# Luma360 AIS Test and Evaluation: A lightweight automatic identification system (AIS) receiver for marine domain awareness (MDA)

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*Introduction*

This paper presents the findings of a field test evaluating Luma360 AIS, a compact, low-cost Automatic Identification System (AIS) receiver deployed at Hopkins Marine Station in Monterey Bay. Conducted as a collaborative research effort between the Synchro tech testbed program and Suburban Marine, we evaluated the value of localized AIS receivers in near-shore environments and explored their potential to address coverage gaps in coastal AIS data collection networks.

AIS is a maritime communication technology that enables vessels to broadcast their identity, position, speed, and heading via VHF radio signals. These signals are received by other ships, terrestrial stations, and satellites to enhance navigational safety, prevent collisions, and facilitate vessel tracking (Emmons et al. 2021). While AIS is widely used by commercial shipping, port authorities, coast guards, and maritime agencies, its effectiveness can be limited in complex coastal zones where terrain or distance impedes signal reception by large-scale monitoring systems. Nearshore applications also include marine protected area management, where marine protected areas sometimes only extend a few miles from the coast. These data are also now in regular use by Regional Associations of the Integrated Ocean Observing System such as in the Alaska Ocean Observing System (AOOS, Wright et al. 2019) and the Central and Northern California Ocean Observing System (CeNCOOS). Such data can be very valuable and processed using models into classifications of vessel classes, activities and more (e.g. Meyer and Kleynhans 2025), but the utility of AIS depends on various quality and quantity aspects that balance signal and noise (e.g. Emmons et al. 2021). The system developed by Suburban Marine offers a modular, portable, and cost-effective alternative to conventional AIS infrastructure. Designed for edge deployment, the receiver captures AIS beacon transmissions in challenging near-shore regions and transmits the data via LTE, Starlink, Iridium, or other communication networks to a centralized server for processing and archival in a spatial database. A live web interface enables both real-time and historical vessel track visualization.

To assess performance, the collected AIS data was compared against the U.S. Coast Guard-sourced dataset available via the Marine Cadastre (https://hub.marinecadastre.gov). The core hypothesis of this technical evaluation was that the Luma360 AIS receiver would demonstrate higher sensitivity in detecting vessel transmissions in coastal areas compared to data available via the Marine Cadastre. The results offer insight into how locally deployed AIS nodes can complement national-scale systems, enhancing maritime domain awareness in data-sparse regions.

In the area of investigation, AIS information users include the Marine Exchange of the San Francisco Bay Region, the Monterey Bay National Marine Sanctuary, the California Department of Fish and Wildlife, and Monterey Harbor authorities. We discuss the applicability of the assessed system to their AIS data needs.

## *Methods*

The Luma360 system was installed on the rooftop of the Agassiz Building  (36.62, -121.91) at Hopkins Marine Station in Pacific Grove, CA on March 26th, 2024 (Figure 1) through May 29, 2025. The hardware took approximately 1.5 hours to setup and was powered by a standard 120VAC outlet. The system was online and reporting data to Suburban Marine on the same day (Figure 2). Data were received by the antenna 24 hours per day, every day while in service. The Luma360 AIS system consists of an i.MX 93 single board computer, AC/DC power supply, LTE router, and AIS receiver. A weather proof enclosure and sealed connectors provide ingress protection. The two internal LTE antennas provide diversity, while a larger external antenna is used to receive AIS. A web based user interface allows viewing ship traffic with time and MMSI filters. More advanced queries can be created via spatial queries on the Postgres+PostGIS data backend (Figure 2).


Figure 1: The Luma360 AIS system is shown as mounted to a non-penetrating antenna roof mount system which is portable and easily installed for short term deployments.

