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CHARTING INDIA'S MARITIME FUTURE

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A compilation of professional articles & field experiences by INHD officers

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From the
EDITOR'S DESK



Lt Cdr Tarun Katiyar
Editor-in-Chief
Hydronaut Magazine

Namaste and welcome to the latest edition of Hydronaut – 2026!!!

It gives me immense pride and satisfaction to present this edition of our magazine. At the outset, I extend my heartfelt congratulations to all contributors whose collective efforts made the previous edition a resounding success. Your insights, experiences, and technical contributions not only enriched the publication but also strengthened the professional fabric of our hydrographic community.

The Indian Navy Hydrographic Department (INHD) stands today at the cusp of a significant transformation. The induction of new survey platforms, equipped with latest multibeam systems, and autonomous survey capabilities is redefining the way we perceive hydrographic operations. However, with progress comes a new set of challenges. The transition towards the IHO S-100 framework marks a paradigm shift in hydrographic data management and dissemination. These transformations are not merely technological; it represents a shift towards greater collaboration, capacity building, and global interoperability.

At the same time, we carry the important responsibility of integrating Agniveers and notably, expanding the role of women in hydrography. Leaner manning structures, reduced intake, and higher attrition present emerging human resource challenges that demand thoughtful and adaptive strategies.

In this journey, collaboration is the key. Strengthening synergies within INHD through humour, professional knowledge and experience sharing which indeed is the main objective of this magazine. Equally important is our outreach. To remain relevant and impactful, we must actively engage across diverse platforms - digital media, technical forums, academic collaborations, and public interfaces. Increased visibility will not only showcase our achievements but also inspire confidence and interest among the wider geospatial and maritime community.

This edition brings together a rich array of articles, technical papers, operational insights, and historical reflections. From advancements in survey technologies to lessons from the field and perspectives on future trends, it captures the dynamic spirit of our profession. As you explore these pages, I hope you find inspiration, knowledge, and a renewed sense of pride in being part of this distinguished community.

Happy Reading!

Jai Hind



VAdm L S Pathania, AVSM

Foreword By
The Chief Hydrographer to the Govt. of India

It gives me great pleasure to present the Second Edition of Hydronaut, the Indian Naval Hydrographic Department's flagship publication. Building on the positive feedback from the first edition, this volume continues to demonstrate the Department's commitment to fostering intellectual growth, upholding professional standards, and promoting a lively exchange of knowledge within the hydrographic community and the broader maritime field.

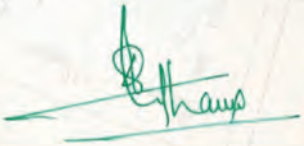
Hydrography forms the bedrock of India's maritime sovereignty, economic resilience, and global stature. Precise and authoritative charting underpins not only naval operations but also the safe and efficient movement of maritime trade, the expansion of modern port infrastructure, offshore energy exploration, and the sustainable utilization of ocean resources in line with the national Blue Economy vision. By fulfilling its commitments under the United Nations Convention on the Law of the Sea and actively engaging as a member of the International Hydrographic Organization, India continues to advance global hydrographic standards and strengthen capacity building worldwide.

The articles featured in this edition reflect the dynamic evolution of our discipline at the intersection of tradition and technology. From the integration of artificial intelligence and machine learning in seabed classification and data analytics to the operational challenges of conducting high-precision surveys in strategically sensitive areas, the contributions from our veterans illuminate both the opportunities and the responsibilities that define contemporary hydrography. The emphasis on intergenerational dialogue between seasoned practitioners and the next generation of hydrographers is especially heartening.

As India advances the cause of strategic autonomy through the indigenous development of survey platforms, sensors, data-processing software, and Electronic Navigational Charts, and as our training institutions evolve into nationally and internationally recognized centres of excellence, Hydronaut stands as a vital instrument of advocacy, inspiration, and institutional memory. It reflects our progress while guiding the course ahead.

I extend my heartfelt congratulations to the editorial team and every contributor for their dedication and scholarship in bringing this edition to fruition. May Hydronaut continue to thrive as a premier platform that amplifies the voice of Indian hydrography, inspires excellence, and unites all those committed to mastering the science and art of charting the seas in service of the nation.

Jai Hind. Sam No Varunah!



VAdm L S Pathania, AVSM

Foreword By
The Joint Chief Hydrographer



RAdm Peush Pawsey

It is with profound satisfaction that I present the Second Edition of Hydronaut to our esteemed readers across the Indian Naval Hydrographic Department and the wider maritime community. The overwhelming response to the inaugural edition has reinforced our belief in the enduring value of a dedicated platform that captures the intellectual and professional pulse of hydrography in India.

In the strategically vital Indian Ocean Region, precise hydrographic data enables everything from safe navigation and submarine operations to effective maritime domain awareness and disaster response. As we embrace transformative technologies, including autonomous survey systems, advanced multibeam sonar suites, and AI-assisted data processing, our ability to map the battlespace with unprecedented fidelity continues to grow exponentially.

This edition of Hydronaut features a notable collection of contributions, including narratives from hydrographers working in challenging terrains, technical discussions on new tools and methods, and reflections on field experiences. I am particularly encouraged by the active involvement of junior and mid-level officers both from India and our Friendly Foreign Countries, whose fresh perspectives and technical skills bring energy and relevance to our collective discussion.

The Naval Hydrographic Department stands at an exciting juncture. Ongoing efforts to augment our survey fleet, induct state-of-the-art autonomous platforms, and elevate training standards at the National Institute of Hydrography to meet the highest international benchmarks are transforming our operational posture. Hydronaut plays a crucial role in documenting this journey, disseminating best practices, and fostering a culture of continuous learning across the community.

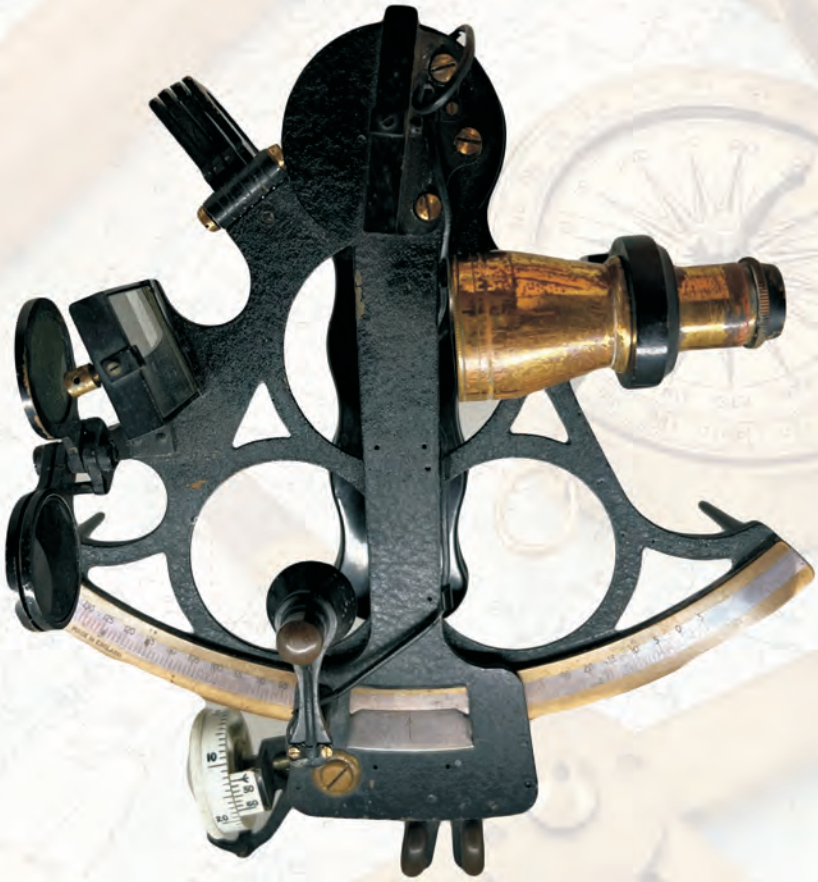
I urge every officer, both serving and retired, to contribute actively to future editions and to engage thoughtfully with the ideas presented in these pages. Your insights will shape the evolution of this magazine and, more importantly, strengthen the professional fabric of Indian hydrography. Together, we will continue to build indigenous capabilities that serve the nation's maritime security and strategic autonomy.

Jai Hind. Sam No Varunah!

RAdm Peush Pawsey

Preface

Officers and Sailors have enriched the magazine with articles that share insights into advancements in hydrography, evolving surveying techniques, data analysis, and their firsthand experiences in the field. These contributions provide a forum for professionals to examine challenges, present research findings, and promote best practices. Topics often range from autonomous underwater vehicles to reflections on past milestones, as well as the integration of artificial intelligence in hydrographic surveying. The magazine is carefully curated to balance two essential dimensions - experience sharing and professional knowledge.



Disclaimer

The views, opinions, analyses, and conclusions expressed in the articles published in this magazine are solely those of the respective authors and contributors in their individual capacities. They do not necessarily reflect the official policies, positions, or views of the Editorial Board, the publishers, or the affiliated organisation.

While every effort has been made to ensure the accuracy and reliability of the information presented, the Editorial Board and the organization assume no responsibility for any errors, omissions, or consequences arising from the use of the published material.

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Section - 1

Professional Articles

Liability in Delict of The Chief Hydrographer to The Government of India - A Critical Analysis

Commodore Tribhuvan Singh Bisht

Abstract.

1. The art and science of hydrography have been identified with safe maritime navigation and charting. The scientific development in recent times and the realisation of the economic potential of the ocean have greatly enhanced the importance of hydrography. Nothing has ever been more important for navigation and linked to seaborne trade for a littoral state than the production and updating of a marine map or chart produced because of hydrographic hard work and vision of a Hydrographer. Hydrography is critical in maritime safety, environmental protection, and economic sustainability. Given the strategic importance of accurate hydrographic data, the legal implications of inaccuracies, especially those that lead to damage or loss, have gained increasing attention in both domestic and international jurisprudence. This article explores the concept of delictual liability within the framework of hydrography, focusing on the responsibilities and potential liabilities of the Chief Hydrographer under Indian and international law.

2. **Introduction.** Hydrography, the science of surveying and charting bodies of water, underpins the safety of navigation and maritime operations. In India, this responsibility falls to the Indian Naval Hydrographic Department, led by the Chief Hydrographer to the Government of India. As the NAVAREA VIII and NAVTEX Coordinator, the Chief Hydrographer holds critical accountability for broadcasting marine safety information (MSI) and producing up-to-date nautical charts. Failure to uphold this responsibility can result in maritime accidents, environmental degradation, and legal liability. The nature of such liability, particularly civil liability arising from wrongful acts or omissions, falls within the scope of delictual law[1].

3. **Understanding the Concept of Delict**. In common law jurisdictions, the term "tort" is used, whereas civil law systems use "delict."[2] A delict refers to a civil wrong that results in harm to another, leading to liability independent of contractual obligations. In hydrography, examples of delictual acts include: -

3.1. Publication of outdated or inaccurate navigation charts.
3.2. Failure to update hydrographic data following construction or natural changes.
3.3. Omission to issue timely warnings through NAVTEX or other systems.

4. The legal foundation of a delictual claim generally requires the plaintiff to establish: -

4.1. A duty of care,
4.2. Breach of that duty,
4.3. Causation,
4.4. Actual harm or damage.

Legal and Regulatory Framework.

5. **National Legislation**. Hydrographic liability in India is shaped by several domestic legal instruments:-

5.1. Indian Contract Act, 1872 – Governs obligations arising from contractual relationships, which may indirectly relate to hydrographic services provided to commercial entities.

[1] Guy NR, The liability in delict of the state Hydrographer, 2002.IHO publication.
[2] Donoghue v. Stevenson [1932] AC 562 (House of Lords).

5.2. Merchant Shipping Act, 1958 - Directly relates to maritime safety, including the carriage of nautical charts.

5.3. Admiralty (Jurisdiction and Settlement of Maritime Claims) Act, 2017 – Empowers Indian courts to adjudicate maritime claims, including those based on navigational failures[3].

5.4. Indian Penal Code (IPC) – Addresses criminal negligence, which may overlap with civil delict in cases of gross misconduct.

6. **Navy and Administrative Regulations**.

6.1. Regulations for the Navy, Part 1, Chapter 20 – Defines the scope and duties of the Indian Naval Hydrographic Department.

6.2. Government of India Business Rules, 1961 – Establishes administrative responsibilities, reinforcing the accountability of hydrographic authorities.

7. **International Obligations**. India is a party to several international conventions relevant to hydrography:

7.1. IMO SOLAS Chapter V (Safety of Navigation) – Mandates member states to ensure hydrographic services and issue up-to-date nautical publications.

7.2. International Hydrographic Organization (IHO) standards – Prescribe the technical guidelines for chart production[4].

7.3. United Nations Convention on the Law of the Sea (UNCLOS), Article 94- Obligates states to ensure that vessels flying their flags are navigationally safe[5].

Case Studies.

8. Queen Elizabeth 2 Grounding (1992). In a landmark case, the Queen Elizabeth 2 struck a shoal near Rhode Island due to outdated hydrographic data, which failed to reflect a 30 ft depth where charts indicated 39 ft. The U.S. government faced a $50 million lawsuit. Although the court eventually exonerated the government, it underscored the necessity of regular chart updates and improved hydrographic diligence (US Court of Federal Claims, 1993)[6].

9. Danish Hydrographic Office Case (2001). A Danish yacht ran aground on a submerged sewer pipe inaccurately depicted in official charts. The hydrographic office had prior knowledge of the change but failed to revise the chart. The court found the Danish HO liable, reinforcing that state hydrographers can be held accountable under delict law for known but uncorrected inaccuracies (High Court of Eastern Denmark, 2003)[7].

10. Key Legal Considerations in Hydrographic Delict. Legal evaluation of hydrographic negligence generally hinges on: -

10.1. Duty of Care. Hydrographers owe a duty to mariners relying on official charts and notices.

10.2. Breach of Duty. Any lapse from IHO or SOLAS standards could qualify.

10.3. Reliance and Foreseeability. Plaintiffs must show they reasonably relied on the hydrographic output.

10.4. Causation. A clear causal link must exist between the data inaccuracy and the resultant harm.

10.5. Negligence vs. Error. Courts distinguish between reasonable errors and negligence - only the latter invites liability.

10.6. Governmental Immunity. Certain jurisdictions provide limited immunity to state functions, though this is increasingly challenged.

11. Obligations of Contracting Governments. Governments must thus balance sovereign immunity with the global imperative for safe seas, as embodied in SOLAS Regulation V/9 [8] and IHO S-100 series standard. Under the IMO and IHO, states are responsible for:

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[3] Government of India. (2017). Admiralty (Jurisdiction and Settlement of Maritime Claims) Act.
[4] International Hydrographic Organization. (2023). IHO Standards for Hydrographic Surveys (S-44).
[5] United Nations. (1982). United Nations Convention on the Law of the Sea (UNCLOS).
[6] The Queen Elizabeth 2 Incident, US Court of Federal Claims, 1993.
[7] High Court of Eastern Denmark, 2003 – Danish Hydrographic Office Ruling.
[8] International Maritime Organisation. (2020). SOLAS Consolidated Edition.

11.1. Issuing Notices to Mariners regularly.
11.2. Updating electronic and paper charts to reflect changes.
11.3. Ensuring data quality through ISO 9001-certified workflows.
11.4. Establishing legal redress mechanisms for damage caused by hydrographic negligence.

Conclusion.

12. Hydrography is not merely a technical service, it is a legal responsibility embedded in national and international frameworks. In an era of automated navigation, digital charting, and increasing maritime trade, the accuracy of hydrographic data has never been more critical. As demonstrated by international jurisprudence and evolving maritime law, the delictual liability of state hydrographers is a developing field requiring greater legal scrutiny, operational diligence, and administrative accountability.

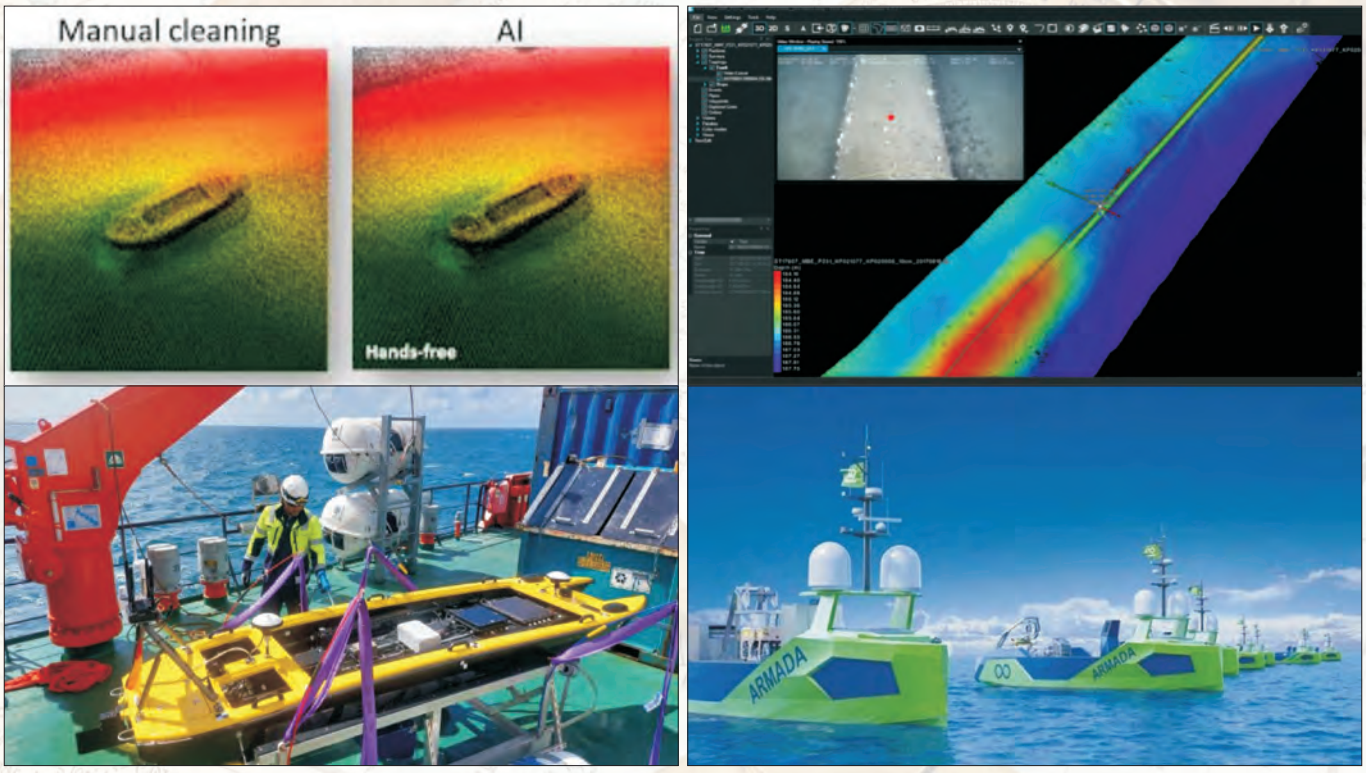


Commodore Tribhuvan Singh Bisht was commissioned in the Executive branch of Indian Navy in 1999. He is an alumnus of the Indian Naval Academy, National Institute of Hydrography, DSSC Wellington and Naval War College Goa. He is a qualified Charge Hydrographic Surveyor and is presently Commanding INS Ikshak.

