The Truth About AUV HISAS – "You Can't Handle the Truth": Evaluating HISAS Integration on Offshore Survey AUVs for Seabed Characterization and Regulatory Frameworks

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1 Introduction

Autonomous underwater vehicles (AUVs) play a central role in offshore energy surveys, enabling high-resolution seabed characterization for infrastructure planning, hazard detection, and environmental review. The world of commercial survey AUV's has undergone some incredible updates since their introduction in 2001. A newer tool to be released Synthetic Aperture Sonar (SAS)—particularly Kongsberg's HISAS—has surpassed legacy Side Scan Sonar (SSS) in clarity, depth performance, and object localization accuracy. This paper evaluates AUV based HISAS performance across varying depths, assesses terrain-aided navigation benefits, and proposes regulatory updates to current guidance that reflect these technological advances and their liabilities.

2 How Side Scan Sonar (SSS) Works

Side Scan Sonar (SSS) generates plan-view seafloor imagery by emitting fan-shaped acoustic pulses perpendicular to the autonomous underwater vehicle (AUV) track and recording the intensity of the returning echoes. This method is well-suited for broad reconnaissance and environmental screening but suffers from several inherent limitations. Current AUV-based SSS systems—such as those deployed on Kongsberg's HUGIN platforms—typically operate in the 300–1200 kHz frequency range, with dual- or triple-frequency configurations available. However, earlier HUGIN systems, including the HUGIN 1000, were equipped with 100 kHz SSS modules like the EdgeTech 2200-M, offering extended range but lower resolution. Lower frequencies (e.g., 300–600 kHz) offer broader swath coverage, while higher frequencies (e.g., 900–1200 kHz) provide finer resolution for near-bottom surveys.

At a typical commercial operating altitude of 40m, AUV SSS units operating at **410 kHz** achieved a resolution of approximately 2-5cm across-track (range resolution) and 40-60m along-track: this gives a general resolution 0.5 m (the along-track resolution is the main limiting factor for SSS resolution with AUV acquisition due to ping rate). Post-processed SSS mosaics are typically generated at 0.5-1.0m pixel size for conventional mapping. According to the US regulatory agency, Bureau of Ocean Energy Management (BOEM) (2022), SSS is generally capable of detecting features ≥0.5 m in size. However, its performance diminishes with increasing range due to beam divergence, leading to degraded resolution and poor feature classification. Additionally, SSS imagery is often susceptible to shadowing effects, which can obscure critical seafloor objects and compromise interpretation accuracy.

3 How Synthetic Aperture Sonar (SAS / HISAS) Works

While SAS systems have been around since the late 1990's, HISAS made its commercial debut on HUGIN AUV systems in the late 2000s, with the HUGIN 1000-MR being one of the earliest platforms to integrate the HISAS 1030 interferometric synthetic aperture sonar. According to Hagen et al. (2008), this configuration was already undergoing extensive evaluation by the Royal Norwegian Navy and had been ordered by the Finnish Navy, with deliveries starting in 2009. This marked the transition of HISAS from experimental trials to commercial off-the-shelf (COTS) deployment, enabling high-resolution imaging and bathymetry for both military and civilian applications. The system has since evolved into newer variants like HISAS 1032, featured on the HUGIN Superior platform launched in 2018 (Kongsberg Maritime, 2018; Offshore Engineer Magazine, 2018).

Kongsberg's HISAS 1030 and 1032, dramatically enhances along-track resolution by coherently combining successive sonar returns into an extended virtual aperture. This signal processing method yields imaging clarity far superior to conventional side scan approaches, making it highly effective for detailed seabed characterization and object-level classification. HISAS typically operates within the **70–100 kHz range**, although advanced configurations can span from 12 kHz for deeper penetration to 115 kHz for ultra-high-fidelity output. At a standard operating altitude of 40 m, HISAS consistently achieves resolutions of approximately 3–5 cm (Hansen, 2011), with swath widths between 150 and 300 m—enabling generation of high-fidelity mosaics suitable for mine countermeasures, archaeological detection, and infrastructure mapping.

