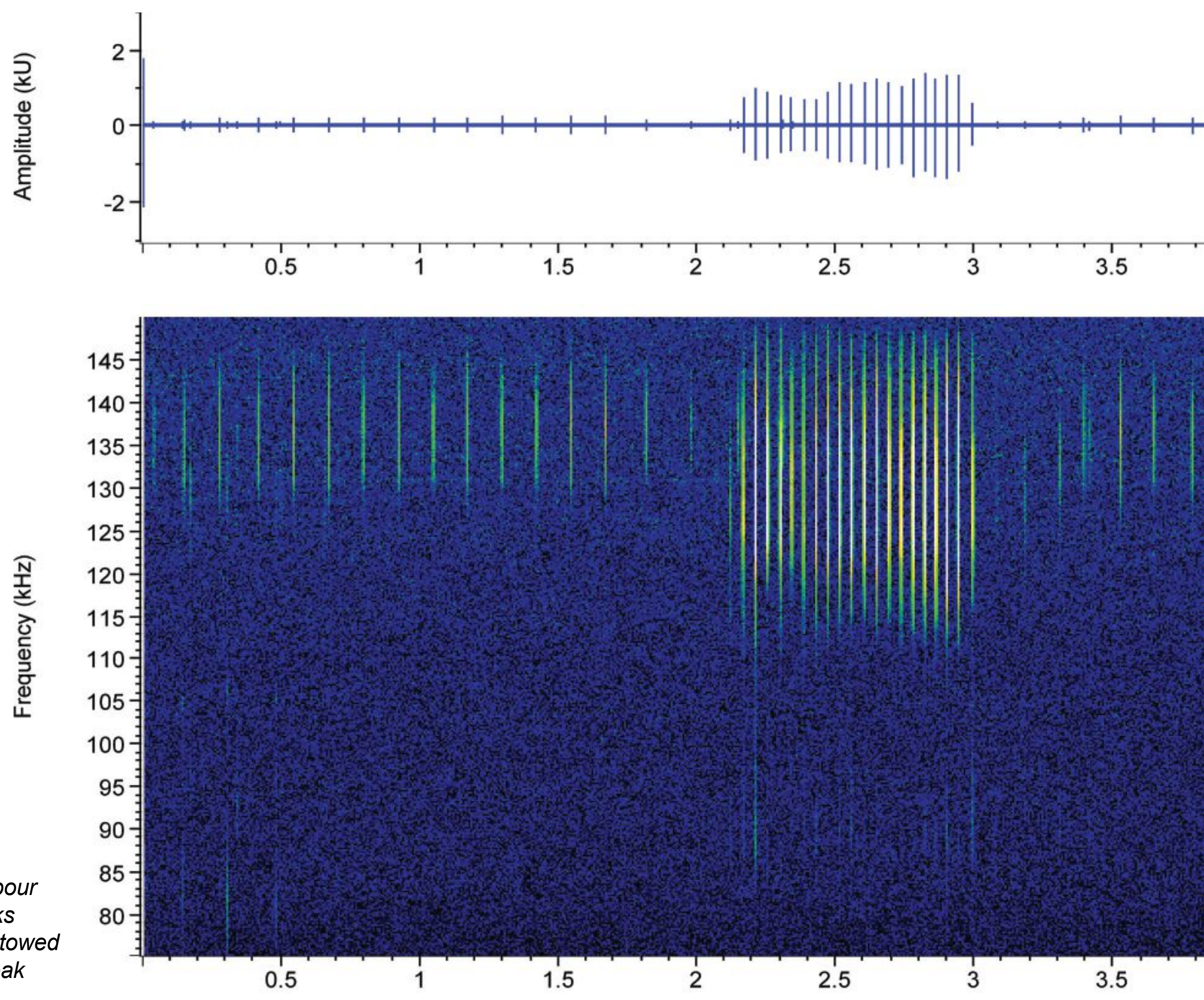
The marriage between USV and hydrophone array is a crucial consideration for successful PAM missions. In collaboration with the acoustic array specialists, Seiche Ltd., two PAM systems have been specifically designed for *AutoNaut*. The first, a lightweight two-channel analogue array 25 m in length, is aimed at the commercial and academic sectors for sound measurement and marine mammal detection. The second, a fully digitized eight-sensor array with configurability and very high sensitivity, is designed for use in defence applications to counter the threat from enemy submarines.

Throughout the development of PAM for *AutoNaut*, three key challenges have been constantly assessed and addressed: 1) Will the USV's performance be affected by the PAM array?; 2) Will there be an unacceptable entanglement risk?; and 3) Will high-quality acoustic data be acquired?

At slower speeds and when utilizing environmental conditions for propulsion, the concern is that inertial drag of a towed array will hinder maritime capabilities of the USV. *AutoNaut*'s pace has been slightly slowed by about half a knot in several trials, but the inertial problem has not been a factor. The effect on manoeuvrability is also a potential problem but, to date, the *AutoNaut* has been able to perform its turning circle of 50-m radius without hindrance.

A serious consideration in the deployment of any array is the risk of entanglement. Significant safety concerns are apparent, and this is especially so from an unmanned platform where no personnel are present to monitor changing conditions. With *AutoNaut*, the PAM array cable is conventionally deployed direct from the stern. The arrangement contains the array to remain clear of the wave-propulsion foils before streaming astern up to 25 m. Installed as a depth of 0.8 m below the waterline, the foils are the only subsea part of the *AutoNaut* and, to date, no problems have occurred.

Finally, to discover just how quiet the *AutoNaut* is, audio recordings have been analysed and assessed. In early



Spectrogram showing harbour porpoise echolocation clicks recorded on the AutoNaut-towed PAM array system, with peak energy at 135 kHz.

tests, analysis of "self-noise" picked out noise from surface waves against the hull, harmonic sounds created by the USV's steering mechanism, and electrical interference from the power supply. The analysis guided technical development to eradicate the latter and reduce the harmonics. While minor, the "surface slap" can be countered by a greater hydrophone depth, which also moves the hydrophone sensors away from sea-surface noise. The depth gauge has recorded a minimum of 10 m, though this will vary depending on speed and environmental conditions.

Identified ambient sounds have included those of nearby vessels and echo sounders with excellent recording clarity. Indeed, during *AutoNaut* trials off Scotland, the system recorded the echolocation click trains of a harbour porpoise. The clarity and high signal-to-noise ratio of the detection gave confidence that these cetaceans, which are generally considered to be shy and wary of boats, were not responding negatively to the vessel.

AutoNaut has completed a series of trials in collaboration with Seiche Ltd. and was successfully operated during Unmanned Warrior 2016. In this UK Royal Navy exercise off the Hebrides in October 2016, *AutoNaut* deployed Seiche's Digital Thin Line Array to successfully detect and track a submarine target. Information was transmitted to the operational commanders for dissemination into the wider operational picture. Much of these data were transmitted in real-time with further meteorological and oceanographic data recorded from a suite of state-of-the-art sensors on board.

The Future of Passive Acoustic Monitoring by USV

For *AutoNaut*, with the maturation of its PAM capability, several projects are upcoming. One mission will be to monitor for marine mammals for the National Oceanographic Centre (NOC) as part of MASSMO4 and another for an oil and gas major. More projects are in the pipeline.

USVs are now coming of age. Craft such as *AutoNaut* have a major role to play in meteorological and oceanographic science, surveillance missions, hydrographic charting, and as an at-sea communications gateway. Listening to our ocean environment, be it for measurement of sound levels, detection of whales and dolphins, or tracking submarines, is now a key capability for USVs.