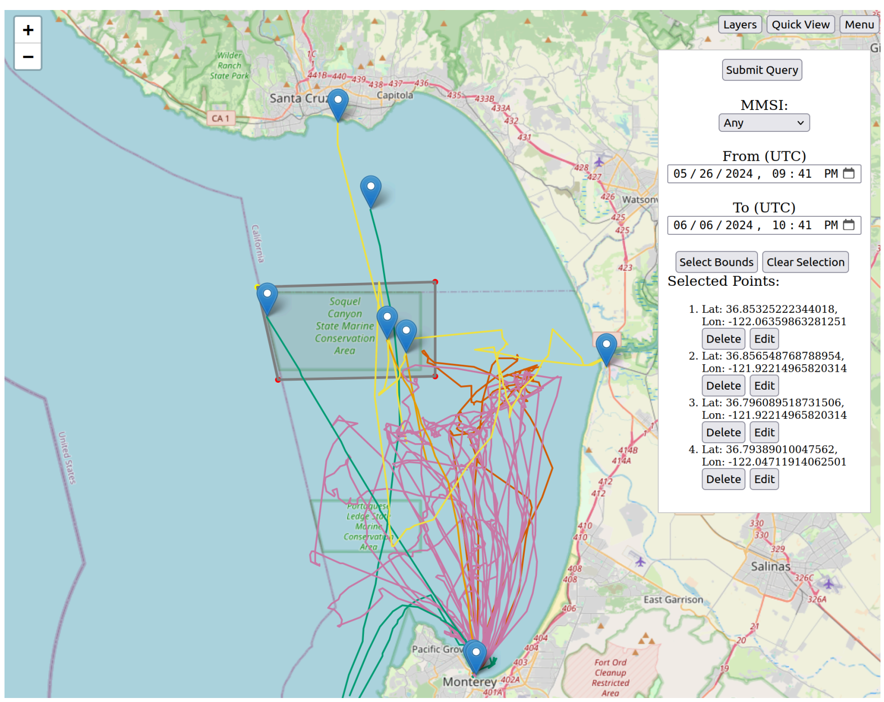


Figure 2: A live view map overlay allows viewing AIS data received by the system in near-real time.

To analyze the performance of the Luma360 system, the AIS data from this site was exported and compared to the Marine Cadastre set in a region of interest around the installation. The region of interest was set to within Monterey Bay in order to filter out targets greater than 40 km away from the Luma360 antenna. Many targets were received beyond 40 km from the installation, even as far as San Francisco Bay; however evaluating the system performance at that distance was outside of the scope of this project's hypothesis. The data comparison was done for the period of July 1, 2024 through December 6, 2024.

To compare the data sets fairly, both data sets were averaged to 1 minute data. The Marine Cadastre data was supposed to be every minute but that was not found to always be the case. Data from both data sets were only used when the speed over ground was greater than zero.

For all AIS data, the position of the data was computed as distance from the location of the Luma360 antenna. The data was looped through for each unique ship identified by the Marine Mobile Service Identifier (MMSI). Distances were binned based upon 0.1 km bins, as distance from the antenna. The total observations were then summed over distance-based bins. We calculated cases where both systems observed the same MMSI at a given distance (Fig. 3). That data was counted as one "ping". If only one system saw the ship then that "ping" was assigned to that specific system (Marine Cadastre - Fig. 4 or Luma360 - Fig. 5).

We also calculated the percentage of the total pings observed by both systems as a function of distance from the antennae (Figure 4).

*Results*

The total unique Marine Mobile Service Identifiers (MMSIs) simultaneously observed July 1, 2024 to December 6, 2024 by the Luma360 and Marine Cadastre were 411 (Figure 3). The distribution of these joint detections was substantially greater nearer to the tested antenna, particularly within 5 km of the antennae. This was the case even though the Marine Cadaster data observed 537 MMSIs (Fig. 4) vs 415 by the Luma360 (Fig. 5).