The HISAS 1030 system, specifically, employs a phased-array transmitter and dual 1.2-meter receiver arrays that extend its operational swath to 260 m per side at 3 knots, with theoretical resolution approaching 2×2 cm across the full range. Hagen et al. (2008) demonstrated that this performance supports area coverage rates of roughly 2 km² per hour, while also generating co-registered full-swath bathymetry—a feature that vastly improves object placement accuracy on non-flat terrain. In addition, HISAS platforms incorporate Terrain-Aided Navigation (TRN), which enables drift correction by matching sonar imagery with known seabed features (Jalving & Gade, 2004). This fusion of imaging and navigation technologies ensures precise georeferencing even during deepwater missions and in GPS-denied environments, making SAS-equipped AUVs indispensable tools for both regulatory compliance and commercial survey excellence.

4 Sonar Performance at 40 m Altitude

At an operational AUV altitude of 40 m, SSS typically achieves a resolution of approximately 0.5 m and covers swath widths ranging from 200 to 500 m (**Table 1**). While effective for general reconnaissance, SSS offers only limited object classification capabilities and generates relatively low to moderate data volumes. In contrast, SAS delivers significantly finer resolutions of around 3 to 5 cm at the same altitude, with swath widths between 150 and 300 m. This enhanced imaging quality supports high-fidelity object classification and results in substantially larger data volumes—often reaching multi-terabyte scales due to the detailed mosaics produced during deepwater surveys. A typical HISAS mission generates **60–90 GB/hr** of raw data, compared to **5–10 GB/hr** for SSS.

Table 1. SSS vs SAS Resolution

Feature	SSS @ 40 m	SAS (HISAS) @ 40 m
Resolution	~0.5 m	~3–5 cm
Swath Width	~200–500 m	~150–300 m
Object Classification	Limited	High-fidelity
Data Volume	Low to moderate	High (multi-terabyte scale)

HISAS data illustrates orders-of-magnitude resolution differences (30x sharper detail at equivalent depth). An example of the improvement in resolution, with both SSS and SAS at the same survey altitude for a fair comparison (**Figure 1**) at a sunken submarine.