Utilisation of AI in INHD with a Defined Road Map – From Planning to Data Acquisition

Commander Amit Kumar Padha

1. **Background**. Hydrography, the science of systematic measurement and description of bodies of water, has been a foundation of scientific exploration and practical navigation for centuries. Hydrography has undergone an extreme transformation with the advent of advanced technologies. One such transformative force is the integration of Artificial Intelligence (AI) into hydrography. The application of AI in hydrography represents a paradigm shift, offering the promise of enhanced efficiency, accuracy, and adaptability in the face of dynamic aquatic environments. In the contemporary era, the abundance of data from various sources, including satellite imagery, sonar systems, and sophisticated sensors, necessitates a shift towards more automated, intelligent systems. The integration of AI in hydrography holds the potential to unlock hidden patterns, predict environmental changes, and optimize survey methodologies.



2. **Fundamentals of Artificial Intelligence**. The goal of artificial intelligence (AI) as a science is to make machines do things that would require intelligence, if done by humans[9]. Therefore, the answer to the question 'Can machines think?' was important. However, the answer is not a simple 'Yes' or 'No', but rather a vague or fuzzy one. Some people are smarter in some ways than others. As humans, we all have the ability to learn and understand, to solve problems and to make decisions; however, our abilities are not equal and lie in different areas. Therefore, we should expect that if machines can think, some of them might be smarter than others in some ways[10].

3. **Fundamentals of Machine Learning**. Machine learning is a branch of artificial intelligence that allows computer systems to learn directly from examples, data, and experience. Many people now interact with

[9] Bodenet-al, 1977
[10] Artificial Intelligence - A guide to intelligent systems, Second edition-2005 by Michael Negnevitsky

systems based on machine learning every day, e.g. in image recognition systems, such as those used on social media; voice recognition systems, used by virtual personal assistants and recommender systems, such as those used by online retailers. In science, machine learning is helping to make sense of the vast amount of data available to researchers today, offering new insights into biology, physics, medicine, the social sciences, and more. AI is the all-encompassing umbrella that covers everything from Good Old Fashion AI (GOFAI) all the way to connectionist architectures like Deep Learning.

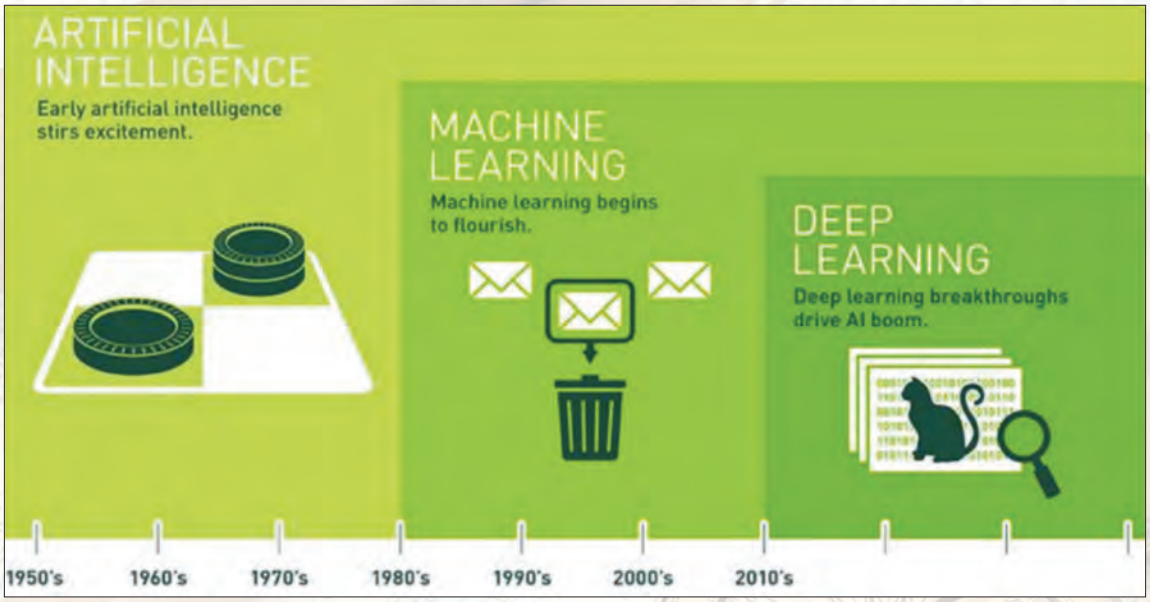


Figure 1: Genesis of AI, Machine Learning and Deep Learning[11]

4. **Significance and Challenges**. The sheer volume and complexity of hydrographic data can be overwhelming for human analysis. This is where AI comes to the rescue, helping us process vast amounts of information quickly and accurately. AI algorithms can efficiently analyze data points, identify patterns, and make predictions, leading to enhanced decision-making and more effective resource allocation[12 13].

Integration of AI in Hydrography and its Potential Benefits.

5. Modern hydrographic measuring systems–whether acoustic systems, laser scanners or satellites–produce large quantities of high-precision measurement data with constantly increasing resolution. Today, it is often not the lack of data but the effort required to refine, normalize and convert the data into products that is the real bottleneck. The interests of maritime engineering sciences, geodesists and surveyors in the land sector areas meet at the coastline, which is constantly changing due to natural dynamics and human activities, should be able to be determined much more precisely from the various data sources with the help of AI methods.

6. Today, data processing in hydrography usually takes place downstream of the initial survey. AI could potentially change this if the initial pattern recognition and evaluation takes place during the ongoing measurement process, for example on an autonomously operating measuring device carrier that automatically adapts the mission sequence on this basis in a control loop. There is another future AI use, a case that does not directly concern the collection and processing of hydrographic information, but which will become relevant with the planned introduction of the IHO's S-100 standardization concept. The plans for a future S-100 ECDIS foresee transmitting a variety of maritime geodata on board to make navigation safer and more effective[14].

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11 Tanya et al, 2008, International Journals of Advanced Research in Computer Science and Software Engineering, ISSN: 2277-128X (Volume-8, Issue-2)

12 AI in Geophysical Surveys: Enhancing Data Acquisition, Processing, and Reporting. An article by Massimo Brebia, RM MENA and Caspian@Global Maritime/ Offshore and Subsea Operations Leader published in Aug 23. https://www.linkedin.com/pulse/ai-geophysical-surveys-enhancing-data-acquisition-massimo-brebbia

13 Embracing the Power of AI in Hydrographic Data. An article by Jaya Chandran, Chief Surveyor, B.Sc in Surveying Sciences https://www.linkedin.com/pulse/embracing-power-ai-hydrographic-data-jeya-chandran?trk=public_post_feed-article-content

14 When will human hydrographic activities be substituted by artificial intelligence? - An article by By Mathias Jonas, Secretary General, IHO on Hydro International in Apr 24

7. First, the AI had to be taught to recognize and remove noise from datasets, which is no easy task. In AI lingo, this is an "imbalanced" dataset and AI algorithms will struggle to learn from so few relative examples. Therefore, the traditional approach of simply 'throwing' enormous amounts of data into the learning algorithm could not be used. Figure 2 shows an example of a typical harbor survey involving approximately 200,000,000 points and about ten hours of survey time. For this particular project, it took approximately six hours to clean by hand, three hours using a traditional grid filter workflow, and just under an hour using the Sonar Noise Classifier - CARIS Mira AI by Teledyne CARIS.

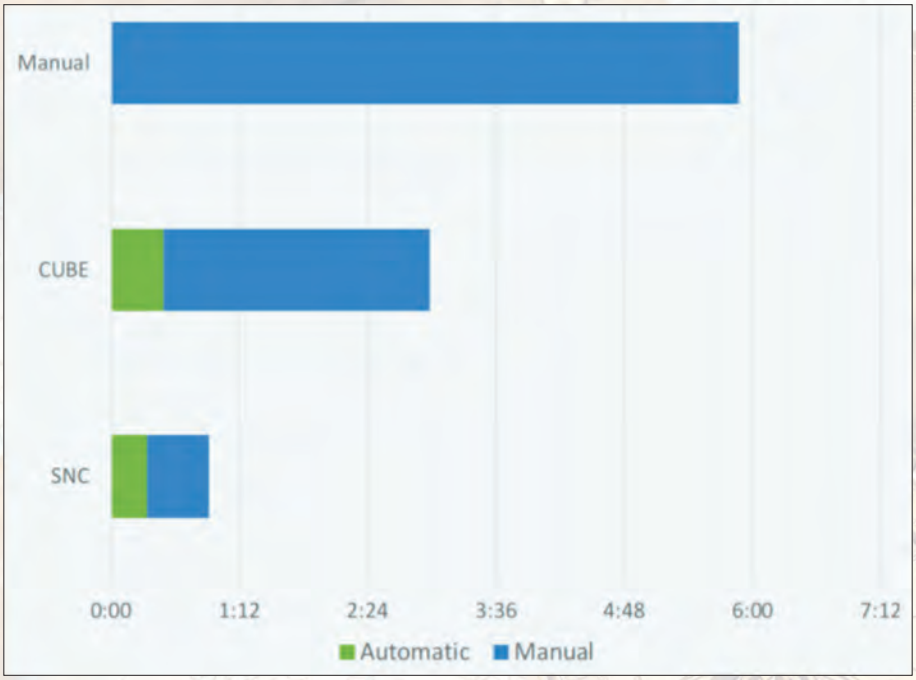


Figure 2: Data cleaning time for a Bathymetric data set [15]

8. In an another example the Geophysical Survey and Mapping team at CSIRO Oceans & Atmosphere put the new tool to test on datasets collected with Kongsberg EM2040, EM710 and EM122 (and some older EM300) sonar systems in a variety of water depths, from very shallow (<50m) to deep (5000m). In two independent cases, they were able to reduce manual editing time by 65%. One of these was for a transit line, which would have normally taken 25 minutes to edit with manual processing. This was reduced to 90 seconds of AI processing, plus 7 ½ minutes of checking and residual editing, resulting in a total time of 9 minutes. A shorter line was used for testing as it was feasible to spend time manually editing the whole dataset to get a baseline time. While this is a relatively short transit line, the 65% improvement shows promising time savings which will be magnified on larger lines or entire survey areas.

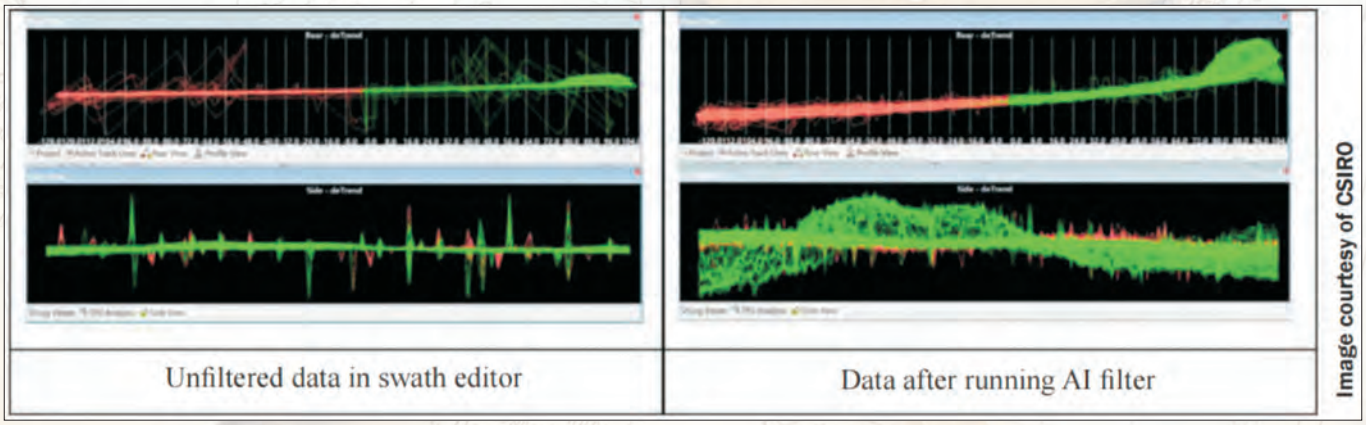


Figure 3: Bathymetric data before (left) and after (right) filtering based on the sonar noise classifier- CARIS Mira AI module in CARIS HIPS and SIPS [16]

[15] Introducing the Game Changer: AI for Sonar Noise Classification by Teledyne CARIS - May/June 2020

[16] Teledyne CARIS – A Voyage into AI - Marine Technology Reporter, Special Content Edition/ Number One http://whitepapers.marinetechnologynews.com/

9. **Autonomy in Ships**. As it is evident from the present scenario that the first autonomous ships will be deployed on simple inland or coastal liner applications where waters are calm, the route is simple, and there isn't much traffic. There's also an inland electric container ship, Yara Birkeland, under construction that was launched in 2020 and has performed fully in autonomous mode till 22. Yara Birkeland completed its first-fully autonomous voyage, under human supervision, from Yara Porsgrunn to a container terminal in Brevik in March 23. After Rolls-Royce sold its autonomous maritime division to Kongsberg, it gave the Norwegian company a boost in its goal of being a leader in the autonomous shipping industry[17].

10. **Real-time Decision Support**. AI is capable of providing real-time decision support during hydrographic surveys. As an example of NaviPac software by EIVA which is a software solution for positioning and navigation of surface and subsea vessels. NaviPac currently facilitates automatic navigation through the Coverage Assist tool which plans navigation runlines in real-time based on the detected depth, to ensure optimal coverage when scanning an area.

AI in Hydrographic Survey Planning onboard Ships.

11. Survey planning is a complex process requiring considerable attention to detail, a flexible approach, good management and effective decision-making. If the planning is thorough, the chances are that the survey will be good too[18]. Once the size and scope of the task has been assessed and the necessary resources required to conduct it decided upon, detailed survey planning can begin. There are a number of factors involved in Hydrographic Survey Planning onboard ships. This article will be limited to the planning and collection of swath data only, which is the most laborious and time consuming activity of a Hydrographic Survey. Therefore in the further part of the article only Artificial Intelligence assisted application in swath data collection will be discussed.

12. **AI applications in Survey Planning**. Artificial Intelligence has various applications in decision making on various subjects and issues, however in planning a Hydrographic Survey, much research on this topic which has AI in it has not been adequately carried out. The planning of a Hydrographic survey as a whole will still be undertaken by the professionals by considering all pre-requisites/ guidelines/ standards mentioned in the Hydrographic Instructions. The planning on individual aspect of survey like Horizontal Control, Vertical control, Tidal stream, Seabed sampling, conspicuous object fixing and other ancillary observations will continue to be undertaken manually. The aspect of automation which involves automatic data collection and processing has been explored by various professionals in the field including software giants like Teledyne CARIS, EIVA. Development of automatic data collection using USVs like world's first Autonomous Hydrographic vessel built for ports by Mythos AI named as Archie has been in place for over a few years.

13. Some key areas where AI is being applied in Hydrographic Survey planning are as follows: -

13.1. **Route and Mission Planning**.

Optimal Path Planning. AI algorithms calculates the most efficient routes for survey vessels, taking into account factors like water depth, currents, and weather conditions. This reduces fuel consumption and survey time.

Adaptive Planning. AI systems dynamically adjust survey plans in response to real-time data, such as changing weather conditions or newly discovered obstacles.

13.2. **Data Integration and Management**.

Big Data Handling. Hydrographic surveys generate vast amounts of data. AI tools manage and integrate these datasets from various sources, providing a unified view for better decision-making.

Geospatial Analysis. AI assists in analyzing geospatial data, creating detailed maps and models of underwater terrains, and integrating them with other geographic information systems (GIS).

13.3. **Risk Assessment and Safety**.

[17] The Incredible Autonomous Ships of The Future: Run by Artificial Intelligence rather than a Crew, an article by Bernard Marr, a world-renowned Futurist, Influencer and thought leader in the fields of business and technology https://bernardmarr.com/the-incredible-autonomous-ships-of-the-future-run-by-artificial-intelligence-rather-than-a-crew/

[18] Revolutionizing AUV operations with AI, an article by Arnt H Olsan, VP Uncrew Platforms

Hazard Detection. AI identifies potential hazards in survey areas, such as underwater mines or obstructions, and assess the risks associated with different survey routes.

Safety Monitoring. AI systems monitor the health and performance of survey equipment and alert operators to potential issues before they become critical.