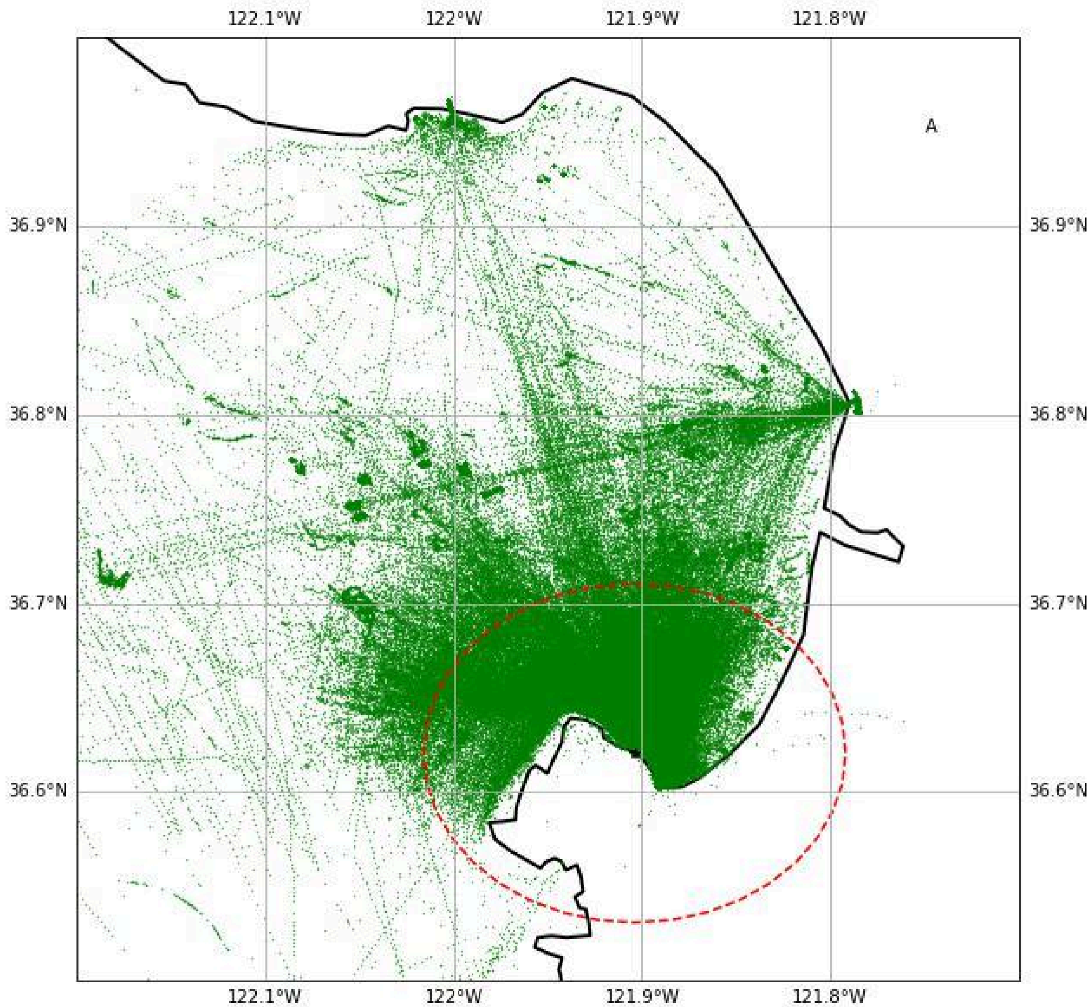


Figure 3. MMSI positions of ships observed from July 1,2024 until December 6, 2024 that were simultaneously observed by Luma360 and found in the Marine Cadastre data. The dashed ring on the figures represents a range ring of 10 km around the tested antenna. The small black star is the location of the antenna at Hopkins Marine Station.