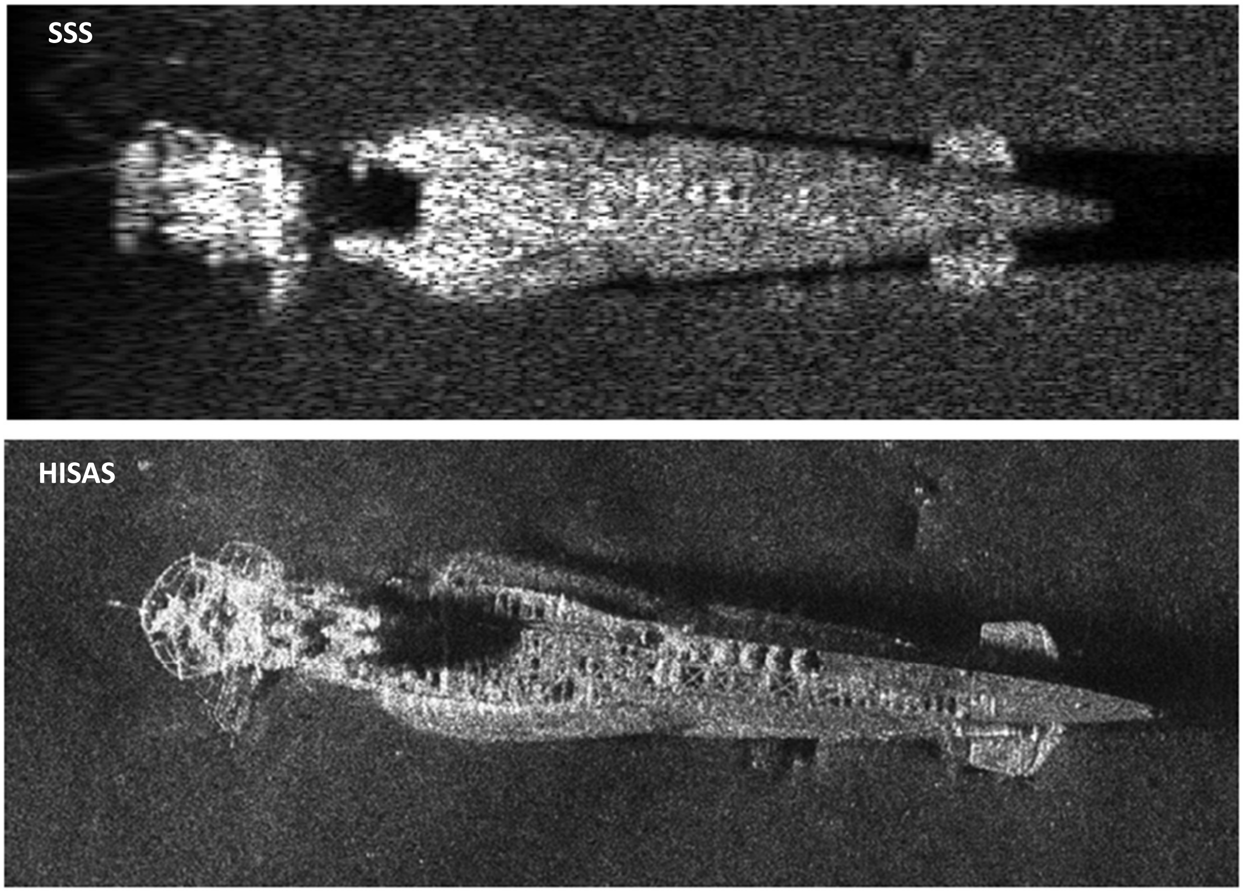

Figure 1. Comparison of traditional SSS to HISAS data (from Hagen 2007)

5 Navigation Accuracy Across Depths

Accurate geolocation during submerged autonomous missions is critical to ensuring valid interpretation of sonar mosaics and delivering actionable data to regulators and stakeholders. Navigation accuracy in platforms such as Kongsberg's HUGIN series has dramatically improved through hybrid sensor fusion techniques that integrate Inertial Navigation Systems (INS), Doppler Velocity Logs (DVL), and Terrain-Referenced Navigation (TRN). This triple-aiding architecture enables consistent drift correction by combining dead-reckoning estimates, bottom-relative velocity, and terrain-matched localization—even in GPS-denied environments.

The HISAS sonar's co-registered bathymetry output minimizes image-to-position mismatch, and when paired with the Kongsberg EM2040 multibeam echo sounder, merged bathymetric swaths of up to 20× vehicle altitude can be achieved—enhancing TRN performance and overall positioning fidelity (Hagen et al., 2008).

In legacy systems, positional errors at depths between 300 and 1,000 m ranged from ±2 to 5 m. With INS+DVL+TRN integration, those margins have been reduced to ±0.5 to 1.5 m. At intermediate depths from 1000 to 3000 m, drift—formerly ±5 to 10 m—is now mitigated to ±1 to 3 m by leveraging high-resolution SAS mosaics that support geospatial correlation. For full-ocean-depth missions between 3,000m to 6,000m, post-mission refinement using NavLab software and TRN techniques has narrowed error margins from ±10–20 m down to ±2–5 m. These improvements, detailed in both Jalving & Gade (2004) and Hagen et al. (2006, 2008), underscore the operational advantages of fusion-based navigation architecture across all depth tiers—ensuring robust positioning for deepwater hazard surveys, archaeological mapping, and offshore infrastructure planning.