13.4. **Resource Optimization**.

Cost Efficiency. AI optimises resource allocation, such as determining the best times and locations for surveys to minimize costs and maximize data quality.

Human Resource Management. AI assists in scheduling and deploying human resources more effectively, ensuring that skilled personnel are available where and when they are needed.

14. Data Collection Strategy using AI. Conventional sounding techniques involving a lead-line were quite simple and directly measured depth. The common term for error in hydrography is 'noise' 8 . Before surveys and final products can be exported, this noise needs to be removed to ensure only 'real' soundings remain. No matter how expensive the equipment being used is or how experienced the operator, some level of noise is inevitable. Multibeam and phase discrimination swath sonar systems have evolved to the point where they collect several thousand samples every second, providing unprecedented coverage and quality. With this increase in collected data volume comes a corresponding increase in the time required to post-process this data. A recent trend has focused on automation for the entire processing chain, involving immediate geo-referencing and basic quality filters in real-time survey, and creating live update of downstream products, e.g., elevation models. However, a significant data processing challenge still exists; despite advances in technology, the marine environment is noisy. With the monotonous data processing task handled mostly through automation, the last remaining significant bottleneck is manual review of the acquired data: to locate, identify and appropriately track any features of interest and also to remove any noise present in the data[19] .

15. Given the physical characteristics of acoustic remote sensing, most systems follow similar designs and operating characteristics. As an extension to this, any noise in the data tends to follow similar patterns, not only within a given hardware vendor's product line, but across vendors as well. Fortunately, research dedicated to locating patterns in massive datasets is something that has just recently become a very large, dynamic industry: Deep Learning. With this knowledge of patterns of noise in any multibeam sonar dataset, it should be possible to apply Deep Learning techniques to automatically locate, classify, and remove noise without operator intervention.

16. Things become even more challenging when dealing with 3D point clouds. There are plenty of techniques, and even entire libraries built, for processing 2D raster images, whether colour images, elevation models, or any other type of raster information. For hydrography, only concern is with one data type: noise. This helps us limit the size and scope of neural network. In addition, some simple data processing techniques can be applied which can down-sample datasets, while still preserving enough information from the source data that the network can make an intelligent classification. With Deep Learning approach in place, a few challenges exists. First, as with any Deep Learning algorithm, there is a requirement of fairly significant amount of "labelled" data available to train the network. This means significant amount of processed multibeam data will be required where the noise points have already been identified as such, either through some existing filter technology or by a human. The second challenge is the variant nature of acoustic remote sensing; the survey platform is a surface vessel which is incapable of adjusting its own distance relative to the seafloor to maintain a consistent scanning density (not more than once anyway). As the survey platform moves into deeper water, the range to the seafloor increases, and the resolution at which we can sample the seafloor decreases with it. In terms of a geo-referenced point cloud (i.e., X, Y, and Z information), there is a requirement to account for this change in scale, either in a pre-processing stage or within the network itself. Few software companies have been successful in developing algorithms which automatically determine the ideal sampling resolution over a given region of points.

Examples of AI in Hydrographic Planning.

17. **AI powered Software tools by EIVA**. EIVA, is working towards autonomous hydrographic operations

[19] IHO Manual of Hydrography - C 13

by developing software tools, which provide automatic, real-time data processing and navigation-aiding. A study by Clinton Marine reveals that "The NaviSuite Coverage Assist tool is ideal for optimally surveying large areas" [13].

18. **NaviPac**[12]. facilitates automatic navigation through the Coverage Assist tool. This tool automatically plans navigation runlines in real-time based on the detected depth, to ensure optimal coverage when scanning an area. The operator can simply define the area to be scanned, as well as the first runline. Then, Coverage Assist creates the most efficient route, one runline at a time. It does so by designing the shortest route to turn, and by following the outer limit of bathymetry data collected on the previous line. In its calculations, Coverage Assist considers the vessel's turn capabilities, as well as custom coverage and density requirements. In other words, it designs the optimal route for that specific vessel, with that survey's specific requirements, and in that way adapts to ensure full area coverage.

19. **Mythos AI**. - Autonomy Aided Hydrographic Survey Vessel- Archimedes Series. Archie is world's first autonomous survey vessel built for busy waterways. The intuitive software provided by Mythos AI in Archie enables start to finish survey planning of most congested waterways in a matter of minutes. There is no need to setup sonars and INSs, plan lines and boundaries or import backgrounds and ENCs; Archie will do that automatically. Only the area required to be surveyed is selected and Archie will fill it with high fidelity depth data. The Nexus Forecast Engine via the cloud provides Go/No-Go charts with adjustable clearance based on local tide gauges[14].

AI in Hydrographic Data Acquisition onboard Ships.

20. **Importance of Data Acquisition**. The depths shown on a nautical chart are its most important feature and the mariner must be able to rely implicitly on accurate bathymetry to avoid danger. An error in position is often more misleading than an error in depth, for a mariner is more likely to navigate clear of a charted danger than to rely on the accuracy of its charted depth and deliberately navigate over it[10]. The disciplines of sounding error monitoring, data checking and Quality Control (QC) are continuous procedures that need to be sustained throughout the entire hydrographic surveying process. Similarly the generation of the final report should commence on completion of the planning stage and be uninterrupted during the remaining phases of the survey; it should not be left until the end when all data acquisition has been completed. In general the hardware configuration of an automated data acquisition system is similar on both survey ship and survey boat, with a suitable hydrographic data acquisition software to control, manage, acquire and store in a specific survey data format from the positioning system and echo-sounder system (SBES/MBES/SSS).

AI-driven Data Acquisition.

21. There are software tools developed by various companies for identifying targets on the seabed, such as rock/boulders, debris and man-made objects. Various tools are being developed which uses backscatter data to segment areas of the seabed based on their material type, for example clay, gravel, sand or rock11. The possibility of real-time data displays to the users allow them to react quickly to any problems during a survey, such as gaps in the collected data – especially because of the extensive list of data display tools in AI driven softwares which can be used to have a realtime quality check (QC) on data. Another automation tool which takes care for automatic, real-time adaptive runline planning resulting in optimal coverage based on real time data acquisition and processing using the cloud.

Examples of AI in Hydrographic Data Acquisition.

22. ***GeoSwath 4 Bathymetric Sonar Software***. It is an AI-powered upgrade to existing automated filtering in the GeoSwath 4 bathymetric sonar software. The project stands out as its aim is to apply machine learning

[13] How the Coverage Assist tool automates and optimises surveys - A case study by Clinton Marine using EIVA software tools https://www.eiva.com/about/case-studies/usv-vessel-based-hydrographic-inspections/coverage-assist-clinton?_gl=1*1n3mbh0*_up*MQ..*_ga*NTc3NDU2ODE5LjE3MTcyNDI1ODE.*_ga_36KZSNYXRY*MTcxNzMxMTA4MS4yLjAuMTcxNzMxMTA4MS4wLjAuMA..

[12] AI is enabling a transformation toward autonomous hydrographic operations by EIVA, Jun 21 https://www.eiva.com/about/eiva-log/ai-enabling-autonomous-hydrographic-operations?_gl=1*8ckamv*_up*MQ..*_ga*MTEwMDk1ODUxNS4xNzE3MzExMTc3*_ga_36KZSNYXRY*MTcxNzMxMTE3Ni4xLjAuMTcxNzMxMTE3Ni4wLjAuMA..

[14] https://mythos-ai.com/wp-content/uploads/2024/02/m_web_bro_v48P.pdf

so that the AI can remove surplus and undesired data autonomously; during acquisition, the system is designed to log virtually clean data, without any user intervention in the cleaning process. The user only needs to pay attention to data quality and coverage, and during post-processing the focus can be purely on geo-referencing of the bathymetric data using deterministic calculations. The final, noise-free and high-resolution bathy products will be fully reproducible with minimal human intervention, with the potential for savings achieved to be passed on to the end user[15].

23. **Sonar Noise Classifier - CARIS Mira AI**. The CARIS process was to ingest the processed data, anonymize it, compress it and send it to the Cloud. The neural network analyzes the data, generates the results and passes it back to the local machine and user. CARIS Mira AI provides insights regarding a multitude of data, allowing the hydro professional to define with precision parameters such as what is noise and what is real; and characteristics, such as where the seafloor is sandy or rocky, or where there is a shipwreck.

24. **AI Powered Software tools by EIVA**. Before autonomous navigation, and even before automatic data analysis, the acquired data can be automatically cleaned. With the data cleaning feature, EC-3D, it is possible to do this by applying a filter to clean sonar data in real time, during data acquisition in NaviPac. EC-3D currently cleans data using a mix of cleaning methods, which can be combined manually to allow for precise automatic cleaning for a given setup. Each setup will generally have its own unique noise based on the environment and equipment, requiring this custom data cleaning. However, efforts are in to cut out this step with the help of machine learning.

Analysis of present AI tools/ resources with INHD viz desired tools.

25. **Automatic Gain Function in Echosounders**. Automatic Gain settings in echosounder can measure the intensity of echo pulse signal, when echo pulse signal is excessively strong, the amplifier of automatic control receiver reduces gain to avoid too much interference signal, when echo pulse signal is excessively small the amplifier of automatic control receiver increases gain to receive echo pulse.

26. **CUBE Algorithm in Multibeam Data Processing**. CUBE algorithm uses uncertainty concept, it is well suited to the International Hydrographic Organization (IHO) standards as defined in S44 publication. CUBE algorithms were developed to work with random errors that are inherent to every measurement. Systematic errors (e.g. misaligned sensors) must be solved before the survey or, when possible, they should be flagged out before running the CUBE processing algorithm.

27. Discussed above are the few examples of Machine language/ Algorithms used in Hydrography in INHD. These uses certain process of automation, however they are not utilising AI in the process. There are various filters which are either pre-programmed or can be customised during the process of data acquisition. These pre-set filters makes the algorithm appears to be automated and a user need to specify which algorithm/ rules/ filters are to be used for a specific purpose. As discussed earlier in the article regarding AI propelled Hydrography which can be explored as a starting point for utilisation of AI in Hydrographic planning and data acquisition. Further options which may come up in future may also be taken into considerations as and when new AI tools come into practice.

Conclusion.

28. By embracing AI-driven technologies and methodologies, hydrographers can unlock new insights into marine environments, improve navigational safety. The roadmap for AI integration in hydrography requires a multifaceted approach, encompassing data acquisition and pre-processing, algorithm development and optimization, interdisciplinary collaboration, and ongoing research and innovation. By addressing challenges such as data quality, algorithm interpretability, while capitalizing on opportunities for innovation and collaboration, INHD can pioneer the future of hydrography with AI, paving the way for a more efficient, accurate and sustainable approach to marine spatial data management.

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[15] Accelerating subsea data processing using artificial intelligence- An article by By Danny Websdale (AI/ML research scientist at GeoAcoustics), Francisco J. Gutierrez (Product specialist for the GeoSwath 4), Hydro International, March 22
https://www.hydro-international.com/content/article/accelerating-subsea-data-processing-using-artificial-intelligence

Recommendations.

29. Following recommended towards implementation of AI in INHD towards hydrographic planning and data acquisition:-

29.1 More research and development in collaboration with academic institutions, research organizations and industry partners to be undertaken to enhance various options of AI algorithms tailored specifically for hydrographic survey planning and data acquisition.

29.2 Training and education programs for hydrographic surveyors from ab-initio courses onwards to familiarize them with AI technologies and their applications.

29.3 Development of AI-powered decision support systems onboard ships to provide real-time recommendations and adaptive survey planning capabilities based on environmental conditions, vessel dynamics and data requirements.

29.4 Establishing platforms for knowledge sharing and exchange of experiences in implementing AI in hydrographic survey planning and data acquisition.



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Artificial Intelligence and Hydrographic Operations: Use Cases

Lt Cdr Deepak Bisht

Abstract.

1. As the Indian Naval Hydrographic Department (INHD) advances into an increasingly data-intensive era, traditional survey methodologies face unprecedented challenges. This article explores the revolutionary potential of integrating Artificial Intelligence (AI) across INHD operations, encompassing its survey ships and varied Hydrographic Survey Units. This article will present how AI, particularly Machine Learning (ML) and Computer Vision, can enhance efficiency and productivity in critical domains: autonomous wreck detection, automated seabed classification, advanced tidal monitoring, data filtering (de-noising), positioning integrity monitoring, Satellite Derived Bathymetry (SDB), and the creation of an AI-driven knowledge repository. The article argues that a comprehensive adoption of these technologies is essential not only for safe navigation and national security but also for providing foundational data for India's expanding Blue Economy.

Introduction.

2. The Indian Naval Hydrographic Department (INHD), with its proud lineage and mandate for charting the vast Indian Ocean Region (IOR), stands at a critical technological inflection point. For decades, the department has provided the baseline safety for maritime commerce and naval operations. However, the nature of hydrography is changing. Modern sensors like Multibeam Echo Sounders (MBES), Side Scan Sonars (SSS), and LiDAR generate gigabytes of data during a single survey mission. This explosion of raw information has created a significant bottleneck due to the inability of human analysts/ data processing team to process and interpret data as fast as it is collected.

3. Historically, hydrography has been a discipline heavily reliant on the nuanced judgment of a highly trained surveyor. While this human expertise remains irreplaceable for final verification and critical decision-making, the rote tasks of sorting signal from noise, identifying features from imagery, and analyzing repetitive tidal cycles are increasingly ripe for automation. Artificial Intelligence (AI) and Machine Learning (ML) present a paradigm shift, transitioning the surveyor's role from a "manual data cleaner" to an "intelligence supervisor." This transition is crucial for INHD to increase its productivity, meet the national demand for electronic charts, support the Blue Economy, and enhance maritime domain awareness. Following are the few use cases of AI that may be explored:-

3.1. **Autonomous Systems**. One of the most promising applications of AI is pushing "intelligence to the edge" - specifically within Autonomous Underwater Vehicles (AUVs) and Unmanned Surface Vehicles (USVs). Traditional autonomous systems operate on pre-programmed survey patterns, with data processed only after the platform is recovered. This lag introduces significant inefficiency, especially during complex missions like wreck investigations, where early detection could alter the survey plan. Traditional wreck investigation surveys using AUVs are fundamentally inefficient. The vehicle must complete its entire mission before a human surveyor can analyze the Side Scan Sonar (SSS) records to identify potential targets. If a wreck is found in post-processing, the ship must re-launch the AUV to the area for closer inspection. By integrating trained Computer Vision models directly into the AUV's processing unit, the vehicle can analyze SSS data in real-time. These models, trained on extensive libraries of SSS imagery of known wrecks and seafloor obstructions, can classify objects with high confidence. Upon a positive detection, the AI system can instantly modify the AUV's mission parameters—slowing down, reducing altitude, or initiating a spiraling

"reacquisition" pass for higher-resolution imaging. This operational "edge intelligence" turns data into immediate action, dramatically increasing the productivity of specialized survey platforms.

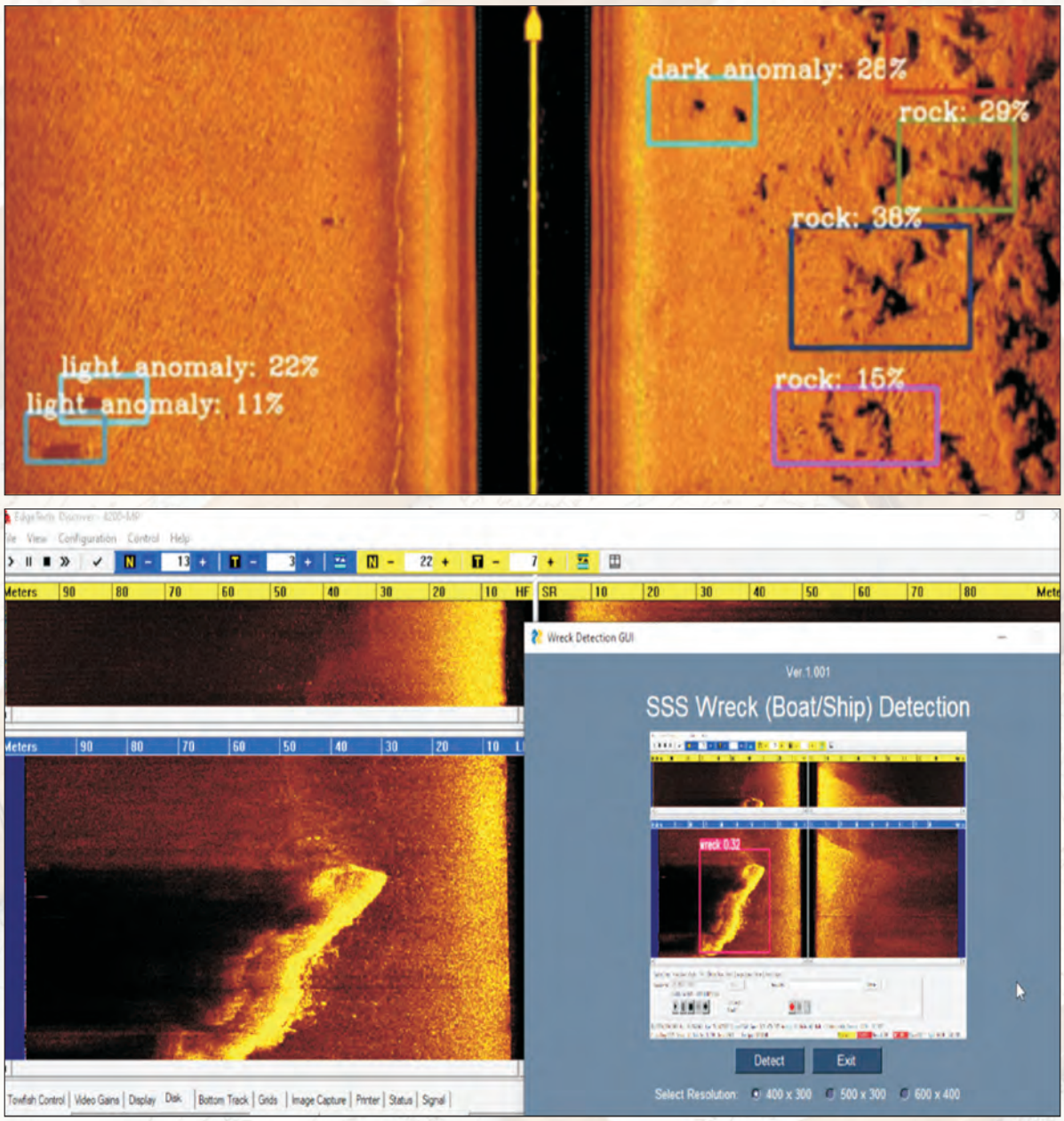


Figure 1: Auto Identification of Features During SSS Ops

3.2. **Machine Learning in Bathymetric and Seabed Analysis**. Beyond target detection, AI is revolutionizing the analysis of bathymetric and geological data, focusing the surveyor's efforts on overall product quality.

