
Examining Multi-Aperture Sonar (MAS): A Cutting-Edge Evolution in Side-Scan Sonar for High-Resolution Geophysical Imaging

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1 Introduction

Synthetic Aperture Sonar (SAS) systems have long been recognized for their ability to produce ultra-high-resolution imagery in geophysical surveys. However, their reliance on precise navigation, post-acquisition processing, and stable platform dynamics can limit operational efficiency, particularly in time-constrained or logistically complex environments. This paper examines Solstice MAS, a new compact Multi-Aperture Sonar (MAS) system developed by Wavefront Systems, as a technically viable alternative to SAS for applications requiring high-resolution acoustic data with reduced processing overhead. Solstice MAS offers onboard real-time data synthesis, co-registered side-scan imagery and bathymetry, and integration flexibility across autonomous and towed platforms. These attributes suggest potential utility in increasing survey density, accelerating data turnaround, and supporting early-phase engineering and environmental assessments ranging from shallow littoral waters down to 600-meter depths.

2 Technology Overview

MAS is a modular Multi-Aperture Sonar system designed to deliver high-resolution acoustic imagery and bathymetric data in real time. Operating in the **700–800 kHz** frequency range, the system employs Multi-Ping Multi-Look (MPML) processing to enhance signal-to-noise ratio and spatial resolution without the navigational sensitivity typically associated with SAS platforms (Wavefront Systems, 2025; Sonardyne, 2025). It produces co-registered side-scan imagery at approximately 3 cm × 3 cm resolution and interferometric bathymetry at 0.5 × 0.5 meters grid spacing, with a swathe width of up to 100 meters per channel when deployed at an elevation of 9–12 meters above the seabed (Figures 1 & 2). Unlike SAS systems, which often require extensive post-processing and external bathymetric integration, Solstice MAS performs onboard data

synthesis, enabling immediate access to processed deliverables upon mission completion. This architecture supports deployment on a range of autonomous underwater vehicles (AUVs), remotely operated towed vehicles (ROTVs), and towfish systems, making it suitable for survey operations where platform size, power availability, and turnaround time are operational constraints.

3 Technology Differentiation

The following (Table 1) provides a comparative overview of MAS, standard side-scan sonar (SSS), multi-beam SSS, and synthetic aperture sonar (SAS), focusing on resolution and bathymetric capabilities (Wavefront Systems, 2025; Kraken Robotics, 2019; Klein Marine Systems, 2024).

Table 1. Frequency and Resolution Comparison

Technology	Frequency Range	Side-Scan Resolution	Bathymetry Resolution
Solstice MAS	700–800 kHz	3 cm (nominal)	Optional 0.5 m grid-capable
Standard SSS	100–500 kHz	15–30 cm	Not applicable
Multi-Beam SSS (Klein 5900)	455 kHz	3–5 cm (nominal)	Optional interferometric (0.5–1 m grid)
SAS (e.g., HISAS 1032)	70–120 kHz	2–3 cm (post-processed/real-time)	Integrated interferometric (5–10 cm grid)

SAS systems can achieve 2 cm × 2 cm resolution at survey speeds of 3 knots, though performance depends on platform stability, navigational accuracy, and environmental conditions. Kraken Robotics (2019) notes that commercial systems such as HISAS typically deliver 3 cm real-time and ~2 cm post-processed resolution in real-world operations due to these complexities. Solstice MAS, by contrast, consistently achieves 3 cm × 3 cm resolution across a 200-meter swath without relying on tight navigation constraints (Sonardyne, 2025).

The following (Table 2) provides a comparative overview of MAS, standard side-scan sonar (SSS), multi-beam SSS, and synthetic aperture sonar (SAS), focusing on data processing modalities, power consumption, and data volume (gigabytes per hour). Large data volumes become more challenging in transmitting the data and can increase processing times, thus decreasing efficiency of delivering a final product (Wavefront Systems, 2025; Kraken Robotics, 2019).