Table 2. AUV Uncertainty with depth

Depth Range	Legacy Nav Error	Hybrid Nav Error (HUGIN Series)	Notes
300–1,000 m	±2–5 m	±0.5–1.5 m	INS + DVL + TRN fusion
1,000–3,000 m	±5–10 m	±1–3 m	Seabed matching from SAS mosaics
3,000–6,000 m	±10–20 m	±2–5 m	NavLab post-processing

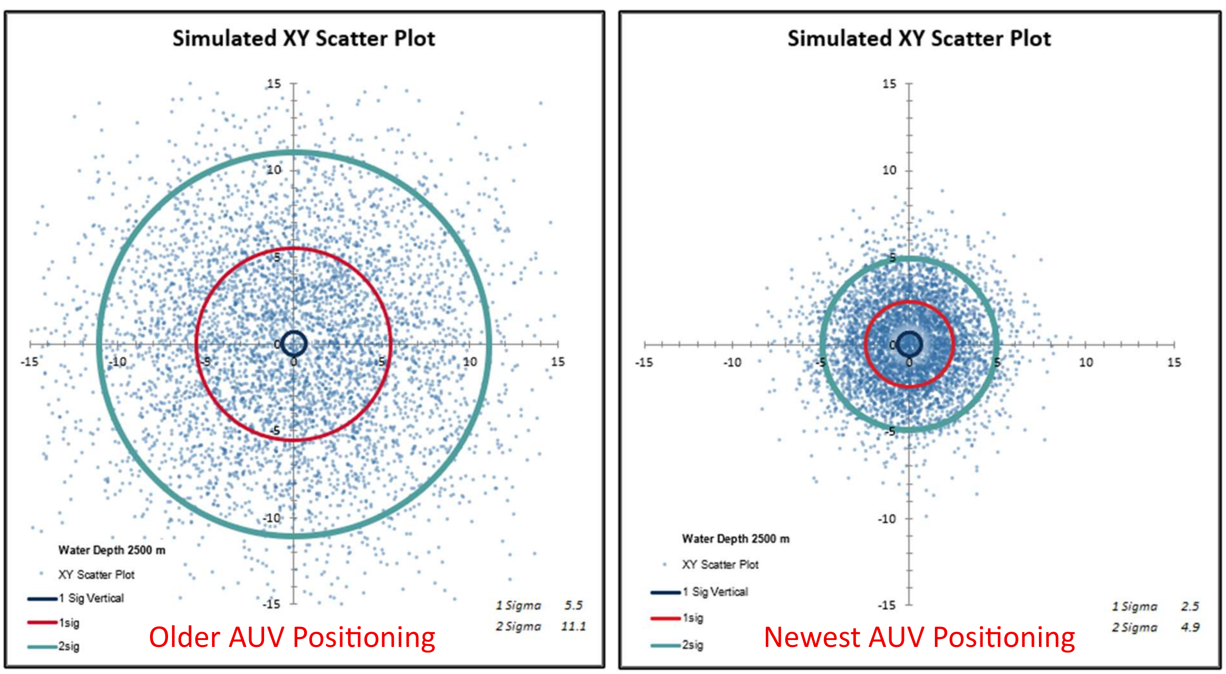

Figure 2. Comparison of old Hugin (left) and newest Hugin (right) Position Uncertainty

A review of older Hugin AUV uncertainty budgets shows that in 2500m water depth, we could have expected 5.5m horizontal uncertainty (at 1 sigma). The latest advances in AUV technology have improved these to 2.5m horizontal uncertainty for the same water depth. While these advances are much improved, it should still be noted that the horizontal position of the AUV far exceeds the resolution capable of the SSS, HISAS and MBES systems. The simulated scatter plot (**Figure 2**) is based on the overall horizontal and vertical uncertainties, run through a Monte Carlo simulation for visualization over 5,000 samples.

A line graph (**Figure 3Error! Reference source not found.**) showing positional error divergence between older and modern HUGIN AUV system across 0-4,500 m depths demonstrates the advances in technology to provide superior accuracy to datasets.