3.3. **Automated Seabed Type Classification**. Seabed classification - distinguishing between soft mud, gravel, broken shells, and various grades of sand - traditionally relies on the surveyor's interpretation of MBES backscatter data and physical grab samples. This process is subjective and varies between operators. A Convolutional Neural Network (CNN), trained on correlated backscatter imagery and actual sample results, can perform consistent seabed classification across the entire survey area. This AI model can precisely distinguish subtle differences in acoustic returns that may elude a human eye. The output is a standardized sediment chart, produced without constant human supervision, allowing surveyors to focus on other critical ground operations while ensuring a uniform standard across different INHD units.

3.4. **Automated Data Cleaning**. The most labour-intensive post-processing task in modern hydrography is "de-noising" or "cleaning" bathymetric data. Multibeam systems generate millions of

points, many of which are spurious soundings caused by acoustic reflections, air bubbles, fish, or system noise.AI systems, such as the technology employed in Caris HIPS and SIPS's Mira AI, leverage cloud-based training data to identify and filter noise with remarkable accuracy. Unlike simple statistical filters, these AI models understand the context of the data, recognizing what constitutes a valid seafloor return versus an artifact. For INHD, deploying similar models (potentially in-house trained for IOR specificities) would reduce manual data cleaning labor by 80% to 90%, speeding up the delivery of critical bathymetric products.

3.5. **Intelligent Tidal Data Acquisition and it's Integrity**. Tide is the crucial vertical component of all survey data. In many operational locations, INHD units rely on manual/ automatic tide gauges. This traditional method is vulnerable to data gaps (due to power/ technical issues), human error in recording and undetected environmental anomalies. An AI model coupled with a visual recognition system can constantly monitor and log tidal data from a calibrated gauge and can be designed to validate these real-time observations against the predicted tide of the area. The model can even detect anomalies, such as "impounding" (water trapped in a harbour), a shift in the gauge's position (due to collision or storm surge), or persistent recording errors. This early warning prevents the catastrophic loss or distortion of weeks of sounding data that might otherwise be rejected during later stages of processing.

3.6. **Integrity Monitoring of Positioning Systems**. A critical quality control check in hydrography involves placing a Positioning Device (usually a similar DGPS set as used for sounding operations) over a precisely known position/benchmark. The derived position must remain within tight tolerances throughout the survey operations to ensure the accuracy of the sounding data. Conventionally, the integrity monitoring is done during the course of survey to ascertain the reliability of positioning. This data is then generally plotted on MS excel sheet to check for any deviation. In case of the deviations found beyond permissible limits the sounding data is rejected, thus leading to days of task/ gaps in the data. Trained AI models can undertake integrity monitoring on a continuous basis. By analysing real-time GNSS satellite signals. The system then can detect inaccuracies, signal "jumps," or even signal spoofing attempts. This proactive approach avoids data rejection by notifying operators of positioning failures before significant sounding work is completed in a flawed state.

3.7. **Optimizing Co-Tidal Charts**. In large survey areas where the range of tide and time difference varies significantly, hydrographers create co-tidal charts (range and time curves) to reduce the sounding data. Traditionally, these curves are generated using interpolation software (like Surfer) but still require extensive expert manipulation to account for complex coastlines or seabed topography. An AI-trained model, leveraging historic co-tidal data and high-resolution digital elevation models, can generate far more robust and accurate curves. The model can simulate complex hydrodynamic physics, providing smooth, consistent tidal corrections that reduce standard survey errors and ensure results are standardized across all INHD units.

3.8. **Satellite Derived Bathymetry (SDB) and Strategic Planning**. Perhaps the most strategic area for AI integration is Satellite Derived Bathymetry (SDB). By analyzing optical and multi-spectral satellite imagery and correlating it with known ground truthing bathymetric data, AI models can extract depth information for uncharted or dynamic coastal areas. The system can use SDB by effectively filtering atmospheric noise, improving water clarity compensation, and accurately modeling light penetration through the water column. While not yet a replacement for direct sounding, AI-driven SDB provides invaluable reconnaissance. It can identify dangerous shallow patches or major changes (such as coral outcrop growth or coastal construction) derived from the latest satellite imagery. This enables a true holistic view of the survey area even before its physical recce. Thus, enabling safe deployment of INHD survey assets, the proper prioritization of resources, and the efficient planning of survey tasking in challenging or hazardous zones.

3.9. **The INHD Knowledge Hub**. The INHD generates a vast amount of policy guidance, hydrographic manuals apart from Admiralty and IHO publications, professional papers, for guiding the survey units for undertaking survey taskings. It is a common operational reality that a complete repository of this

critical text is either incomplete or not immediately accessible, particularly to newly commissioned units. A previous attempt at a digital repository, Application “Dhara”, laid important groundwork, but a robust AI training was required to unlock its potential. AI Large Language Model (LLM), trained comprehensively and securely on this entire repository, will serve as an instant, interactive "Hydrographic Assistant" for INHD units. Survey Recorders on distant survey grounds can query the model ("What is the specific procedure for MBES calibration?" or "List the current requirements for SVP casts during day night surveys?"). By providing immediate, validated answers from official sources, this cognitive hub ensures the uniform adoption of correct methods for every survey task.

4. **The Road Ahead**. The potential applications of AI across the INHD are not theoretical; they are the immediate future of the discipline. Implementation, however, requires careful consideration. AI must not be viewed as a displacement of the human surveyor but rather as a fundamental tool that augments their capability. The critical bottleneck for AI development is data - both the massive volume of raw hydrographic data INHD already possesses and, more importantly, labelled datasets. Further, security and data sovereignty must be built into these systems, suggesting that these models should ideally be trained and deployed within INHD infrastructure. The continuous exploration of these use cases will not only provide INHD with more efficient and accurate data but will also position the department as a national leader in marine technology, charting the course for India’s Blue Economy and maritime security.



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Comparison of Drift of The Established Geodetic Station at NIH Rooftop with Drift of The IGS Stations

Lt Cdr SPSK Gamage

Introduction.

1. Establishment of precise horizontal control is prerequisite in hydrographic as well as in land surveys. Setting up of well accurate coordinates at suitable landmark/ human build permanent mark on the ground mainly in X and Y axis is generally used for establishing horizontal control. These coordinates will be used for deriving the coordinates of the ground for the rest of the survey. The accuracy required depend upon the order or purpose of the survey. All the hydrographic surveys are conducted complying to the standards of S-44 publication. Moreover, NIH is affiliated with Goa University, India and award Master of Science in Hydrography degree for Long Hydrography course and Post Graduate Certificate for Basic Hydrography courses. Apart from aforesaid courses, various other courses are also conducted for national and International hydrographic trainees.

Background.

2. NIH conducts Long Hydrography courses for national and International naval officers annually. Permanently erected geodetic position at NIH rooftop is utilized to establish the Horizontal Control during respective Complex Multidisciplinary Filed Project at end of each course. 25 hours static GPS observation is conducted, and same data post processed by Leica Infinity software using International GNSS System (IGS) stations as reference stations to derive the precise position of the NIH rooftop geodetic station. It is observed that the derived positions by post processing of observed static GPS data are different by each course. Hence, it is essential to calculate the annual drift pattern and magnitude for future application of the geodetic location.

Aim.

3. The aim of this study is to determine quantification and pattern of drifting of the established Geodetic Position at NIH rooftop and comparison to the drift of the selected IGS stations.

Study Area.

4. Established geodetic station at NIH rooftop located at west coast of India and following IGS stations are the study area of the study.

Table 1: Selected IGS Stations

Ser	IGS Station	IGS Station Code
1	Diego Garcia Island	DGAR00GBR
2	Tuen Mun - China	HKSL00HKG
3	Manama - Bahrain	BHR300BHR
4	Cibinong - Indonesia	CIBG00IDN

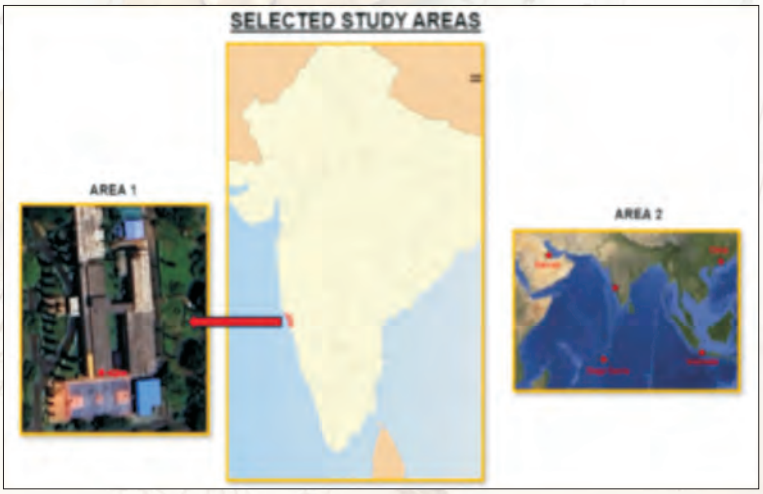


Figure 1: Study Area

Methodology.

5. The conceptual framework for the case study was developed based on the method of data collection, data processing and analyzing technique utilized for the case study. The flowchart of the methodology is shown in figure 2.

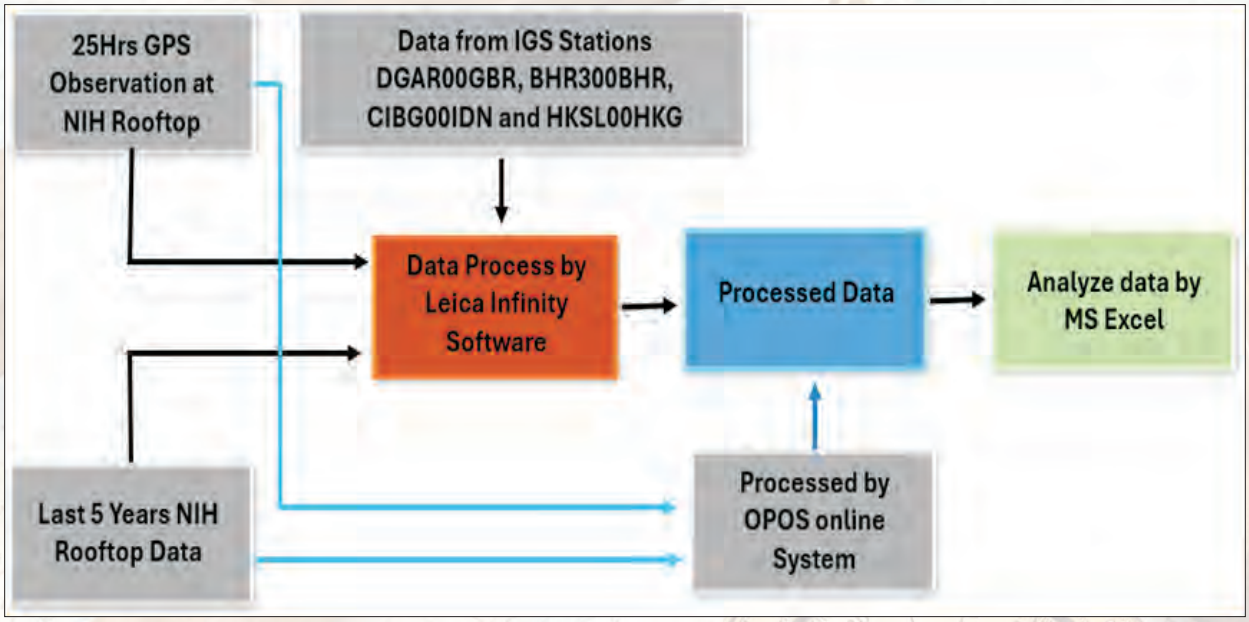


Figure 2: Conceptual Framework

Data Collection.

6. **GNSS Data Collection**. GNSS data was observed and logged at NIH rooftop geodetic station on 28 Mar 25 for 25 hrs. Leica Viva GS 10 GNSS system was utilized for data logging. The period of 25 hrs selected for covering two rotations of GNSS systems.

7. **Previous Years GNSS Data**. Previous five years 25 hrs GNSS data was taken from NIH data archive for previous 5 years (2024, 2023, 2022, 2021, and 2020). Time stamp of GNSS data collected and the training courses involved for data observation is depicted table 2. These data will be utilized to compare the coordinate drift at the NIH rooftop geodetic station 1 throughout the last five years.

Table 2: Previous Years GPS Data

Ser	GNSS Data Logged Training Course Name	Date
1	Long H course No 083-046	17 Oct 24
2	PO Q course No 083-625	25 Mar 23
3	Leading Q course No 083-620	10 Nov 22
4	Basic H course No 083-246	12 Nov 21
5	Basic H course No 083-245	02 Jan 21

Data Processing.

8. This year logged 25 hrs GNSS data and previous five years archived GNSS data at NIH geodetic station no 1 is processed by Leica Infinity version 3.3.2 software separately. Further, aforesaid data will be uploaded to OPUS online software and obtain processed data for compare the originally process data using Leica Infinity software.

Findings.

9. Observed GPS data for 25 hrs on 28 Mar 25 at NIH rooftop geodetic station 1 and other GPS observation data by the several courses indicated in above table 2 was processed by Leica Infinity V 3.3.2 software and the network adjusted with respect to WGS 84 co-ordinates system. Further, same GPS raw data was uploaded to OPUS online processing software and derived coordinates in ITRF system.

Table 3: Each Year NIH Geodetic Station Drift and Direction (2020-2025)

Ser	Year/ Date	WGS 84		ITRF		
		Co-ordinates	Shift/Angle (CM)	Co-ordinates	Shift/Angle (CM)	Epoch
1	2025 28 Mar	15° 24' 16.74531" N 73° 49' 15.70093" E	5.2447 227.86^0	15° 24' 16.75228" N 73° 49' 15.72154" E	2.510 134.51^0	EPOCH: 2025.0868
2	2024 17 Oct	15° 24' 16.74645" N 73° 49' 15.70219" E	23.994 40.51^0	15° 24' 16.75285" N 73° 49' 15.72096" E	10.044 43.26^0	EPOCH: 2024.7951
3	2023 25 Mar	15° 24' 16.74054" N 73° 49' 15.69714" E	22.118 237.60^0	15° 24' 16.75048" N 73° 49' 15.71873" E	4.086 63.99^0	EPOCH: 2023.2295
4	2022 10 Sep	15° 24' 16.74438" N 73° 49' 15.70319" E	9.6118 16.22^0	15° 24' 16.74990" N 73° 49' 15.71754" E	5.288 39.08^0	EPOCH: 2022.6939
5	2021 12 Nov	15° 24' 16.74139" N 73° 49' 15.70232" E	22.695 72.18^0	15° 24' 16.74857" N 73° 49' 15.71646" E	2.446 47.15^0	EPOCH: 2021.8649
6	2021 02 Jan	15° 24' 16.73914" N 73° 49' 15.69532" E	-	15° 24' 16.74803" N 73° 49' 15.71588" E	-	EPOCH: 2021.0059

10. The summery of the drifting of NIH geodetic station 1 with respect to WGS 84 coordinate system derived from Leica Infinity post processing software and coordinates derived from OPUS online processing software is as follows.

Table 4: Annual Drift Rate of NIH Rooftop Geodetic Station 1 and Direction

Ser	Year	WGS 84		ITRF	
		Total Shift (CM)	Annual Shift (CM)	Total Shift (CM)	Annual Shift (CM)
1	28 Mar 25	25.74	6.007	22.59	5.34
2	02 Jan 21	-	-	-	-
Drift direction		**42.280**		**54.500**	

11. IGS stations annual rate of drift and the general direction is depicted in the table 5. Further, Hyderabad IGS station data calculate to compare the drift of NIH geodetic station.

Table 5: IGS Station and Tectonic Plate drifting Comparison

Ser	IGS Station	Drifting Rate	Direction	Tectonic Plate	Drifting rate	Direction
1	HYDE00IND	5.44cm	49.050	Indian	5.4cm	NE
2	DGAR00GBR	5.78cm	54.930	Australian	7.0cm	NE
3	BHR300BHR	4.36cm	45.850	Arabian	1.5cm	NE
4	HKSL00HKG	3.48cm	109.580	Euro Asian	2.3cm	SE
5	CIBG00IDN	-	-	Euro Asian	2.3cm	SE

Conclusion.

12. According to above findings, established geodetic station 1 at NIH rooftop annual drift is 6.007 cm per year towards the direction of 42.280 with respect to WGS 84 coordinate system and 5.34 cm per year towards the direction of 54.500 as per ITRF coordinate system. Furthermore, it was derived that IGS station at Hyderabad drifting rate is 5.44 cm per year towards 49.090 direction while drifting rate of Indian tectonic plate is 5.4 cm per year towards NE direction. The difference of both WGS 84 and ITRF coordinate systems arises because WGS 84 is treated as a stable but slowly updated global frame, while ITRF is a dynamic, epoch-dependent frame that models real crustal motion. Accordingly, it can be concluded that established geodetic station at NIH rooftop is drifting towards 54.500 (Northeast) direction at rate of 5.34 cm per year (based on ITRF coordinate system) and it comply with the annual drifting rate and direction of Indian tectonic plate and the IGS station at Hyderabad.