Table 2. Resolution and Data Rate Comparison

Technology	Typical Power Usage	Processing Method	Data Rate/Volume
Solstice MAS	18–30 W	Onboard; real-time output	6–9 GB/hr (side-scan only vs. with co-registered bathy)
Standard SSS	50–100 W	Onboard; imagery only	0.5–1 GB/hr (low-res imagery only)
Multi-Beam SSS (Klein 5900)	80–150 W	Onboard with optional post-processing	2–5 GB/hr (higher due to multi-beam and optional bathy)
SAS (e.g., HISAS 1032)	150–250 W	Offline; post-processed	60–90 GB/hr (estimated raw; high-res imagery + bathy)

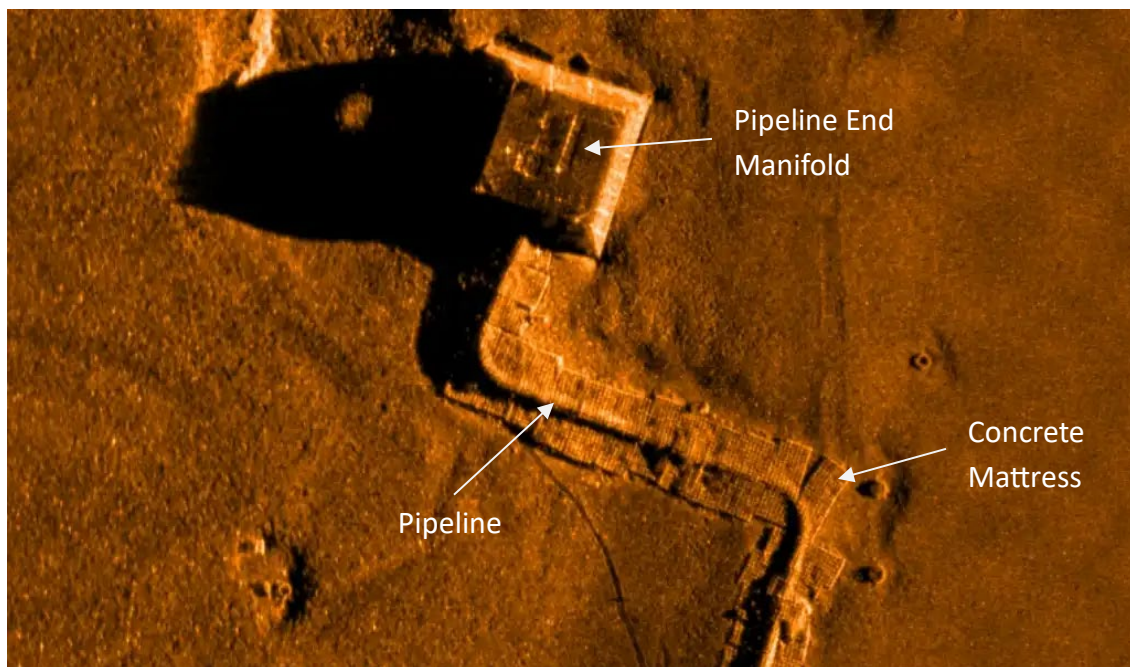


Figure 1. Pipeline End Manifold with mattress covering pipeline (Wavefront Systems 2025).