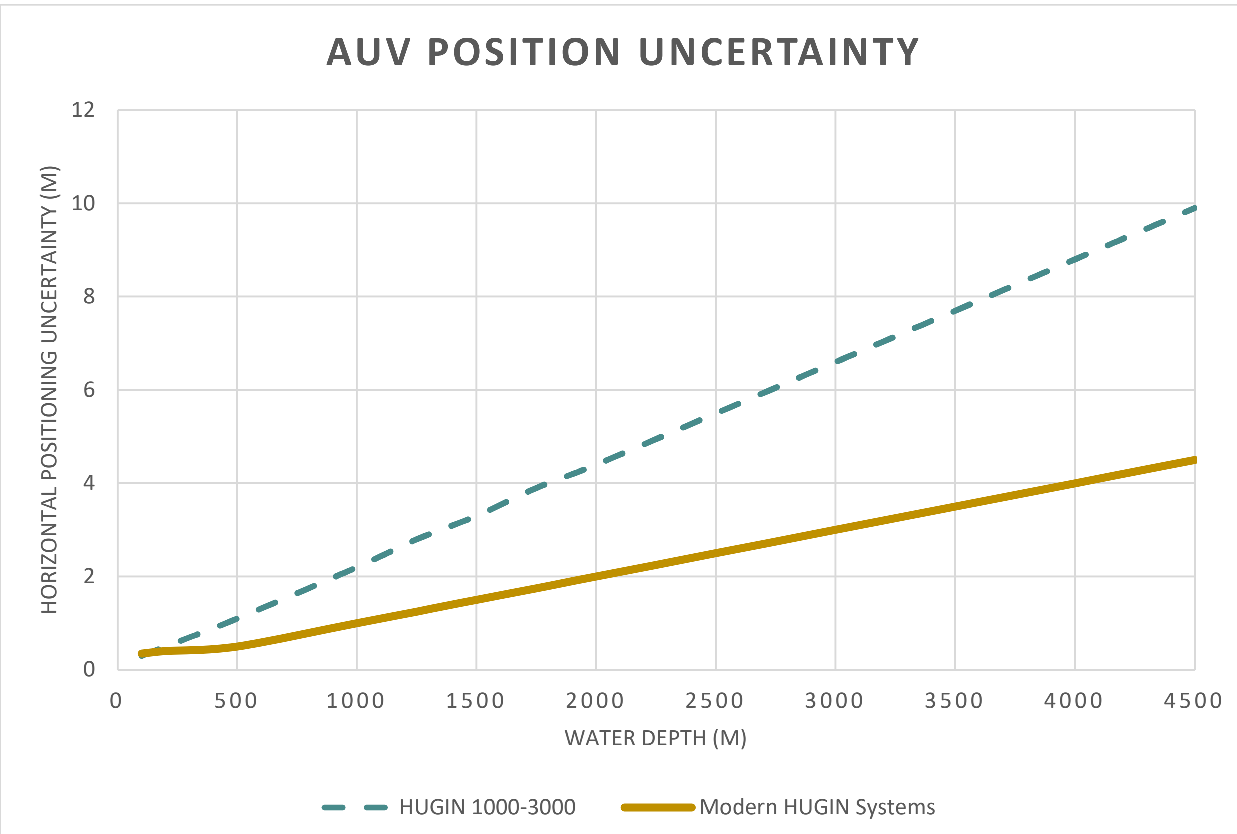

Figure 3. AUV positioning uncertainty comparison

6 Processing HISAS vs SSS

Processing time for HISAS is substantially longer than for standard side scan sonar (SSS), due to the complexity and volume of data involved. SSS systems typically require only 1–2 hours of post-processing per hour of acquisition, as their outputs are relatively lightweight and often usable directly from the field (Hagen et al., 2006). In contrast, HISAS missions generate 60–90 GB of raw data per hour and demand advanced processing steps such as synthetic aperture reconstruction, phase gradient autofocus (PGA), micro navigation, and interferometric bathymetry integration

(Kongsberg Maritime, n.d.; Hydro International, 2020). These workflows can extend processing time to 4–8 hours or more per hour of acquisition, depending on resolution and mission complexity. The inclusion of multi-aspect imaging and terrain-referenced navigation (TRN) further increases computational load, making HISAS processing highly dependent on specialized hardware and software infrastructure (Jalving & Gade, 2004). While some in-mission processors now support real-time compression and previewing, full-resolution analysis remains a resource-intensive task that far exceeds the demands of traditional SSS workflows.