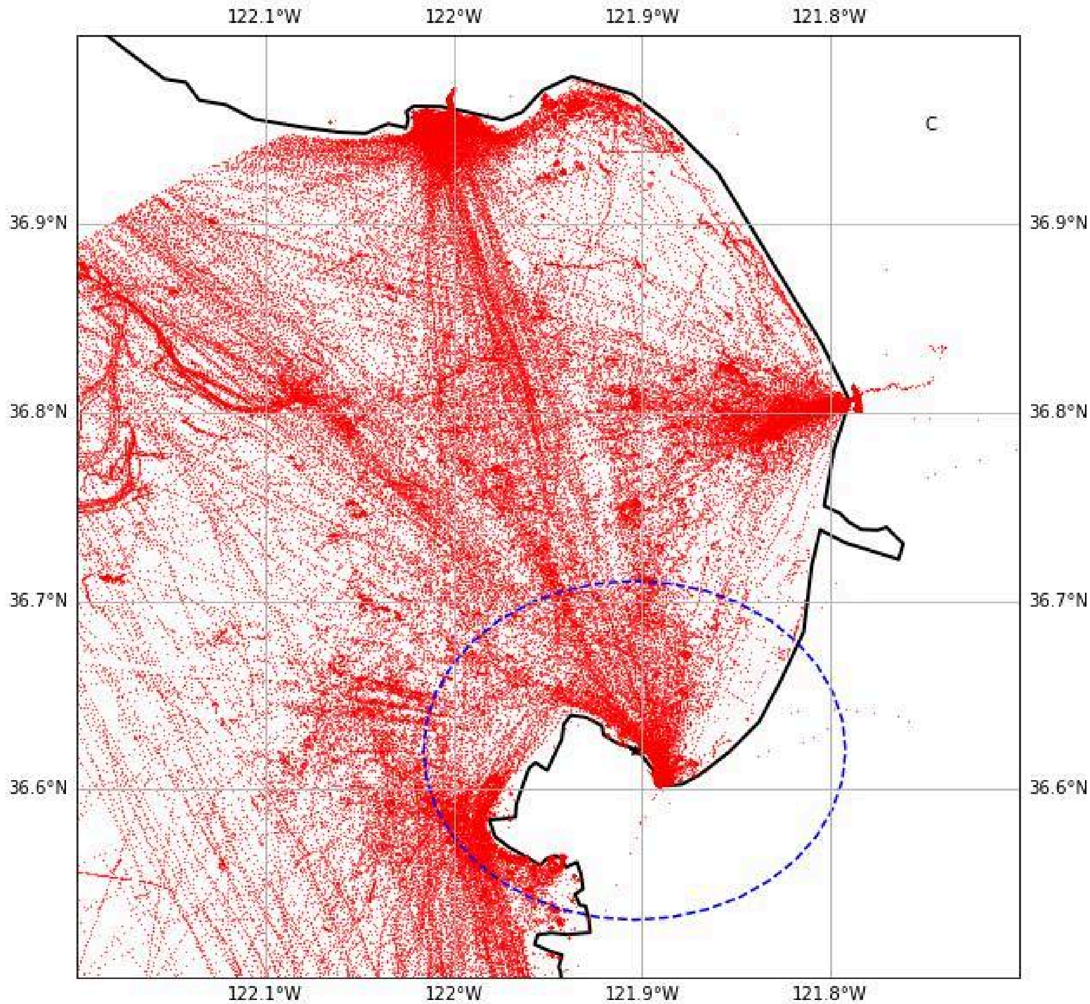


Figure 4. MMSI positions of ships observed that were found in the Marine Cadastre data. The dashed ring on the figures represents a range ring of 10 km around the tested antenna. The small black star is the location of the antenna at Hopkins Marine Station.