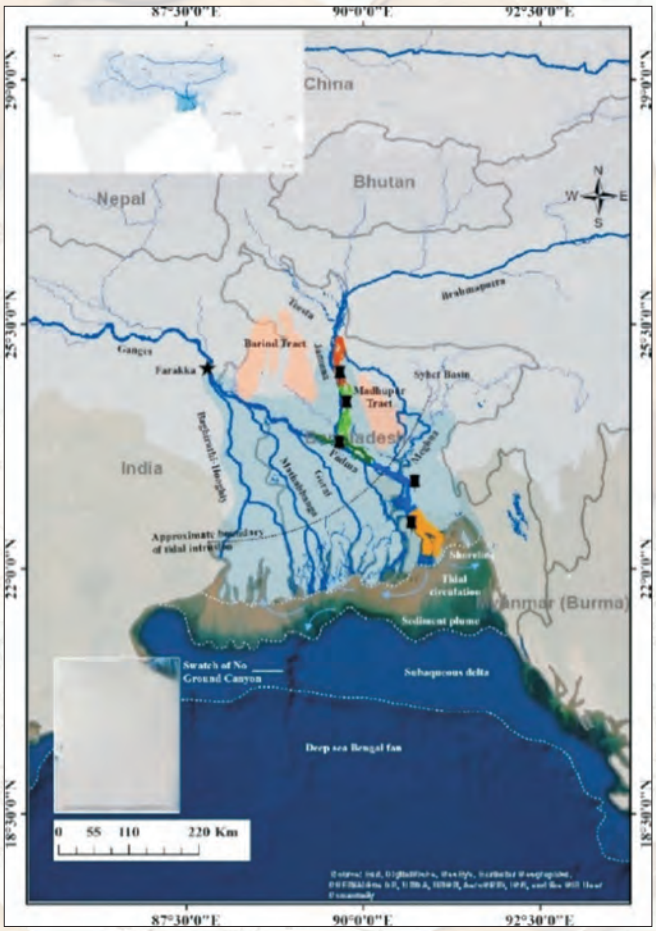
Lt Cdr SPSK Gamage (NRX 2663) of Sri Lankan Navy and completed the Long Hydrography Course (083:047) at the National Institute of Hydrography (NIH), Goa, India in 2025. The author has pursued Basic Hydrography Course at NIH in year 2018 and performed duties as Manager MSIS, Tide monitoring, Training and Administration at Sri Lanka Navy Hydrographic Service since 2020 to 2022 and conducted several surveys during this tenure as hydrographic surveyor. Further, he has appointed as OIC of the Hydrographic Survey School at Naval and Maritime Academy – Sri Lanka from 2023 to 2024. He has pursed staff course at Defence Services Command and Staff College – Sri Lanka and possess Master of Science degree in Defence and strategic studies. He has commanded four Fast Attack Crafts.

Analysing The Impact of Water Turbidity on Bottom Detection Performance by MBES and SBES

Cdr S M Rahat Jobayar

Introduction.

1. Echo sounder performance varies greatly depending on the pertinent marine environmental conditions. One of the most significant challenges being its application in the Ganges-Brahmaputra-Meghna (GBM) delta region, which encompasses the coastal areas of Bangladesh. These areas are known to be present a highly dynamic and complex environment[20] for hydrographic surveys due to seasonal sediment deposition, strong tidal currents, and significant variations in water turbidity[21]. Echo sounders, both single-beam echo sounders (SBES) and multibeam echo sounders (MBES), are used extensively for bathymetric survey and underwater navigation in these waters. However, their performance is often compromised by the region's unique environmental characteristics, particularly water turbidity. Given the vast sediment load of the GBM delta, bathymetric surveys here are prone to inaccuracies due to acoustic signal attenuation and scattering. The research sets out to document, analyse, and understand the degree to which high turbidity impairs the accuracy and operational efficiency of two critical sounding techniques deployed in deltaic waters.



Source: Aktar, Sumaiya et al., 2025

Figure 1: GBM Delta System

Problem Statement.

2. Echo sounders play a vital role in underwater mapping, yet their effectiveness can vary sharply with changing environmental factors, notably water turbidity. In Bangladesh's GBM delta, seasonal sediment influx and strong tidal activity lead to extremely turbid water conditions, complicating echo sounders' ability to accurately track the seabed.

Table 1: Quantification of Turbidity in Coastal Waters off Bangladesh

Quantification of Turbidity in Coastal Waters off Bangladesh				
River/Estuary	**Location**	**Season**	**Turbidity (NTU/FTU)**	**Key Influencing Factors**
Meghna Estuary	Various sampling points	Wet Season (Monsoon) Dry Season (Winter)	Mean: 56.8 ± 7.59. Range: 50.90 to 65.40 NTU Mean: 22.7 ± 0.65. Range: 22.70 to 23.40 NTU	High flow, runoff, and sediment load Lower river flow and calmer conditions

[20] Ahmed, S Firoz. 'BATHYMETRIC SURVEY IN THE COASTAL AREA OF BANGLADESH - A CHALLENGING EXPERIENCE FOR THE SURVEYOR.' IHR, 30 Nov. 2016. https://ihr.iho.int/articles/bathymetric-survey-in-the-coastal-area-of-bangladesh-a-challenging-experience-for-the-surveyor/.

[21] Madhumita Chakraborty, Anith Kumar Mishra, Abhijit Mukherjee, Influence of hydrogeochemical reactions along flow paths on contrasting groundwater arsenic and manganese distribution and dynamics across the Ganges River, Chemosphere, Volume 287, Part 2, 2022, 132144, ISSN 0045-6535, Accessed from https://doi.org/10.1016/j.chemosphere.2021.132144

Quantification of Turbidity in Coastal Waters off Bangladesh				
River/Estuary	**Location**	**Season**	**Turbidity (NTU/FTU)**	**Key Influencing Factors**
Ganges River	Upstream coastal reach	Monsoon Winter	Up to 169.4 FTU Down to 10.82 FTU	High monsoon precipitation and associated turbulence Reduced river flow and sediment transport
Ganges-Brahmaputra Confluence	Coastal delta region	Monsoon Winter	Up to 152.48 FTU Down to 8.37 FTU	High flow and mixing of two major river systems Calmer river state and lower sediment load

Source: Various

3. SBES operates at higher frequencies, providing precise results in clear water but struggling in turbidity, often misinterpreting suspended sediments as the seafloor, while MBES, despite its multi-beam advantage, loses fidelity under extreme turbid conditions due to scattering and noise issues. The continual shifting of river channels and seabed morphology further complicates survey operations, demanding adaptive equipment selection and advanced calibration strategies to maintain data integrity.

Methodology.

4. The research adopts an experimental and comparative approach, leveraging both literature review and in-situ data from Bangladesh Navy Hydrographic School (BNHYDS) and Chittagong Port Authority (CPA) operations. Archived SBES and MBES bathymetric datasets collected in the Chattogram region serve as the empirical foundation, analysed using specialized hydrographic processing software.

5. Three sets of data were collected at the upstream of Karnaphuli River and downstream of the same river was used for this study. Due to weather conditions and other operational constraints, both data sets are within the periods of month of October but spread over a duration of 02 (two) years. SBES data from one OEM's equipment and MBES data from 2 separate OEM's equipment were available. For data acquisition, Hysweep ® and Qinsy ® were used. For data processing, Caris HIPS & SIPS 11.x was used. DGPS with subscription-based SBAS (Atlas H10 Offshore) were available in all cases, providing a high level of positional accuracy.

Study Area and Pertaining Conditions Around Sounding Operation

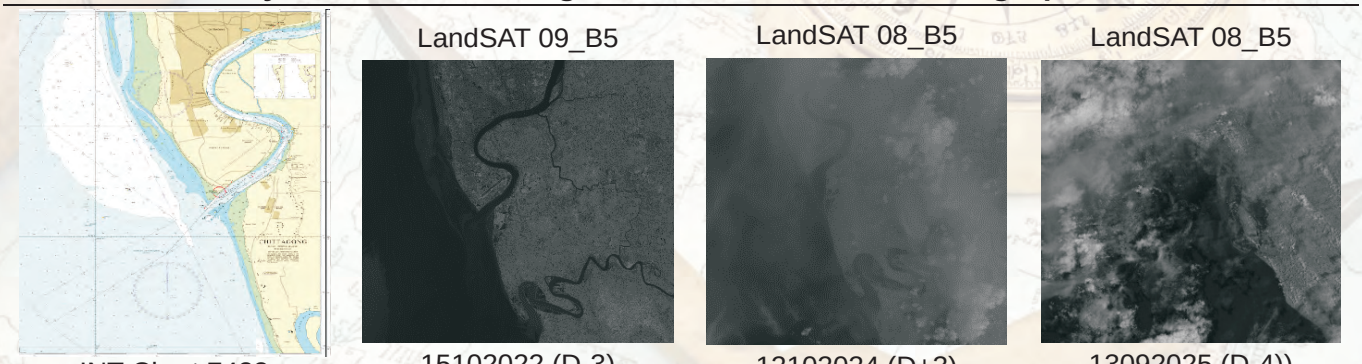


Figure 2: Study Area and Pertaining Conditions Around Sounding Operation

6. Meteorological data and satellite imagery (Landsat-8 OLI) were used to supplement sediment transport and turbidity assessment, mapping spatial patterns and temporal changes in silt deposition. The study incorporates cross-validation metrics involving previously charted depths and multi-source data, with sensor calibration and quality assurance processes strictly adhering to International Hydrographic Organization (IHO) guidelines[22] for reliability. Principal variables examined include bathymetric conditions, sound velocity profiles, and bottom tracking consistency, with particular attention to the limitations imposed by incomplete seasonal and spatial data coverage.

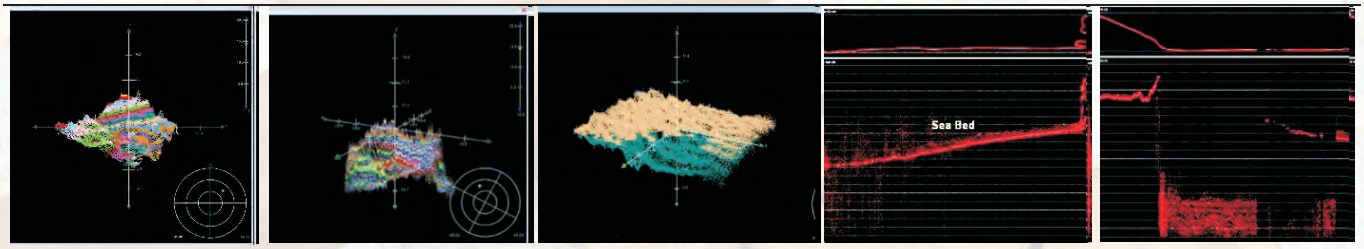
Analysis.

7. Analysis of the datasets reveals that both MBES and SBES systems encountered distinct challenges under turbid conditions. MBES, equipped with advanced beamforming and processing algorithms, demonstrated superior bottom tracking capability compared to SBES, especially in moderately turbid environments where its

[22] IHO, C-13. 'C_13_Chapter_3_December2010.Pdf'. Accessed 15 June 2025. https://iho.int/uploads/user/pubs/cb/c-13/english/C_13_Chapter_3_December2010.pdf.

multi-beam averaging could offset the effects of scattered signals. However, the performance of MBES degraded notably in peak turbidity or during monsoon conditions, with an increased prevalence of false or noisy bottom returns and a higher requirement for intensive data cleaning and post-processing.

Echo Sounders' Bottom Tracking as Seen in Subset Editor



Reson T50P | Norbit iWBMSH (Port, Hull Mount) | SBES High Noise, lost bottom

Figure 3: Echo Sounders' Bottom Tracking as Seen in Subset Editor

8. Sensor calibration, real-time monitoring of positioning accuracy, and systematic updating of sound velocity profiles were found as most important practices in maintaining operational continuity in challenging environments. The inability to access comprehensive water column imagery, seasonal and spatially varied data hampered full evaluation of MBES performance under monsoon stress scenarios, which was a marked limitation of the research, leaving scope for further study on this topic.

Results.

9. The study showed a clear correlation between elevated turbidity and diminished bottom detection performance, with MBES generally outperforming SBES in accuracy and consistency. Both systems successfully tracked the seafloor during the surveyed periods, provided operator intervention and calibration procedures were diligently followed. Results showed that modern MBES technology can maintain reliability within typical deltaic conditions, with bottom depth measurements agreeing closely with existing bathymetric charts. However, lack of extreme weather-condition datasets and full water column/raw backscatter imagery limited the study's ability to conclusively characterize MBES performance degradation during flooding and peak turbidity events - a major source of measurement error in real-world hydrographic operations. Data analysis of vessel track lines indicated that outliers and signal noise increased in estuarine and river channel areas, further validating the hypothesis that turbidity acts as a significant obstacle to echo sounder accuracy.

Conclusion.

10. Despite the constraints posed by data availability and seasonality, this research offers valuable insights into the operational boundaries of MBES and SBES in turbid coastal environments. The findings portray that while MBES technologies have advanced considerably - through improvements in hardware, software, and adaptive calibration - no system is yet wholly immune to performance loss under extreme turbidity, such as during Bangladesh's monsoon and flood periods. Operator skill, real-time calibration, and adherence to robust survey practices are crucial for reliable data acquisition. To further the reliability and scientific understanding of seabed mapping, systematic data collection across all seasons, including peak monsoon months, is strongly recommended, along with the integration of multi-frequency MBES, water column imagery, and advanced post-processing algorithms. These approaches will equip hydrographic services in sediment-rich regions with the tools and methodologies necessary to confront the persistent challenges of turbid water bathymetry, improving strategic planning and operational outcomes in coastal hydrographic surveys.



Cdr S M Rahat Jobayar, (H2), psc, BN was commissioned in the Executive Branch of Bangladesh Navy on 01 December 2008. He completed his Category "B" Hydrography Course from BN Hydrography School, Officers' Basic Electronic Chart Course from PN Hydrography School, Karachi and Category "B" in Cartography from UKHO. He also underwent Applied Oceanography course from NOAMI, Adaptive Planning & Water Resources Management Course by IHE Delft, Netherlands, from Bangladesh Maritime University, Dhaka and GTO Course from ISSB, Dhaka. The officer is a Masters of Defence Studies graduate of Defence Services Command and Staff College, Mirpur. The officer has served onboard all survey platforms of Bangladesh Navy under different capacities. His other notable appointments include Officer-in-Charge Cartography at BNHOC and Staff Officer (Hydrography) at Naval Headquarters. Under blue helmet, the officer served as Operations Officer, Malakal Detachment, BANFMU-5 at UNMISS and awarded with Force Commander's Commendation. Cdr Rahat Jobayar has a keen interest in Geospatial technologies and their applications to GEOINT. He likes to write on creative topics as his hobby, and cares after a small rooftop garden in his leisure time.

Faster, Or More Accurate? Comparing GNSS and EDM Trilateration in the Field

LEUT Benjamin White

Introduction.

1. Accurate positioning is fundamental to modern surveying, geodesy, construction, and navigation. As technology advances, professionals have more options than ever for determining coordinates quickly and precisely. Two of the most common methods - GNSS positioning and electronic distance measuring trilateration - offer different strengths, yet are often viewed as competing tools. This article summarises a recent case study comparing both techniques under real-world conditions, providing insight into their respective performance, advantages, and limitations. The findings will help surveyors (and engineers) decide which tool best fits their needs...and when a hybrid approach might be the smartest option.

What are GNSS and Electronic Distance MeasuringTrilateration?

2. **Global Navigation Satellite System (GNSS).** Positioning includes constellations like GPS, GLONASS, and Galileo. GNSS receivers calculate their position by measuring the time it takes for satellite signals to reach the ground. When supported by correction services like Real-Time Kinematic (RTK) or Post-Processed Kinematic (PPK), GNSS can deliver centimetre-level accuracy in near real time, particularly in open-sky conditions.

3. **Electronic Distance Measuring (EDM)**. Trilateration, on the other hand, is a ground-based technique. It determines the position of an unknown point by measuring distances from multiple known control points using electronic distance measurements. Unlike GNSS, it requires line-of-sight between the instrument and target, but it's trade-off is that it is highly reliable-especially in GNSS signal-obstructed areas.

How the Comparison Was Conducted?

4. The field study was conducted at **INS GOMANTAK, Vasco-da-Gama, Goa-India**, a site selected for its mix of open and obstructed terrain. Pre-established Goa Naval Area geodetic stations were utilised, measured using various methods of GNSS positioning.

5. The GNSS data was collected using a Leica GS 10 Receiver and Antenna operating in **Post-Processed Kinematic** mode, while total station observations were made using a Leica GS 15 Total Station and Leica GPR111 Circular Prism with trilateration from three known control points.

6. Each observation was timed and repeated to assess consistency, and environmental conditions (like canopy cover, terrain slope, weather conditions, and other environmental) were recorded to evaluate performance sensitivity.

Key Results and Field Insights.

Accuracy:

In open-sky areas, GNSS consistently achieved horizontal accuracy within required S44 Standards [±5cm], with vertical accuracy slightly lower due to satellite geometry. Total station electronic distance measurement trilateration also performed well, with consistent sub-centimetre results also within all S44 Standards - particularly in the areas with reliable control geometry.

Efficiency:

7. GNSS had the potential to be notably faster as once initialised, the new control point could be measured within minutes without moving the instrument. However, accuracy requirements can dictate anywhere from

15minutes of data collection up to 24hrs on a single point. Total Station setups took longer due to the need for physical alignment, multiple setups, and line-of-sight checks. However, in compact areas, the total stations allowed for rapid sequential measurements once in place.