6.1 Processing, Visualization, Interpretation Compute Power Needed for HISAS

Processing data from HISAS sonar systems requires a much more powerful computer than most people typically use. A single mission can collect hundreds of gigabytes of detailed imagery in just a few hours, and that adds up fast—especially over large survey areas. To handle this kind of data, analysts need machines with very fast processors, a huge amount of memory, top-of-the-line graphics cards, and large, high-speed storage drives. Without this kind of setup, the data either crashes the software or takes far too long to process. That's why full-resolution HISAS analysis usually happens on specialized workstations that cost as much as a small car. For anyone without this level of equipment, the data must be simplified—either by shrinking the image size or breaking it into smaller pieces—so it can be reviewed more easily without sacrificing important details.

Processing HISAS data demands a workstation far beyond standard GIS or survey setups due to the sheer volume and complexity of synthetic aperture sonar outputs. Without this level of hardware, HISAS data must be down sampled or tiled—limiting fidelity and delaying regulatory deliverables. For full-resolution processing and visualization, a workstation in the $12,000–$18,000 range is typically required (Kongsberg Maritime, n.d.; Hydro International, 2020).

Most interpreters, regulators, and industry professionals use standard computers that simply can't handle full-resolution HISAS imagery without heavy down-sampling or breaking the data into smaller tiles. Additionally, transferring these high-detail mosaics—whether via cloud platforms or external hard drives—can be time-consuming and cumbersome due to their massive file sizes.

Hence the title of this paper: The Truth About AUV HISAS – "You Can't Handle the Truth". Unless the industry undergoes a widespread upgrade to high-cost computing infrastructure, a practical compromise is essential. To balance accessibility and analytical precision, one approach is to down sample regional datasets while reserving full-resolution processing for site-specific targets identified as critical.

7 A Suggested Tiered Resolution Strategy for HISAS Efficiency

MGC recommends a 5-tiered resolution strategy (**Table 3**Figure 2) to balance data fidelity, processing efficiency, and regulatory relevance—particularly when deploying HISAS-equipped AUVs for offshore geophysical and geotechnical surveys. This framework ensures that deliverables align with the hardware capabilities of end users and the specific analytical demands of each review task.

Table 3. Recommended HISAS Resolution Tier Matrix (5-Tier Model)

Tier	Nominal Resolution	Primary Use Case	Regulatory Alignment
Tier 0	1–2 m	Reconnaissance overlays, baseline avoidance corridors	PDF-level documentation, early permit scoping
Tier 1	50 × 50 cm	Regional avoidance mapping	General BOEM permit coverage
Tier 2	25 × 25 cm	Site characterization, infrastructure planning	Environmental and engineering review
Tier 3	10 × 10 cm	Benthic habitat assessments, scour modeling, near-field screening	Ecological and construction risk analysis
Tier 4	5 × 5 cm	Cultural resource assessment, UXO surveys, HDD corridor targeting	Critical path regulatory compliance

By pairing each resolution tier with audience-specific delivery formats and realistic hardware expectations, this strategy promotes accessibility across regulatory reviewers, survey contractors, and specialized analysts—while maintaining scientific rigor, operational scalability, and regulatory clarity for decision-making and stakeholder engagement (**Table 4**).

Table 4. Recommended Delivery Formats by Audience Capability

Audience	Delivery Format	Hardware Baseline
BOEM reviewers	Tiled GeoTIFF with pyramids + shapefiles	16–32 GB RAM, standard GPU
Survey contractors	TRN-corrected mosaics + metadata layers	64–128 GB RAM, mid-range GPU
Specialized analysts (e.g. UXO)	Full-res tiles + NavLab logs + multi-aspect imagery	256+ GB RAM, RTX 6000-class GPU
NOAA-NMFS benthic reviewers	Tiled GeoTIFF with pyramids + shapefiles	16–32 GB RAM, standard GPU