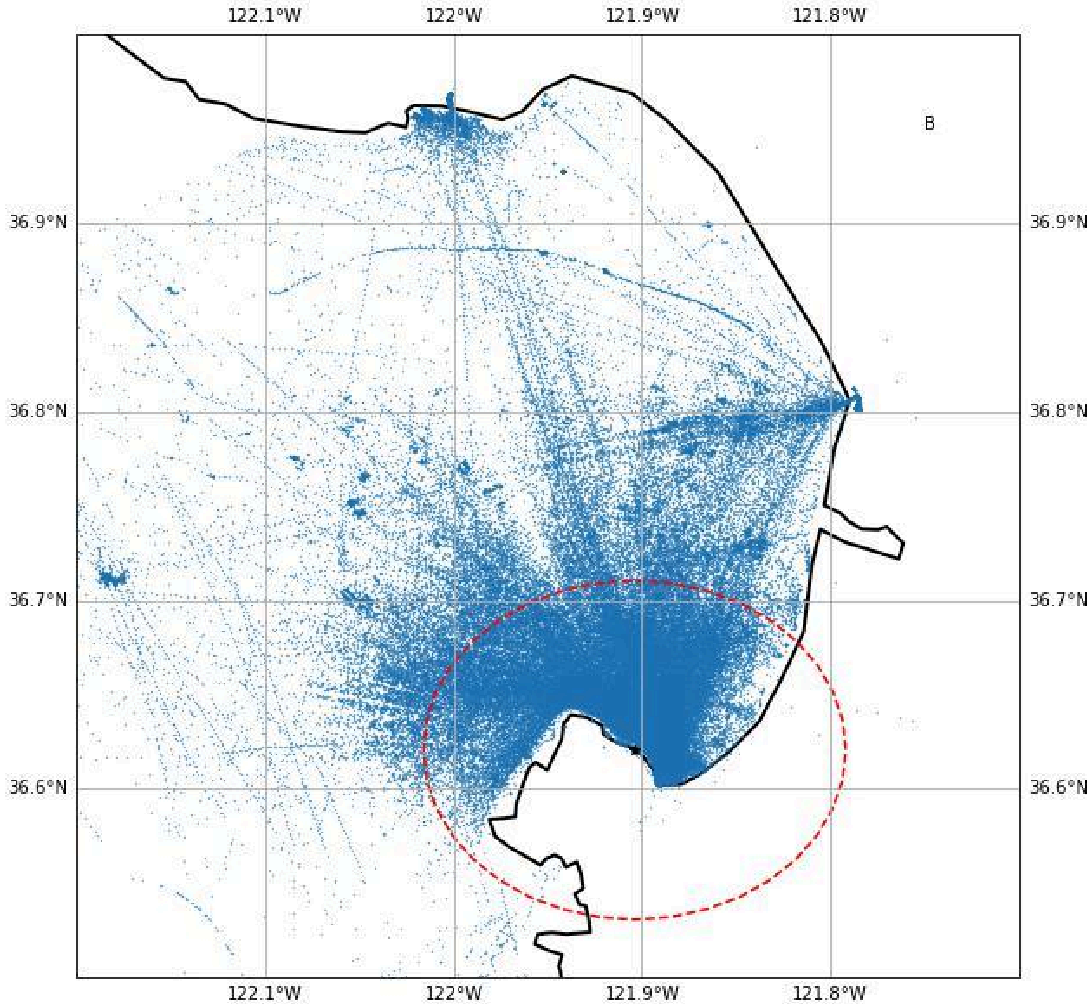


Figure 5. MMSI positions of ships observed that were observed by the Luma360 system. The dashed ring on the figures represents a range ring of 10 km around the tested antenna. The small black star is the location of the antenna at Hopkins Marine Station.

As a function of distance from the antenna, the percentage of total vessel pings that were observed by Luma360 AIS (blue) was about 50% higher than Marine Cadastre (red) for the first ~7 km (Fig. 6). This data comparison indicated that the Luma360 system received more vessel pings out to approximately 8-10 km away from the antenna. At a range of ~10 to ~20 km from the antenna, both perform about the same in receiving vessel pings. Beyond 20 km from the antenna, Marine Cadastre data had a higher proportion of  receiving targets. It should be noted that the exact source of individual  Marine Cadastre pings is anonymised in the public data records, but does not include the tested antennae.