Environmental Impact:

8. In forested or obstructed areas, GNSS accuracy drops due to satellite signal blockage and multi-path effects. Meanwhile, total station performance remains stable, provided line-of-sight was maintained. Total station measurements would normally require curvature and refraction corrections, however reciprocal observations were conducted to eliminate these errors, GNSS required none.

Repeatability:

9. Electronic distance measurement results showed higher consistency in short-range observations. GNSS results varied more in obstructed environments but were very stable in clear conditions.

Takeaways for Surveyors and Engineers.

10. This comparison highlights that no single method is universally superior—instead, each method excels under specific conditions.

Use GNSS when:

Working over large or distributed areas
Open-sky conditions are available
Speed and mobility are critical

Use ground-based electronic distance measuring when:

High accuracy is required in small, confined areas
Line-of-sight between points can be guaranteed
Working under canopy, indoors, or in GNSS-denied zones

11. **Consider hybrid use**: Establish GNSS control points and use total stations to detail features or measure points in obstructed zones. This approach combines GNSS speed with the precision and reliability of optical instruments.

Conclusion.

12. Modern surveying isn't about choosing between GNSS and ground-based Trilateration—success lies in selecting and combining the right tools based on environmental conditions, accuracy requirements, time constraints, and available resources.

13. GNSS excels in projects that demand speed, mobility, and real-time access to position data over wide areas. It's particularly advantageous for coastal mapping, where its signal strength and satellite visibility are unhindered. Total stations, on the other hand, continue to prove their value in areas where visibility to the sky is compromised. These instruments allow surveyors to work with confidence in environments where GNSS simply cannot operate effectively.

14. Surveyors who understand both systems and can switch fluidly between them will continue to lead in precision, productivity, and project efficiency.



LEUT Benjamin White is a Maritime Geospatial Officer serving in the Royal Australian Navy. Joining the RAN in the year 2000 as a Hydrographic Systems Operator, LEUT White progressed to the senior of sailor ranks of Warrant Officer in 2017. After completing Command Staff Course in 2021, he commissioned as an MGO – Hydrography specialist in 2023, and completed his advanced technical mastery course at NIH, India in 2025. LEUT White is married to his partner Kate, they have five children, and they reside in Wollongong, New South Wales, Australia.

Acoustic Backscatter Analysis for Seafloor Profiling in Recommending Submarine Cable Route in North Natuna Water

Lieutenant Arya Meiko Waliyanto

Introduction.

1. Submarine communication cables are vital infrastructures, carrying more than 99% of international data traffic. Their reliability and longevity depend heavily on accurate route planning, which requires a detailed understanding of seafloor conditions. As the world's largest archipelagic state, Indonesia faces significant challenges in the development of submarine cable networks. One of the most strategic areas is the North Natuna Sea, a major international maritime corridor with complex geological settings. To minimize risks during installation, acoustic backscatter analysis from Multibeam Echosounder (MBES) systems is an effective approach for characterizing seabed conditions.By integrating backscatter mosaics with sediment ground-truth samples, seabed substrates can be mapped with high accuracy. This study aims to recommend a suitable cable route in the North Natuna Sea and present a comparative view with Kabil - Batam. The Batam comparison is not intended for cable route analysis, but to illustrate how seabed complexity may differ across locations.

Keywords: Acoustic Backscatter, Multibeam Echosounder, Submarine Cable, Seabed Classification, North Natuna, CARIS HIPS SIPS,

Methodology.

Survey and Data Acquisition.

2. The hydro-oceanographic survey was conducted using the Indonesian Navy vessel KRI Spica-934 equipped with a Kongsberg EM2040 MBES. Survey lines were designed in a grid pattern with mainlines and crosslines to ensure complete coverage.

3. In addition, sediment samples were collected using a Van Veen grab sampler to validate the acoustic classifications. Samples were analyzed for grain size, texture, and composition, and then compared with acoustic reflectivity.



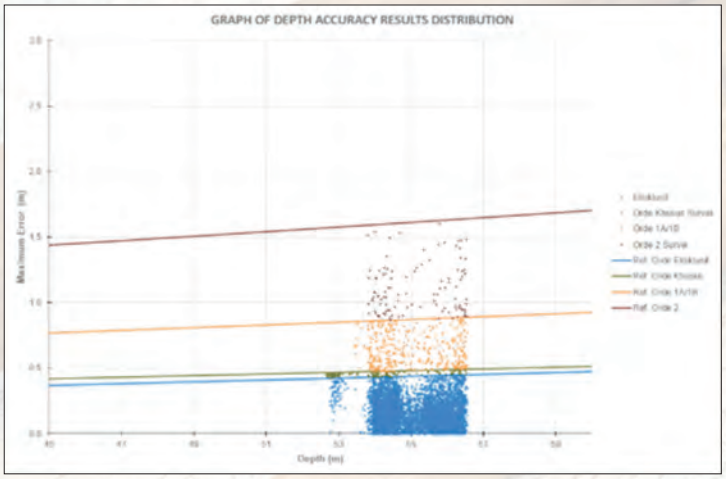
Figure 1: Survey Data Acquisition

Data Processing.

4. Raw MBES data were processed in CARIS HIPS & SIPS 11.3 using the GeoCoder engine. The workflow included radiometric corrections, angle normalization, and mosaic generation. Quality control consisting of

patch tests, crossline analysis, and Total Vertical Uncertainty (TVU) checks confirmed compliance with IHO S-44 accuracy standards.

5. Sediment classification was carried out using both the Wentworth grain size scale and the IHO C-13 table. This dual approach ensured finer separation of silt and clay while remaining aligned with international standards.



NAMA TIPE SEDIMEN		DIAMETER (mm)	INTENSITAS
BATU (ROCK)	BOULDER	>256	>12.27 dB
	COUBLE	65 - 256	12.25 s/d 6.91
	PEBBLE	4-64	6.85 dB s/d -3.98 dB
	GRANULE	2-4	-5.1 dB s/d- 6.69 dB
PASIR (SAND)	VERY COARSE SAND	1-2	-6.69 dB s/d -9.4 dB
	COARSE SAND	1/2 -1	-9.4 dB s/d -12.01 dB
	MEDIUM SAND	1/4 - 1/2	-12.01 dB s/d -14.81 dB
	FINE SAND	1/8 - 1/4	-14.81 dB s/d -17.52 dB
	VERY FINE SAND	1/16 - 1/8	-17.52 dB s/d -20.23 dB
LUMPUR (SILT)	COARSE SILT	1/32 - 1/16	-20.23 dB s/d -22.94 dB
	MEDIUM SILT	1/64 - 1/8	-22.94 dB s/d -25.65 dB
	FINE SILT	1/128 - 1/64	-25.65 dB s/d -28.36 dB
	VERY FINE SILT	1/256 - 1/128	-28.36 dB s/d -31.07 dB
LEMPUNG (CLAY)	COARSE CLAY	1/640 - 1/256	-31.07 dB s/d -33.78 dB
	MEDIUM CLAY	1/1024 - 1/640	-33.78 dB s/d -36.49 dB
	FINE CLAY	1/2360 - 1/1024	-36.49 dB s/d -39.20 dB
	VERY FINE CLAY	1/4096 - 1/2360	-39.20 dB s/d -41.91 dB

Figure 2: Data Processing

Results and Discussion.

Seafloor Characterization.

6. The base surface generated through CUBE processing provided a detailed topographic model of the Natuna seabed.

7. Slope variations and morphological features such as ridges and depressions were clearly identified, highlighting zones of potential risk.

8. Backscatter analysis indicated that high-intensity returns corresponded to coarse sediments and rocky substrates, whereas low-intensity returns were associated with mud and fine silt. Classification results from Caris HIPS & SIPS confirmed that much of the Natuna seabed consists of fine sediments, offering relatively stable conditions for cable laying.

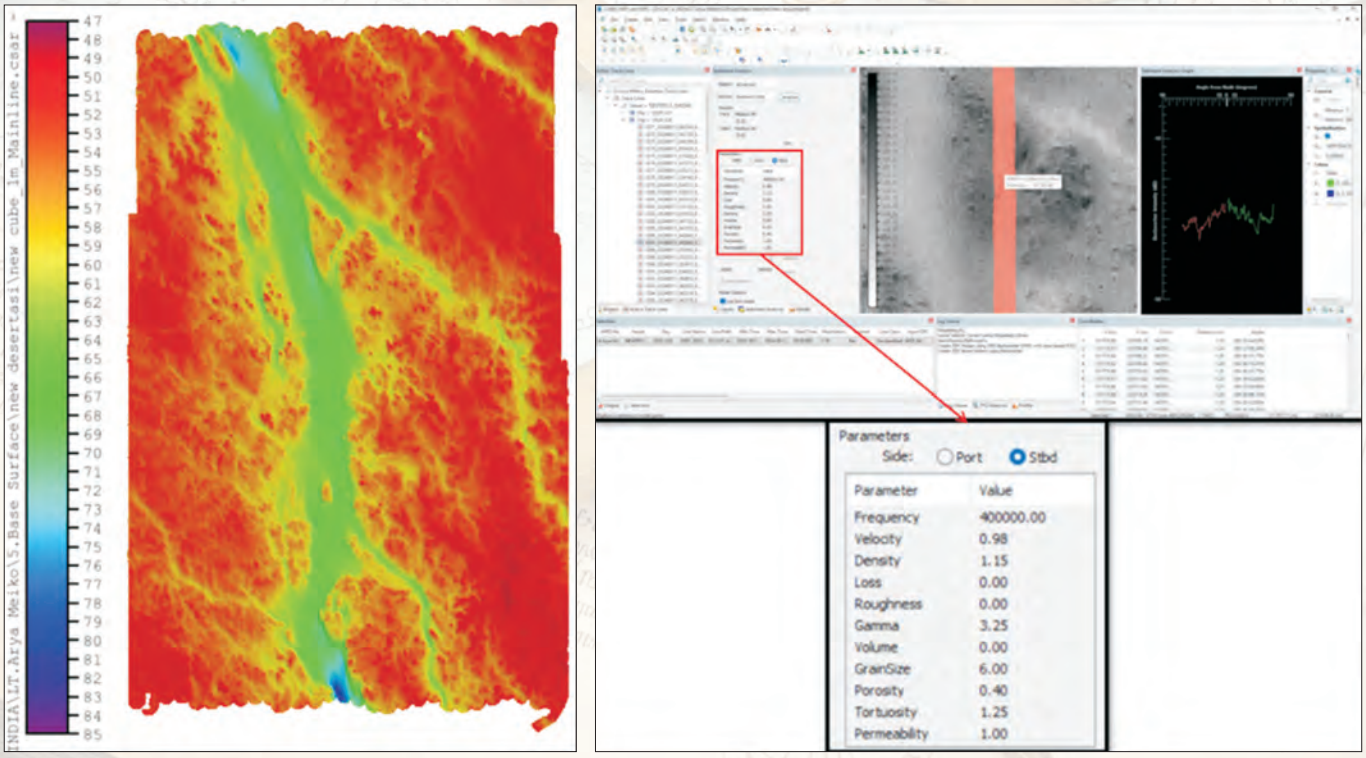


Figure 3: Seafloor Characterization

Sediment Classification and Validation.

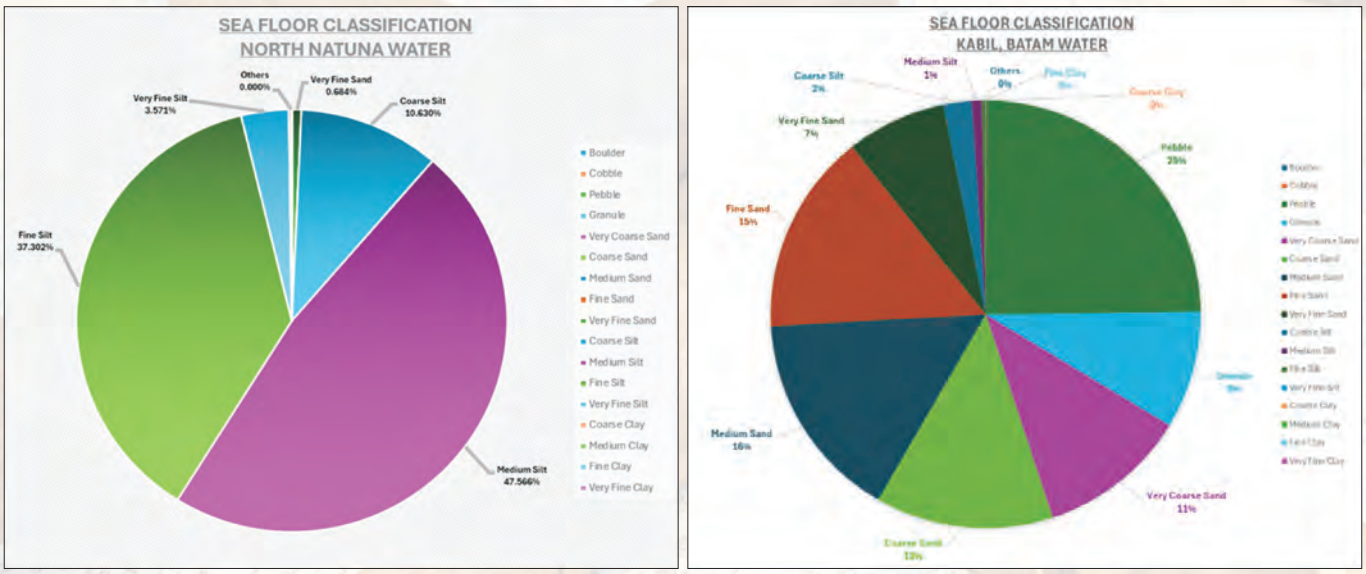


Figure 4: Sediment Classification and Validation

9. The Wentworth scale classification produced detailed sediment maps. In Natuna, fine sand and silt were dominant, whereas Batam exhibited a wider variety of seabed types, including coarse sand and gravel.

10. This comparison is crucial to demonstrate different levels of seabed complexity across sites. Natuna is relatively simple, while Batam presents a more diverse sediment composition.

11. By showing Batam as an example of a complex seabed, readers can better appreciate why integrated acoustic backscatter and ground-truth approaches are important in both simple and complex environments.

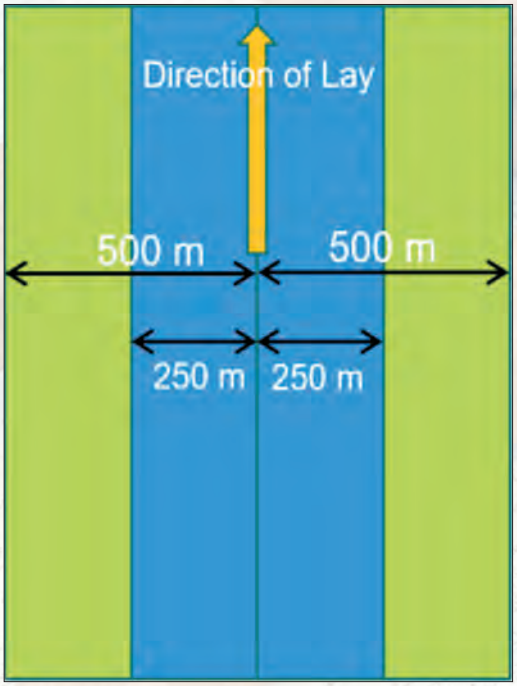
12. Validation was carried out by overlaying grab sample positions on the backscatter mosaic. Results showed a strong correlation between backscatter intensity and sediment hardness, and the combined analysis confirmed good agreement between acoustic predictions and physical samples.

Table 1: Seabed Classification With Coordinates

No.	Latitude	Longitude	Grab Sampling	Backscatter
1	2° 4' 39.41" N	105° 4' 14.28" E	Silty Sand	Very Fine Sand
2	2° 4' 14.59" N	105° 5' 42.31" E	Sand	Fine Sand
3	2° 3' 43.03" N	105° 8' 17.5" E	Sandy Silt	Medium Silt
4	2° 2' 41.89" N	105° 9' 8.86" E	Sandy Silt	Coarse Silt
5	2° 1' 59.05" N	105° 5' 45.54" E	Sandy Silt	Fine Silt
6	2° 1' 33.94" N	105° 3' 43.17" E	Silty Sand	Very Fine Sand
7	2° 0' 45.01" N	105° 8' 0.28" E	Silty Sand	Very Fine Sand
8	1° 59' 23.37" N	105° 6' 40.65" E	Coarse Sand	Medium Silt
9	1° 59' 12.02" N	105° 6' 5.61" E	Sandy Silt	Fine Silt
10	1° 57' 51.77" N	105° 8' 48.7" E	Silty Sand	Very Fine Sand
11	1° 56' 57.43" N	105° 6' 16.6" E	Sand	Fine Sand
12	1° 56' 34.52" N	105° 3' 53.68" E	Sandy Silt	Medium Silt

Cable Route Recommendation.

13. Based on sediment type, slope stability, and ICPC recommendations, the safest cable route was identified in the North Natuna Sea. The recommended corridor avoids rocky outcrops, steep slopes, and unstable sediments. The final suggested alignment and overlay with the backscatter mosaic demonstrate a technically feasible and environmentally sustainable submarine cable route.