8 Regulatory Reassessment

Current U.S. regulatory technical guidance—such as *BOEM NTL No. 2022-G01, NTL 2022-A01, NTL 2009-G39, NTL 2009-G40, JOINT NTL No. 2023-N03*, and the *Guidelines for Providing Geophysical, Geotechnical, and Geohazard Information Pursuant to 30 CFR Part 585*—reflect legacy expectations based on SSS capabilities, typically specifying resolution thresholds of 1–1.5 m and positional accuracy of ±5 m. In the US Offshore Renewables industry, BOEM reviews the survey data in final reports called Marine Site Investigation Report (MSIR) and Marine Archaeological Resource Assessment (MARA), among other documents in a submitted Construction Operations Plan (COP). BOEM recommends greater than 500kHz for SSS surveys, less than this can risk acceptance of a MARA. Traditionally, AUVs have had 120 kHz/410 kHz SSS systems; and newer HISAS systems operate at 70-100 kHz; however, HISAS data provides exponentially better resolution, even at this lower frequency.

Emerging high-resolution platforms like HISAS routinely detect seafloor features smaller than 0.1 m and, through terrain-referenced navigation (TRN), achieve geolocation precision within ±0.5–2 m. These advancements far exceed the assumptions embedded in current federal guidance and necessitate a reassessment of data handling standards—particularly regarding mosaic formats, geospatial referencing, and resolution metadata.

To align with modern capabilities and operational demands, it is recommended that regulatory guidance be updated across all relevant agencies, including BOEM, BSEE, NOAA/NMFS, USACE, EPA, USFWS, and State Historic Preservation Offices (SHPOs). Specifically, updates should:

(1) Replace minimum frequency requirements with resolution requirements.

(2) Define resolution tiers that correlate with survey risk and regulatory task type.

(3) Permit down sampling of mosaics for expedited review by agencies with limited hardware.

(4) Mandate full-resolution submission only in culturally or environmentally sensitive zones.

(5) Support GIS deliverables corrected with TRN and post-processed via tools like NavLab.

(6) Integrate cross-agency standards, including NOAA's Essential Fish Habitat Information Needs (Dec 2023), BOEM's Benthic Habitat Survey Guidelines, and USACE's Nationwide Permit Requirements for seabed disturbance

These updates would ensure consistency, efficiency, and scientific rigor while enabling broader adoption of next-generation survey technologies across federal and state review workflows.

9 Conclusion

Synthetic Aperture Sonar (SAS), particularly in its high-fidelity form, represents a transformative leap in offshore geophysical surveying. Its ability to resolve sub-decimeter features enables unprecedented clarity in identifying archaeological sites, biological habitats, infrastructure hazards, and seabed construction zones. However, this fidelity comes at a cost: HISAS datasets are computationally intensive, slow to process, and challenging to store and manage at scale.

Industry (e.g. operators, developers) should carefully evaluate the resolution required for HISAS for specific projects, recognizing that while full-fidelity datasets offer unmatched detail, they also significantly impact processing requirements, data handling workflows, data delivery timelines, and accessibility across standard mapping platforms.

MGC recommends a tiered-resolution strategy to fully harness the benefits of HISAS while maintaining operational efficiency. For broad-area reconnaissance and regulatory compliance, down-sampled imagery at 1-2m resolution may be sufficient to meet avoidance and mitigation goals, especially in deepwater contexts where feature density is low. This approach dramatically reduces processing time and data burden while still supporting informed decision-making.

Critically, HISAS allows for site-specific reprocessing at full fidelity when higher resolution is warranted—such as during pipeline crossings, archaeological verification, or habitat delineation. This flexibility enables targeted precision without overwhelming survey workflows.

Given these capabilities, regulators should evolve to:

(1) Recognize resolution tiers and allow for scalable fidelity based on survey objectives.

(2) Encourage down sampling for regional surveys while preserving raw data for future reprocessing.

(3) Define thresholds for when full-resolution HISAS imagery is required (e.g., within buffer zones or near known cultural resources).

(4) Update requirements to include minimum resolution rather than frequency.

(5) Update metadata and submission formats to accommodate multi-resolution workflows and deferred processing.

By embracing a resolution-smart framework, regulators and operators can achieve the best of both worlds: efficient survey execution and high-confidence site characterization, without compromising data integrity or delaying development timelines.