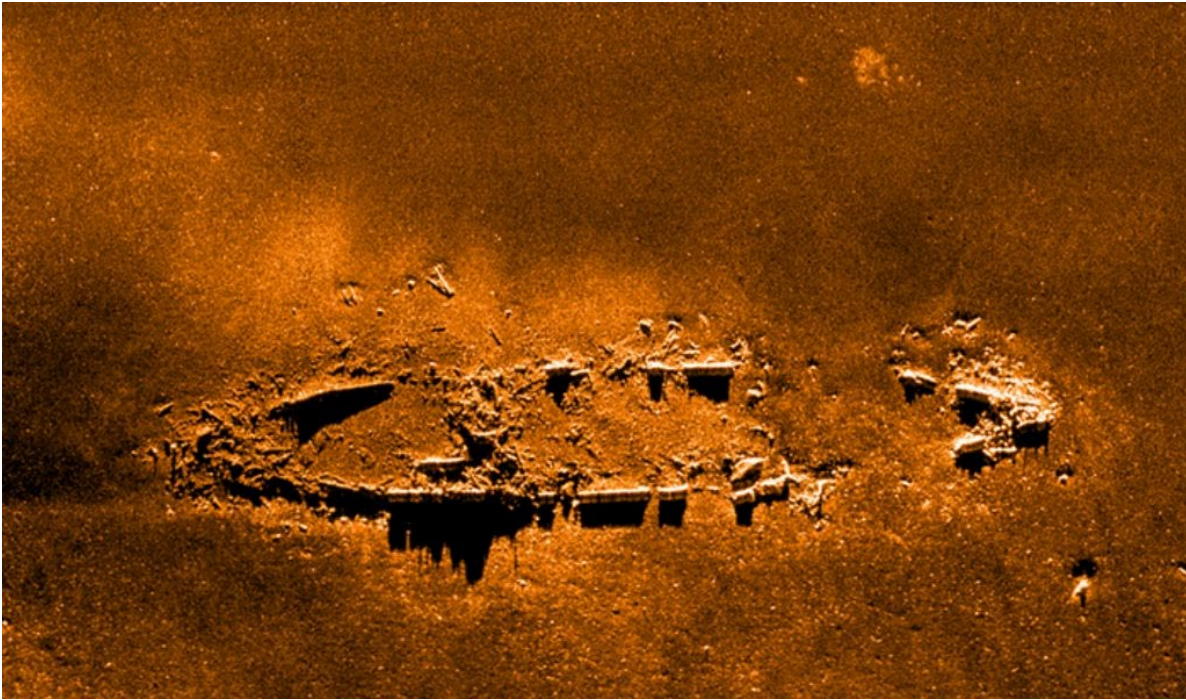


Figure 2. Partially buried wreck (Wavefront Systems 2025).

Solstice MAS offers a balanced data throughput profile that supports high-resolution imaging and bathymetry without overwhelming downstream workflows. The system generates approximately 6 GB per hour during side-scan-only missions and up to 9 GB per hour when acquiring co-registered bathymetry and imagery simultaneously (Wavefront Systems, 2025). This represents a significant improvement over traditional standard side-scan sonar (SSS) systems, which typically produce only 0.5 to 1 GB per hour but at much coarser resolutions (15–30 cm), limiting their utility for detailed target discrimination (Flemming, 1985). In contrast, synthetic aperture sonar (SAS) systems like the Kraken HISAS 1032, while capable of ultra-high-resolution imagery (~2–3 cm), often generate ~60 to 90 GB per hour of raw data due to their dense data capture and reliance on integrated bathymetric workflows, leading to substantial processing and storage demands (Callow, 2003; Kraken Robotics, 2019).

Multi-beam side-scan systems such as the Klein 5900 bridge this gap, producing around 2–5 GB per hour with resolutions of 3–5 cm and optional interferometric bathymetry, but they still require higher power (80–150 W) and may not match MAS's real-time onboard synthesis (Klein Marine Systems, 2024). By delivering 3 cm resolution at data volumes far lower than HISAS/SAS equivalents (6–9 GB/hour vs. ~60–90 GB/hour raw), MAS minimizes transmission bottlenecks in remote AUV operations, accelerates post-mission analysis, and reduces storage costs—critical for high-density surveys in offshore wind, pipeline routing, or UXO mapping. Coupled with its low

power consumption (18–30 W), this makes MAS exceptionally suited for extended AUV deployments where battery life and data handling efficiency are paramount.

Solstice MAS is particularly well-suited for survey missions that demand high-resolution imaging within constrained timeframes and across complex or variable seafloor geometries. Its capabilities align with a range of operational scenarios, including:

- Concept-level pipeline routing
- Monopile siting for offshore wind
- Debris field mapping following subsea infrastructure failure
- Rapid-response cable landing surveys
- Asset Integrity surveys

Additionally, its fine-scale resolution and co-registered bathymetry support dense target classification in archaeological zones and areas with unexploded ordnance (UXO) risk, where regulatory guidance often requires detailed object discrimination (BOEM, 2022).

The system's compact form factor and low power consumption—typically between 18 and 30 watts—enable deployment on a wide variety of platforms, including small autonomous underwater vehicles (AUVs), remotely operated towed vehicles (ROTVs), and lightweight towfish systems (Wavefront Systems, 2025; Trittech, 2022). This versatility broadens its application across environmental, geotechnical, and cultural resource survey campaigns, particularly in regions where traditional SAS platforms may be impractical due to size, power, or post-processing constraints (Callow, 2003).

When integrated with a littoral-capable autonomous underwater vehicle (AUV) equipped with video or still imaging, Solstice MAS becomes a highly effective tool for offshore wind infrastructure maintenance surveys, particularly in assessing structural wear and seabed interaction. The system's high-resolution acoustic imagery and co-registered bathymetry enable detection of scour, sediment displacement, and potential deformation around monopiles and cable landings (Wavefront Systems, 2025; Trittech International Ltd., 2022). Once acoustic anomalies are identified, the AUV's video payload can be deployed for targeted visual inspection, confirming material degradation, corrosion, or marine growth accumulation (Figure 4)—supporting proactive maintenance and regulatory compliance in dynamic nearshore environments (BOEM, 2022).