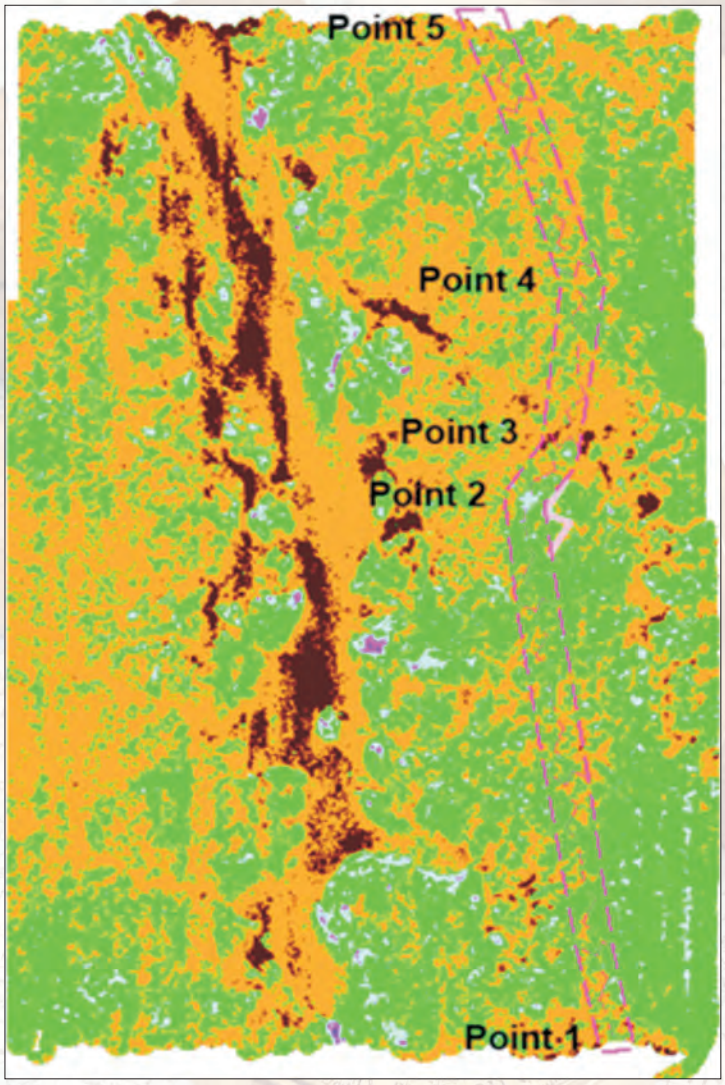


Figure 5: Cable Route Recommendation

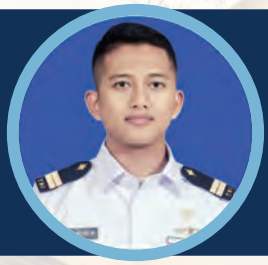
Conclusion.

14. **Backscatter for Seabed Classification**. Acoustic backscatter from MBES (Kongsberg EM2040, processed in CARIS HIPS & SIPS 11.3 with GeoCoder) proved effective in identifying seabed texture, showing strong agreement with ground-truth samples.

15. **Ground-Truth Sampling**. Grab samples from 12 stations validated the backscatter results, confirming the necessity of physical verification.

16. **Recommended Cable Route**. The suitable route crosses stable sediments (fine sand and medium silt), avoiding steep slopes, canyons, rocky seabed, or active bedforms. Burial depth is recommended at 1.5–1.8 m, with corridor spacing up to 750 m.

17. **Hypothesis Testing**. A strong correlation was found between backscatter data and seabed sediment properties in North Natuna Waters. The null hypothesis (no relationship) is rejected, supporting the use of backscatter as a reliable tool for submarine cable route selection.



Lieutenant Arya Meiko Waliyanto (20699/P) of the Indonesian Navy, and completed the Long Hydrography Course (083:047) at the National Institute of Hydrography (NIH), Goa, India in 2025. He graduated from the Indonesian Naval Academy (AAL) in 2013 and began his naval career serving aboard Indonesian Navy combat ships until 2022. In 2018, he completed the Surface Weaponry Specialist Officer Course, graduating at the top of his class, and subsequently served as Commanding Officer of the Indonesian Navy Patrol Craft (KAL Welang).In 2022, the author earned his Bachelor's Degree in Hydrography from the Indonesian Naval Technology College (STTAL), obtaining the Bachelor of Engineering (Hydrography) degree and receiving the Best Thesis Award in his cohort. Following his academic achievements, he joined the Indonesian Naval Hydro-Oceanographic Centre (Pushidrosal), where he continues to serve at present.

Comparative Study of Multibeam Data Processing: Hips Vs Hypack

Lieutenant Commander Yogesh Bhatt

Introduction.

1. In modern hydrographic surveying, the demand for precise, reliable, and efficiently processed bathymetric data has grown substantially with the advancement of multibeam echo sounder (MBES) systems. Among the various post-processing software solutions available today, CARIS HIPS and SIPS and HYPACK are two of the most widely adopted. Both software platforms provide comprehensive workflows for multibeam data handling, yet they differ in architecture, operational flexibility, and analytical capabilities. This case study undertakes a comparative evaluation of HIPS and HYPACK, focusing on key parameters such as CUBE (Combined Uncertainty and Bathymetry Estimator), Digital Terrain Model (DTM) generation, and GEOCODER functionality.

Overview of Software Systems.

2. CARIS HIPS and SIPS, developed by Teledyne CARIS, is a globally recognized hydrographic data processing suite. It offers an integrated environment for processing, analysis, and visualization of multibeam, single-beam, and side-scan sonar data. Its CUBE algorithm revolutionized uncertainty-based bathymetric estimation, enabling objective data cleaning and surface modelling.

3. On the other hand, HYPACK, developed by Xylem Inc., is a versatile and cost-effective software primarily known for its integrated survey design, data collection, and processing features. While it provides essential MBES post-processing tools, its approach emphasizes ease of use, real-time data quality monitoring, and simplified editing workflows.

Methodology.

4. For this study, identical raw multibeam datasets were processed separately in both HIPS and HYPACK environments. Each dataset underwent data cleaning, CUBE surface generation, and DTM creation, followed by geocoding and visual assessment. Parameters such as processing speed, accuracy, surface smoothness, and noise handling efficiency were compared.

5. The datasets were collected using an ELAC SeaBeam 3012 multibeam echosounder, operated under standard hydrographic survey conditions. The same vessel configuration, sound velocity profiles, and tidal corrections were applied to both processing streams to maintain uniformity and ensure objective comparison.

Results and Analysis.

6. The comparative evaluation revealed distinct strengths in each software suite.

7. In CARIS HIPS, the CUBE algorithm produced a more statistically reliable and smoother DTM, with automated uncertainty management that significantly reduced manual editing time. The GEOCODER tool within HIPS facilitated advanced backscatter mosaic generation with enhanced feature differentiation and tonal consistency, making it highly suitable for seabed classification and habitat mapping applications.

8. In contrast, HYPACK demonstrated greater operational simplicity and faster initial data turnaround. Its user-friendly interface and efficient editing tools allowed quick detection and removal of outliers. However, DTM surfaces generated in HYPACK displayed slightly higher noise levels, and manual editing was often required to match the quality achieved in HIPS. The absence of a full CUBE-based uncertainty model limited its statistical robustness in high-precision hydrographic products.

9. Quantitatively, HIPS processing yielded marginally higher vertical accuracy (within ±0.05 m) and improved grid consistency compared to HYPACK. Nevertheless, HYPACK's processing time was approximately 25–30% faster, underscoring its suitability for rapid survey turnaround and operational field use.

Discussion.

10. The study highlights a trade-off between processing sophistication and operational efficiency. CARIS HIPS, with its advanced algorithms and detailed QC capabilities, is ideal for chart production and scientific seabed mapping, where accuracy and repeatability are paramount. Conversely, HYPACK's strength lies in its field usability, offering real-time integration, cost-effectiveness, and streamlined workflows suited to small- and medium-scale hydrographic operations.

11. Both software systems ultimately contribute significantly to the modern hydrographic domain. The choice between them should be guided by operational objectives - whether the priority is speed and simplicity (HYPACK) or precision and analytical depth (HIPS).

Conclusion.

12. This comparative study reaffirms that while both HIPS and HYPACK efficiently process multibeam data, their applications serve different operational needs. CARIS HIPS stands out for high-end bathymetric analysis, surface modelling, and uncertainty quantification, making it the preferred choice for official hydrographic charting. HYPACK, on the other hand, remains an excellent solution for real-time data collection and rapid processing, offering a practical balance between performance and usability.

13. As hydrographic surveying continues to evolve with enhanced sonar technologies and AI-driven automation, the integration of these software capabilities will likely converge, offering even more robust and intelligent processing frameworks in the years ahead.



Lieutenant Commander Yogesh Bhatt (09393-Y) is a hydrography specialist Officer from the 94th course of Indian Naval Academy. He has tenanted appointments as Assistant Hydrographic Surveyor and Navigating Officer onboard IN Ships Nirupak, Investigator and Sarvekshak. Officer has undergone his Long H course from NIH, Goa in 2025 and presently posted onboard INS Jamuna.

A Comparative Study of Open-Source GNSS Processing Software and Leica Infinity for GPS Data Post-processing

Lt Cdr Osbert Clarence Nielemah Nuotuo

Introduction.

1. Accurate positioning is essential in hydrographic surveying, ensuring precise coordinates for control points and depth measurements. The reliability of nautical charts and marine projects depends on achieving high accuracy. Contemporary GNSS, such as GPS, Galileo, GLONASS, and BeiDou, provide positioning data, but raw observations often fail to meet the accuracy required for hydrographic surveys[23]. Techniques such as differential corrections, Real-Time Kinematic (RTK), and Precise Point Positioning (PPP) are employed to achieve sub-meter to centimeter-level accuracy[24, 25].

2. For geodetic control, post-processing static GNSS observations over extended periods is standard practice, allowing hydrographers to remove errors related to satellite orbits, clocks, and atmospheric conditions[26]. Commercial software like Leica Infinity, Business Centre, MAGNET Office Tools, and Emlid Studio offer comprehensive, hardware-integrated workflows but are costly and restrictive for multi-user deployments in smaller organisations or academic institutions. Uploading data into online services like Online Positioning User Service (OPUS) and the Australian Positioning Service (AUSPOS) present connectivity and possible information security concerns, highlighting the need to evaluate offline open-source alternatives.

3. This study assesses the positional accuracy, and suitability of selected open-source GNSS software compared to Leica Infinity. Accuracy (closeness to the true value, quantified via Root Mean Square Error [RMSE]) and precision (repeatability, measured by standard deviation) serve as primary evaluation metrics.

Methodology.

4. The study compared open-source packages with Leica Infinity using a 25-hour static GPS dataset collected at NIH Rooftop Station 1, Goa, India, with a Leica Viva GS25 GNSS receiver (Fig.1). Proprietary Leica DBX files were converted to RINEX format and processed with standardised parameters: GPS-only selection, 30-second observation interval, 15° elevation mask, and precise ephemerides from the International GNSS Services.

5. Leica Infinity served as the benchmark due to its proven performance in high-precision workflows. It features a graphical interface, baseline processing, and network adjustment via proprietary least squares algorithms, simultaneously optimising multiple baselines to enhance precision and accuracy[27].

6. Open-source tools selected included GNSS Laboratory Tool Suite (gLAB)[28] and Precise Point Positioning with Ambiguity Resolution (PRIDE PPP-AR)[29] both employing PPP, calculating each station's position independently using precise satellite orbit and clock corrections. The Real-Time Kinematic Library (RTKLIB)[30] and Softwel (SW) GNSS[31] utilise differential processing but are limited to single-baseline

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[23] Akpinar, B., & Aykut, N. 0. (2017). Determining the coordinates of control points in hydrographic surveying by the precise point positioning method. The journal of navigation, 70(6), p1-4.

[24] International Hydrographic Organization (IHO). (2022). Standards for Hydrographic Surveys, Special Publication No. 44 (S-44), 6.1 Edition, IHO: Monaco, p18.

[25] El-Sheimy, N., & Lari, Z. (2020). GNSS Applications in Surveying and Mobile Mapping. Position, Navigation, and Timing Technologies in the 21st Century, p1716.

[26] Mageed, K. M. A. (2015). Comparison of GPS commercial software packages to processing static baselines up to 30 km. ARPN J. Eng. Appl. Sci, 10(11), p10641.

[27] Leica Geosystems. (2022). Leica Infinity Software: Product Brochure.

[28] Ibáñez, D., Rovira-García, A., Sanz, J., Juan, J. M., González-Casado, G., Jiménez-Banos, D., López-Echazarreta, C., & Lapin, I. (2018). The GNSS Laboratory Tool Suite (gLAB) updates: SBAS, DGNSS and Global Monitoring System. 9th ESA Workshop on Satellite Navigation Technologies (NAVITEC, 2018).

[29] Geng, J., Chen, X., Pan, Y., Mao, S., Li, p., Zhou, J., & Zhang, K. (2019). PRIDE PPP-AR: an open-source software for GPS PPP ambiguity resolution. GPS solutions, 23, p1-10.



Figure 1: Set-Up and Configuration of Leica Viva GS25 and AS10

solutions without network adjustment. The final coordinates from open-source software were compared against the validated Leica Infinity solution, which provides sub-centimeter accuracy.

Results and Discussion.

Accuracy and Precision.

7. The gLAB software outperformed other open-source software, producing coordinates nearly identical to Leica Infinity, with RMSE values of 0.0011 m (Latitude), 0.0011 m (Longitude), and 0.0001 m (Height) and similarly low standard deviations (Fig.1 and 2). PRIDE PPP-AR also performed well, achieving low RMSE values close to gLAB and the commercial benchmark. RTKLIB and SW GNSS produced larger errors due to their single-baseline limitation and lack of network adjustment, with SW GNSS showing the highest ellipsoidal height RMSE (1.6723 m).

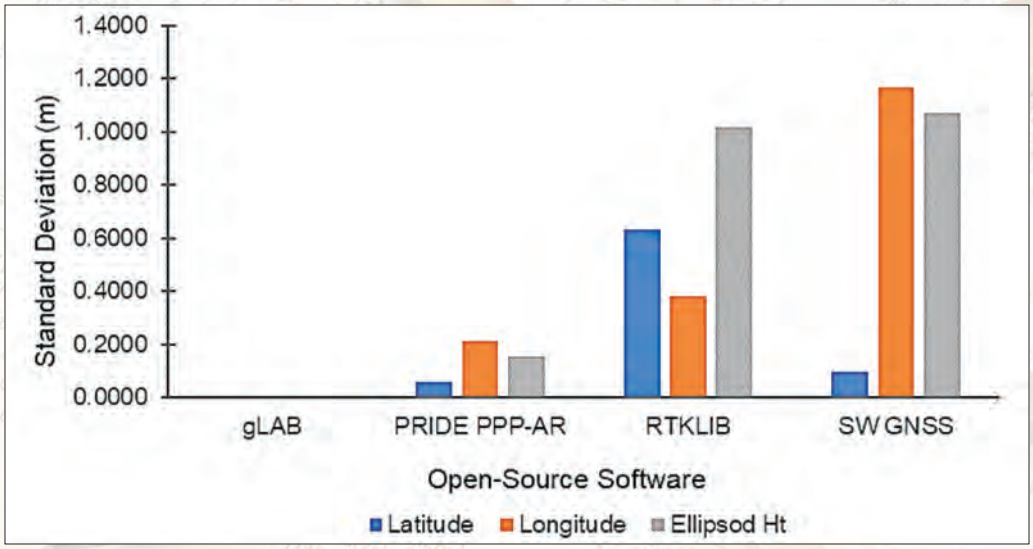


Figure 2: Bar Graph Showing the Standard Deviations of NIH Rooftop Station One Position Coordinates for Open-Source GNSS Post-Processing Software

[30] Takasu & Yasuda, Development of the low-cost RTK-GPS receiver with an open-source program package RTKLIB, p123-130.
[31] AviyaanTech (2021). Aviyaan GitHub Webpage. Accessed 1 June 2025. https://github.com/AviyaanTech/SW_GNSS

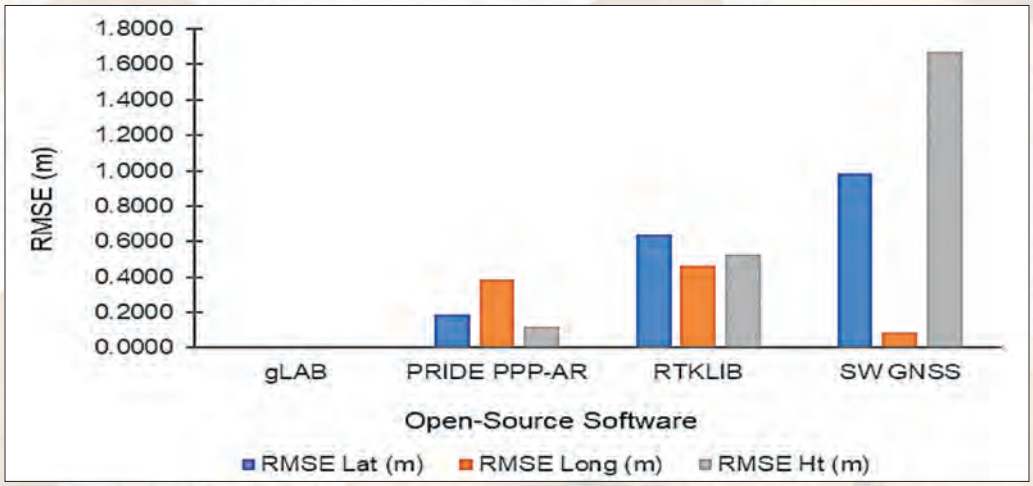


Figure 3: Bar Chart Showing the Root Mean Square Error (RMSE) of NIH Rooftop Station One Position Coordinates for Open-Source GNSS Post-Processing Software

Hypothesis Testing.

8. A two-tailed t-test at 95% confidence assessed whether open-source results differed significantly from Leica Infinity. The null hypothesis (no significant difference) could not be rejected for any software across latitude, longitude, and height. gLAB had the lowest t-value (-0.0746), confirming its statistical alignment with the Leica reference. RTKLIB and SW GNSS, despite larger vertical errors, remained below the critical t-value (±4.303), supporting practical applicability for static GNSS post-processing (Fig.4).