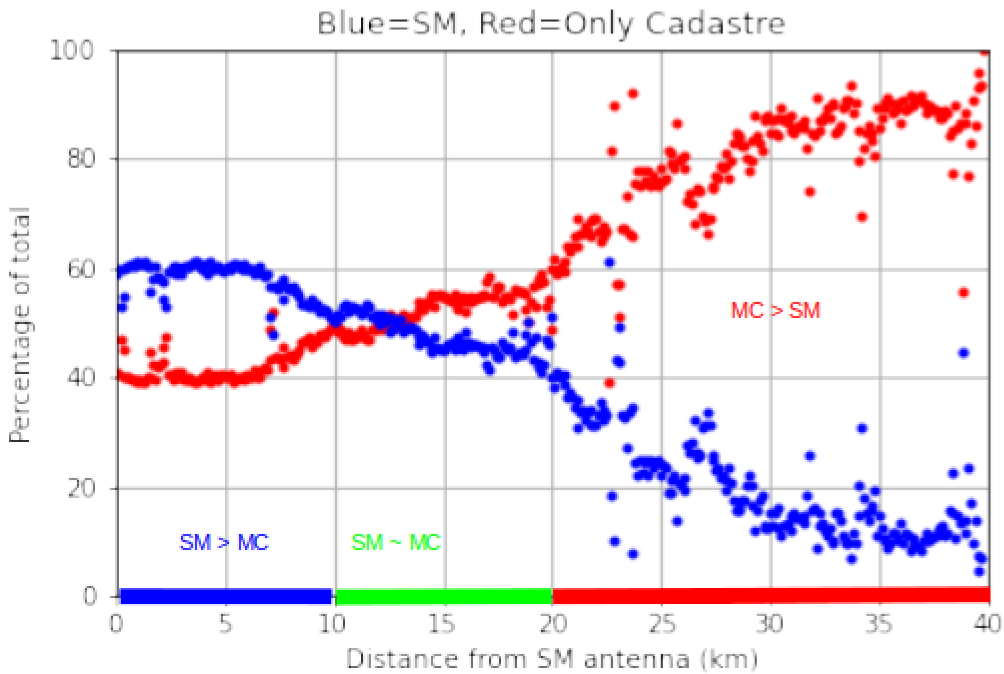


Figure 6: Percentage of targets received by Suburban Marine (blue) and Marine Cadastre (red) in 0.1km incremental distances from the antenna installations at Hopkins Marine Station.

*Discussion*

This analysis shows a stronger detection performance in the number of observed vessels in the 0-8 km distance / nearshore environment compared to the conventional Marine Cadastre data. The deployment of localized AIS receivers in nearshore environments reveals clear advantages in data fidelity and coverage compared to traditional wide-area systems. This enhanced resolution is particularly valuable in coastal zones where vessel density is high and signal interference from terrain or infrastructure is common.

Monterey Harbor and the Monterey Bay National Marine Sanctuary monitor marine traffic to understand both harbour facilities management and potential impacts of activities in the area. There are regular various issues arising from transiting vessels including discharges of pollutants, groundings and sinkings. Better AIS data near such harbors can improve reaction time and resolution of activities in such high traffic areas, which share ocean waters with protected marine life such as marine mammals.

As some MPAs are located near shore or adjacent to terrain features that may limit conventional AIS coverage, localized AIS systems offer additional value in tracking vessel traffic in and around these sensitive zones. This capability can be further strengthened by integrating local radar stations to detect non-cooperative targets—vessels not broadcasting AIS signals—or, more critically, to identify vessels that intentionally disable their transponders upon entering MPAs. Such layered sensing approaches enhance enforcement and support conservation efforts by providing a more complete operational picture.

Organizations such as the Marine Exchange of the San Francisco Bay Region, which supports maritime safety, efficiency, and environmental compliance in one of the nation's busiest port regions, collects and shares AIS data regularly. . The ability to monitor vessel movements with greater precision in nearshore areas—especially in zones with terrain-induced blind spots—would improve real-time traffic management, incident response, and compliance monitoring. Localized AIS systems could provide the vessel traffic management and ship operators with an added layer of situational awareness that complements their existing tracking infrastructure, ultimately helping to ensure smoother operations and increased maritime safety in the Bay Area.

These findings highlight the added value  of modular, edge-deployable AIS systems as a complement to national AIS data products, especially in regions where traditional coverage is limited or inconsistent.

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References

Wright, D., Janzen, C., Bochenek, R., Austin, J., & Page, E. (2019). Marine Observing Applications Using AIS: Automatic Identification System. *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2019.00537.

Emmens, T., Amrit, C., Abdi, A., & Ghosh, M. (2021). The promises and perils of Automatic Identification System data. Expert Syst. Appl., 178, 114975. https://doi.org/10.1016/J.ESWA.2021.114975.

Meyer, R., & Kleynhans, W. (2025). Vessel classification using AIS data. *Ocean Engineering*. https://doi.org/10.1016/j.oceaneng.2024.120043.

Appendix
The AIS antennae data processing code is available here;
https://www.researchworkspace.com/file/45009378/compute_sums_per_distance_cleanedup.ipynb
An example of how the data was organized is presented in this example table;
https://www.researchworkspace.com/file/45020771/AIS_cadastre_SuburbanMarine_data_example.csv