Solstice MAS's compact footprint and low power consumption (typically 18–30 W) make it ideal for integration on smaller AUVs operating in shallow water zones typical of offshore wind farms (Hayes et al., 2020). Notably, the system has been successfully integrated into several platforms

suited for such missions, including the L3Harris Iver4 900, which combines MAS with the Voyis Recon LS video and laser payload; the Eelume-S All-Terrain AUV (Figure 3), designed for persistent inspection in complex subsea environments; and General Dynamics' Bluefin-12 and Bluefin-9, which offer long-endurance capabilities with MAS as a standard or optional payload (Wavefront Systems, 2025).



Figure 3. Eelume S Series All-Terrain AUV can come equipped with 4K still camera and MAS systems (Eelume, 2025).

4 Commercial and Regulatory Implications

Survey density and throughput remain key constraints in offshore wind and hydrocarbon site characterization. Solstice MAS addresses both:

- Faster site coverage accelerates engineering feasibility assessment
- Real-time deliverables improve stakeholder turnaround and permit filing
- Swath width and resolution support dense target classification within BOEM and BSEE guidance for archaeological and UXO risk zones

As regulators increasingly request reproducible, high-resolution imagery from early-phase development surveys, technologies like MAS can improve compliance and reduce iterative re-survey requirements (BOEM, 2022; NOAA Ocean Exploration, n.d.). Additionally, some regulatory guidelines from BOEM and BSEE recommend SSS data at frequencies > 500 kHz; which the MAS more than exceeds. The MAS system, with higher than standard SSS frequencies, can also support detailed Essential Fish Habitat (EFH) assessments as outlined in NMFS guidelines (National Marine Fisheries Service, 2023) (Figure 4).

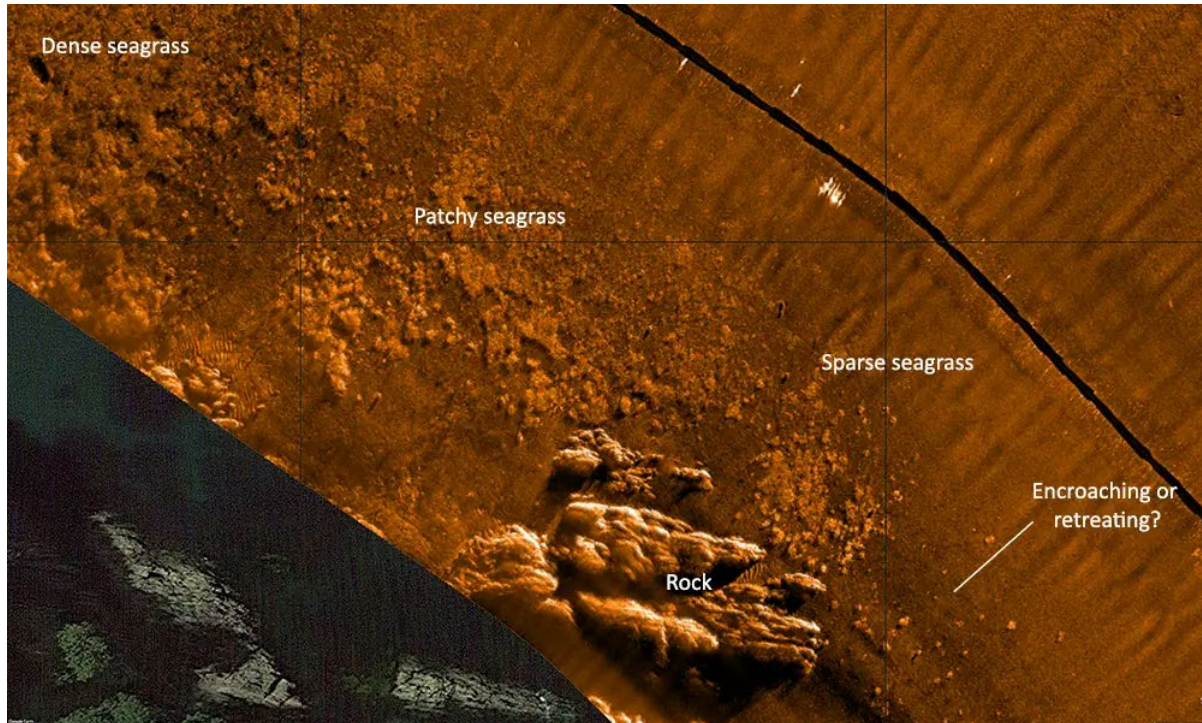


Figure 4. MAS data showing seagrass assessment (Wavefront Systems, 2025)

5 Limitations of MAS

While Solstice MAS offers significant advantages in high-resolution imaging and platform versatility, it is not without operational constraints. One of the primary limitations is its unsuitability for deepwater operations, with current pressure housings only capable of up to 600 meters water depth. The system is optimized for deployment at elevations between 9 to 12 meters above the seabed, which restricts its effective use to shallow to mid-depth environments (Wavefront Systems, 2025).