10 References

Bureau of Ocean Energy Management. (2020, May 27). *Guidelines for providing geophysical, geotechnical, and geohazard information pursuant to 30 CFR Part 585*. U.S. Department of the Interior. https://www.boem.gov/about-boem/gg-guidelines

Bureau of Ocean Energy Management. (2019, June). *Guidelines for providing benthic habitat survey information for renewable energy development on the Atlantic Outer Continental Shelf pursuant to 30 CFR Part 585*. U.S. Department of the Interior. https://www.boem.gov/sites/default/files/renewable-energy-program/Regulatory-Information/BOEM-Renewable-Benthic-Habitat-Guidelines.pdf

Bureau of Ocean Energy Management & Bureau of Safety and Environmental Enforcement. (2023, September 27). *Joint NTL No. 2023-N03 – BSEE BOEM renewable energy geospatial data*. U.S. Department of the Interior. https://www.bsee.gov/notices-to-lessees-ntl/joint-ntl-2023-n03-bsee-boem-renewable-energy-geospatial-data

Bureau of Ocean Energy Management. (2022, October 1). *BOEM NTL No. 2022-G01 – Shallow hazards program (Gulf of Mexico OCS)*. U.S. Department of the Interior. https://www.boem.gov/about-boem/regulations-guidance/gom-shallow-hazards-ntl-2022-g01

Bureau of Ocean Energy Management. (2022, October 1). *BOEM NTL No. 2022-A01 – Shallow hazards survey and evaluation for OCS exploration and development drilling (Alaska OCS)*. U.S. Department of the Interior. https://www.boem.gov/about-boem/regulations-guidance/ak-shallow-hazards-ntl-2022-a01

Hansen, R. E. (2011). *Introduction to synthetic aperture sonar*. https://doi.org/10.1109/MOC.2011.6084026

Hagen, P. E., Hansen, R. E., Knutsen, K. D., & Langli, B. (2006). Post-Mission Analysis with the HUGIN AUV and High-Resolution Interferometric SAS. In Proceedings of OCEANS 2006 MTS/IEEE, Boston, MA, USA.

Hagen, P. E., Fossum, T. G., & Hansen, R. E. (2008). Applications of AUVs with SAS. In OCEANS 2008 MTS/IEEE Conference Proceedings, Quebec City, Canada. https://doi.org/10.1109/OCEANS.2008.5152013

Hagen, Per Espen & Hansen, Roy & Midtgaard, Øivind. (2007). SAS and Side Scan Sonar Systems Compared: Experimental Results from HUGIN AUVs. https://www.researchgate.net/publication/321529580_SAS_and_Side_Scan_Sonar_Systems_Compared_Experimental_Results_from_HUGIN_AUVs

Hydro International. (2020, January 23). *Synthetic Aperture Sonar Challenges*. Retrieved from https://www.hydro-international.com/content/article/synthetic-aperture-sonar-challenges

Jalving, B., Gade, K., Hagen, O. K., & Vestgård, K. (2004). *A toolbox of aiding techniques for the HUGIN AUV integrated inertial navigation system*. *Modeling, Identification and Control*, **25**(3), 173–190. https://doi.org/10.4173/mic.2004.3.3

Kongsberg Maritime. (n.d.). *HISAS 1030 Sonar Specifications*. https://www.kongsberg.com

Kongsberg Maritime. (n.d.). *Synthetic Aperture Sonar – HISAS*. Retrieved from https://www.kongsberg.com/discovery/naval/HISAS/

Kongsberg Maritime. (2018). *Autonomous Underwater Vehicle, HUGIN Superior*. Retrieved from https://www.kongsberg.com/discovery/autonomous-and-uncrewed-solutions/auv/autonomous-underwater-vehicle-hugin-superior

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

Offshore Engineer Magazine. (2018, December 5). *Kongsberg Unveils HUGIN SUPERIOR AUV*. Retrieved from https://www.oedigital.com/news/460402-kongsberg-unveils-hugin-superior-auv

Tang, Y., Wang, J., Jin, S., et al. (2023). High-quality SSS imaging based on AUVs. *Journal of Marine Science and Engineering*, 11(9), 1769. https://doi.org/10.3390/jmse11091769