This elevation requirement also imposes constraints on platform altitude control, particularly in areas with steep bathymetric gradients or dynamic current regimes. Additionally, the maximum swathe width is limited to approximately 100 meters per channel, which, while sufficient for dense target mapping and site-specific investigations, may be less efficient for large-area reconnaissance compared to wider-swath systems such as interferometric multibeam or deepwater synthetic aperture sonar (Callow, 2003). These limitations necessitate careful mission planning and platform selection to ensure optimal data coverage and resolution, especially in heterogeneous seafloor conditions or when survey efficiency is a critical factor.

Recognizing these constraints, next-generation variants of MAS are currently in development, with design enhancements aimed at extending operational depth and increasing swathe coverage. These planned upgrades include pressure-rated housings for full ocean depth, adaptive

altitude control algorithms, and enhanced signal processing for wider elevation envelopes, which would allow deployment on deepwater-capable AUVs and ROTVs (Wavefront Systems, 2025). If realized, these improvements could significantly broaden the system's applicability to deepwater geohazard mapping, cable route planning, and infrastructure inspection in frontier offshore regions.

6 Conclusion

Multi-Aperture Sonar (MAS) introduces a valuable new tool to the geophysical surveying toolkit, offering a compelling balance of high-resolution imaging, operational efficiency, and real-time data readiness that advances geophysical survey capabilities in environments ranging from 600-meter depths to very shallow littoral waters (Sonardyne 2025). Complementing established technologies like Synthetic Aperture Sonar (SAS), which sets benchmarks for image fidelity in optimal conditions, MAS excels in diverse scenarios by providing seamless integration with low-logistics platforms such as autonomous underwater vehicles (AUVs) and delivering co-registered imagery and bathymetry on the fly. This makes it particularly well-suited for emerging applications, including offshore wind infrastructure monitoring, cable route planning, and environmental baseline surveys. As deeper-rated variants continue to evolve and gain validation, MAS promises to expand its role across broader offshore domains, enhancing commercial and regulatory workflows with scalable, high-resolution acoustic products.

7 References

Blake, R. (2018). *Side-Scan Sonar Fundamentals for Marine Surveyors*. Hydrographic Institute Technical Series.

Bureau of Ocean Energy Management. (2022). Guidelines for Providing Archaeological and Historic Property Information Pursuant to 30 CFR Part 585.

<https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/Archaeology-Guidelines.pdf>

Callow, G. (2003). Signal Processing for Synthetic Aperture Sonar Image Enhancement. PhD Thesis, University of Canterbury.

https://www.math.ucdavis.edu/~saito/data/sonar/Callow_thesis.pdf

Eelume. (2025). Eelume S-series autonomous underwater vehicles.

<https://www.eelume.com/eelume-s-series>

Hayes, M. et al. (2020). *Efficiency Tradeoffs in Synthetic Aperture Sonar for Deepwater Applications*. IEEE Journal of Oceanic Engineering, 45(1), 115–128.

Kraken Robotics. (2019). *HISAS 1032 Synthetic Aperture Sonar*.

<https://krakenrobotics.com/products/hisas/>

National Oceanographic and Atmospheric Administration, Ocean Exploration. (n.d.). *Emerging Technologies: Multi-Aperture Sonar*. <https://oceanexplorer.noaa.gov/>

National Marine Fisheries Service. (2023, December 7). *Essential Fish Habitat information needs for offshore wind energy projects along the U.S. Atlantic*. NOAA Fisheries, Office of Habitat Conservation. Retrieved from <https://www.fisheries.noaa.gov/s3/2023-12/07Dec2023-Essential-Fish-Habitat-Information-Needs-for-OffshoreWind-Energy-Projects-Formatted.pdf>

Sonardyne. (2025). Solstice Multi-Aperture Sonar.

<https://www.sonardyne.com/product/solstice/>

Wavefront Systems. (2025). Solstice MAS Specifications.

<https://www.wavefront.systems/solstice-mas/>