SOFTWARE	Variance	Std Dev	Calculated-t
PRIDE PPP-AR	0.0372	0.1929	-2.9316
gLAB	0.0000	0.0015	-0.0746
RTKLIB	0.7898	0.8887	0.5303
SW GNSS	1.2579	1.1216	1.9999
Critical t-value			**±4.303**

Figure 4: Coordinate Differences and t-Test Results for GNSS Open-Source Software Compared to Leica Infinity at 95% Confidence Level

Comparison with IHO Standards.

9. Comparing results to IHO S-44 standards, gLAB and PRIDE PPP-AR met the 1-meter radial buffer of Leica Infinity, suitable for Exclusive Order surveys. RTKLIB and SW GNSS, though less precise, met the 2-meter buffer, appropriate for Special Order surveys (Fig.5).

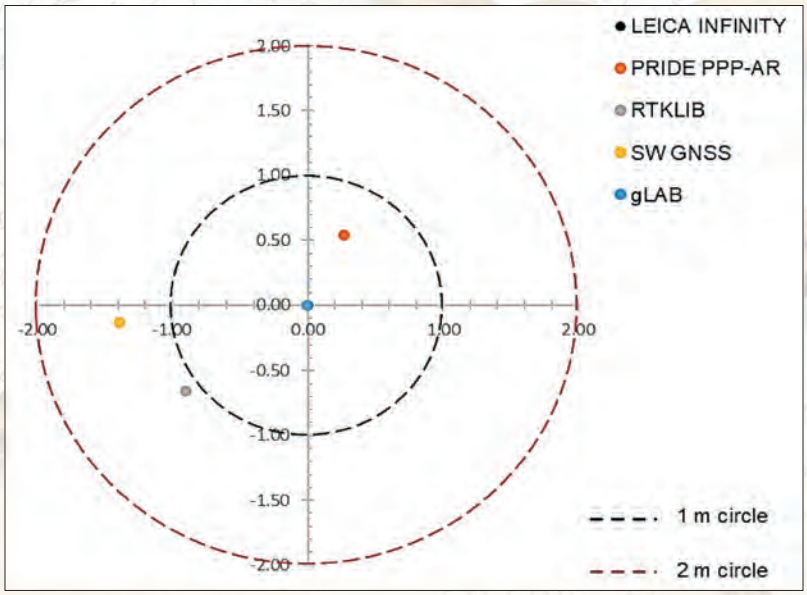


Figure 5: Scatter Plot of Horizontal Position Errors relative to Leica Infinity, with One-metre and Two-metre accuracy circles

Conclusion and Recommendations.

10. Several open-source GNSS software packages offer viable, cost-effective alternatives for geodetic and hydrographic applications. gLAB and PRIDE PPP-AR deliver positional accuracy and stability sufficient for high-precision tasks (Exclusive Order), effectively leveraging PPP with accurate orbit and clock corrections. However, they do not support conventional baseline processing or network adjustment, a key strength of proprietary software like Leica Infinity. RTKLIB and SW GNSS are suitable for Special order surveys and below, providing meter-level accuracy at low cost but limited by single-baseline processing.

11. Institutions and projects requiring high-accuracy and precision results, especially where ambiguity resolution is critical, should consider gLAB and PRIDE PPP-AR as complementary or alternative tools. Those requiring single-single-baseline processing may use RTKLIB and SW GNSS. However, applications demanding multi-baseline solutions, network adjustment, or strict quality control should continue to rely on proprietary solutions.

12. Future research should incorporate multi-GNSS and kinematic datasets, continuous benchmarking of updated software versions, and formal usability evaluations to facilitate broader adoption of open-source GNSS tools.

References.

1. Akpinar, B., & Aykut, N. 0. (2017). Determining the coordinates of control points in hydrographic surveying by the precise point positioning method. The journal of navigation, 70(6), p1-4.
2. International Hydrographic Organization (IHO). (2022). Standards for Hydrographic Surveys, Special Publication No. 44 (S-44), 6.1 Edition, IHO: Monaco, p18.
3. El-Sheimy, N., & Lari, Z. (2020). GNSS Applications in Surveying and Mobile Mapping. Position, Navigation, and Timing Technologies in the 21st Century, p1716.
4. Mageed, K. M. A. (2015). Comparison of GPS commercial software packages to processing static baselines up to 30 km. ARPN J. Eng. Appl. Sci, 10(11), p10641.
5. Leica Geosystems. (2022). Leica Infinity Software: Product Brochure.
6. Ibáñez, D., Rovira-García, A., Sanz, J., Juan, J. M., González-Casado, G., Jiménez-Banos, D., López-Echazarreta, C., & Lapin, I. (2018). The GNSS Laboratory Tool Suite (gLAB) updates: SBAS, DGNSS and Global Monitoring System. 9th ESA Workshop on Satellite Navigation Technologies (NAVITEC, 2018).
7. Geng, J., Chen, X., Pan, Y., Mao, S., Li, p., Zhou, J., & Zhang, K. (2019). PRIDE PPP-AR: an open-source software for GPS PPP ambiguity resolution. GPS solutions, 23, p1-10.
8. Takasu & Yasuda, Development of the low-cost RTK-GPS receiver with an open-source program package RTKLIB, p123-130.
9. AviyaanTech (2021). Aviyaan GitHub Webpage. Accessed 1 June 2025. https://github.com/AviyaanTech/SW_GNSS



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Comparative Evaluation of GNSS-based Positioning Systems for Coastline Delineation in Accordance with IHO SP-44 Standards

Lt Pyae Phyo Kyaw

Introduction.

1. Accurate coastline delineation forms the foundation for hydrographic surveying, nautical chart compilation, and coastal zone management. This study evaluates the positional accuracy of three Global Navigation Satellite System (GNSS)-based positioning techniques - Standalone GPS, Differential GPS (DGPS) with GAGAN correction, and Real-Time Kinematic (RTK) - by comparing them with Total Station observations considered as ground truth. The survey was conducted around the periphery of the National Institute of Hydrography (NIH), Goa, India, using fifteen control points to simulate a coastline. Observations were collected under uniform field conditions and processed using Leica Infinity software. The results demonstrated mean horizontal deviations of 0.087 m for RTK, 2.102 m for DGPS, and 7.508 m for Standalone GPS when compared with Total Station data. Based on the International Hydrographic Organization (IHO) SP-44 standards, RTK and DGPS achieved compliance across all survey orders, while Standalone GPS satisfied all but the Exclusive Order (≤ 5 m). The study emphasizes the operational importance of correction-based GNSS systems in hydrographic data acquisition and underscores the need for adherence to IHO accuracy standards for reliable coastline mapping.

2. Coastline delineation defines the dynamic boundary between land and sea and is crucial for safe navigation, chart updating, and coastal management. The accuracy of coastline positioning directly affects the quality of hydrographic charts and consequently maritime safety. The International Hydrographic Organization (IHO) has established survey accuracy requirements under publication Standards for Hydrographic Surveys (S-44), which defines permissible horizontal and vertical uncertainties for various survey orders. Advancements in GNSS technology have transformed hydrographic positioning by enabling centimetre- to metre-level accuracies depending on the technique applied. Among these, Standalone GPS, DGPS, and RTK are widely used for coastal and nearshore mapping. Complementarily, the Total Station remains a reference instrument for establishing high-precision ground control. This study, conducted as part of the Long Hydrography Course (083:047) at NIH Goa, compares the accuracy of GNSS-based systems with Total Station under controlled field conditions, with particular emphasis on compliance with IHO SP-44 horizontal accuracy standards.

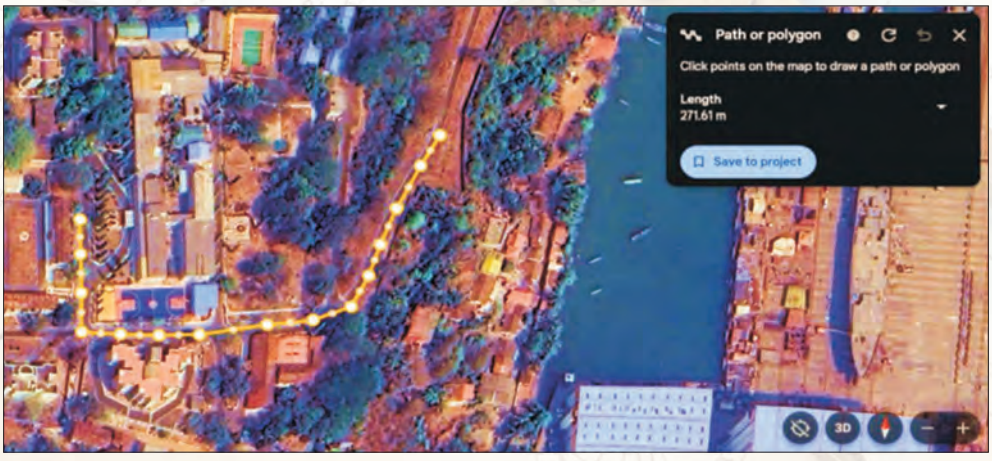


Figure 1: Simulated Coast Line

Data Acquisition.

3. The study was carried out along a simulated coastline surrounding NIH, Goa, covering approximately 270 meters. Fifteen survey points were marked at equal spacing to represent intermediate coastal features. Two local benchmarks located on the NIH rooftop and Sanshodhak Block rooftop served as geodetic control points. Static GNSS observations of 25 hours and 6 hours were conducted at these sites to determine precise coordinates using IGS stations (BHR4, CUSV, DGAR, and POL2) and precise ephemerides for network adjustment. The instruments used included Leica Viva GS10/CS10 GNSS receivers for Standalone, DGPS (GAGAN), and RTK modes, and Leica TS15 Total Station for high-accuracy reference data. Accessories such as tripods, prisms, and UHF radio links were used to ensure stable and consistent observation. All data were processed using Leica Infinity software.

4. Each positioning technique followed a uniform procedure to ensure comparability. For Standalone GPS, two-minute static observations were recorded at a one-second sampling rate with a ten-degree masking angle in WGS84 coordinates without correction. DGPS observations were conducted in a similar way but used real-time corrections from the GAGAN SBAS system. RTK observations involved one receiver fixed at the NIH rooftop as a base and a rover receiver used to collect data at all fifteen points with real-time corrections transmitted through UHF radio. Total Station observations were performed using the open traverse method with a known backsight to ensure internal consistency. Three sets of Total Station observations were conducted on different days to ensure data repeatability. Before fieldwork, the Total Station was calibrated using EDM line checks, and GNSS instruments were validated through long static sessions against IGS precise ephemerides. All observations were conducted under clear weather conditions between March and June 2025.



Figure 2: Data Acquisition in the Field

Data Processing.

5. All collected data were imported into Leica Infinity software for baseline computation, coordinate extraction, and accuracy assessment. The processing involved adjustment using IGS precise ephemerides, comparison of GNSS coordinates with Total Station reference values, and computation of horizontal deviations (ΔE, ΔN) for each point. The mean horizontal deviation for each positioning method was determined to evaluate compliance with IHO SP-44 horizontal accuracy standards. Total Station coordinates were averaged from three separate observations to provide a consistent reference frame. Network adjustment was also applied to Standalone GPS data to observe the improvement achievable through post-processing.

Comparison of Data.

6. The results revealed a clear hierarchy in positioning accuracy. RTK achieved a mean horizontal deviation of 0.087 m, DGPS achieved 2.102 m, and Standalone GPS achieved 7.508 m. After network adjustment using IGS precise ephemerides, Standalone GPS accuracy improved to within 4.5 m. According to IHO SP-44 Edition 6.1.0, Exclusive Order surveys require ≤ 5 m accuracy, while other orders allow ≤ 10 m. Therefore, RTK and DGPS satisfied all survey order standards, whereas Standalone GPS without correction met only the lower-order requirements. These findings align with theoretical expectations, as RTK's carrier-phase observations and real-time differential corrections provide centimetre-level precision,

while DGPS corrections from GAGAN mitigate most atmospheric and clock errors to achieve meter-level accuracy. Standalone GPS, operating solely on pseudorange measurements, remains the least precise due to uncorrected satellite, ionospheric, and multipath effects.

Table 1: Data Comparison

Point No	Horizontal Distances From Total Station Observations		
	RTK	DGPS	Standalone GPS
1	0.0707	1.8651	6.3490
2	0.0384	2.0097	7.3336
3	0.0315	2.1988	6.7704
4	0.0544	1.1955	8.1655
5	0.1512	1.2328	9.8730
6	0.0293	1.5171	8.8888
7	0.0932	1.8804	7.3357
8	0.0548	1.1877	8.8491
9	0.0863	2.3741	5.9700
10	0.0674	2.6417	8.1236
11	0.1363	2.9365	6.6925
12	0.0971	3.0975	7.3499
13	0.1313	2.6649	7.1295
14	0.1052	2.5452	6.7804
15	0.1615	2.1844	7.0124
Mean	**0.087**	**2.102**	**7.508**

7. Minor discrepancies in RTK data were attributed to multipath effects and partial obstructions from buildings and trees, especially near the Sanshodhak Block. DGPS results showed degradation up to three meters where satellite geometry produced higher GDOP values or when signal latency occurred. Standalone GPS exhibited large deviations of six to nine meters due to poor signal strength and atmospheric refraction. The Total Station, in contrast, maintained sub-centimetre precision, validating its suitability as the control reference. Environmental and operational challenges, such as uneven terrain affecting instrument levelling and temporary loss of RTK UHF communication, were effectively mitigated through repeated setups, resurveying, and scheduling observations under favourable sky conditions.

Data Compliance Evaluation.

8. In compliance evaluation with IHO SP-44, RTK achieved centimetre-level precision suitable for Exclusive Order hydrographic surveys such as harbour and jetty mapping. DGPS met all Special to Order 2



Figure 3: Horizontal Differences between modes

requirements, adequate for coastline delineation and general charting. Standalone GPS was deemed unsuitable for precision hydrography but adequate for reconnaissance or large-scale mapping tasks. The study confirms that even though GNSS technology has become widely accessible, the selection of positioning methods must align with survey accuracy objectives defined by IHO standards.

9. The findings of this study reaffirm the performance hierarchy of GNSS techniques in hydrographic applications. RTK provides the highest level of precision and reliability, ideal for real-time surveys where accuracy is critical. DGPS offers a balance between accuracy and operational simplicity, making it suitable for coastal mapping where moderate accuracy suffices. Standalone GPS, while cost-effective and easy to deploy, is inadequate for high-order surveys unless post-processed using precise ephemerides and correction data. Post-processing of Standalone

10. GPS data with IGS information significantly reduced error magnitudes, emphasizing the value of correction data even in non- differential methods.

Conclusion.

11. This study concludes that accurate coastline delineation is fundamental to safe navigation and chart production. RTK GNSS and DGPS with GAGAN correction both achieve accuracy levels compliant with IHO SP-44 requirements. Total Station observations continue to serve as an indispensable reference for validating GNSS-derived positions. Environmental and operational parameters, including sky visibility, calibration, and stable setup, remain critical factors influencing positional quality. Integrating GNSS with traditional geodetic instruments enhances both efficiency and accuracy in hydrographic data collection.

12. To ensure reliable survey results, several recommendations are proposed. GNSS observations should be conducted under clear-sky conditions with favourable satellite geometry to minimize multipath and atmospheric distortion. Instruments must be regularly calibrated before deployment to maintain consistency. Cross-verification of GNSS results with Total Station control should be incorporated as part of quality assurance. For RTK surveys, the line of sight between base and rover should be unobstructed, and the communication link should be continuously monitored to prevent data loss. Observation schedules should consider redundancy and repetition to detect random or systematic errors. Finally, the use of precise ephemerides and post-processing for Standalone and DGPS datasets is strongly recommended to enhance positional integrity and compliance with IHO S-44 accuracy requirements.

13. In summary, this technical evaluation demonstrates the importance of selecting appropriate GNSS methods based on the intended order of the hydrographic survey. RTK remains the most precise technique for Exclusive Order applications, DGPS is suitable for general coastline delineation, and Standalone GPS can be used for low-order mapping or reconnaissance tasks when correction data are unavailable. Consistent calibration, favourable observation conditions, and proper data validation remain essential to achieving the accuracy standards required by the IHO for safe and dependable nautical charting.

List of References.

1 The World Factbook - The World Factbook

2 DAVID WELLS, GUIDE TO GPS POSITIONING, Concept of Point Positioning 1.0-Page 1.1

3 Sputnik 1 – Wikipedia

4 AHMED EL-RABBANY, Introduction to GPS: The Global Positioning System, Second Edition, Page-2

5 Understanding GPS GNSS- Principles and Applications 3rd Rd Kaplan HEGARTY, Page-90

6 Understanding GPS GNSS- Principles and Applications 3rd Rd Kaplan HEGARTY, Page-91

7 One-way Ranging | GEOG 862: GPS and GNSS for Geospatial Professionals

8 https://www.e-education.psu.edu/geog862/node/1736

9 AHMED EL-RABBANY, Introduction to GPS: The Global Positioning System, Second Edition, Page-44

10 https://www.e-education.psu.edu/geog862/node/1723

11 AHMED EL-RABBANY Introduction to GPS: The Global Positioning System, Second Edition, 65-66

12 AHMED EL-RABBANY Introduction to GPS: The Global Positioning System, Second Edition, 67

13 Relative Positioning | GEOG 862: GPS and GNSS for Geospatial Professionals

14 GAGAN (GPS Aided Geo Augmented Navigation), Objectives, Features and Importance

15 AHMED EL-RABBANY Introduction to GPS: The Global Positioning System, Second Edition, Page 76

16 AHMED EL-RABBANY Introduction to GPS: The Global Positioning System, Second Edition, Page 76

17 Total Station in Surveying : Parts, Least Count, Operations, Field Procedure, Uses, Advantages & Disadvantages - Dream Civil and Total station - Wikipedia

18 S-44_Edition_6.1.0 page v

19 S-44_Edition_6.1.0 page 4

20 S-44_Edition_6.1.0 page 1-2



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Integrated DEM Generation for Coastal Hydrography - Experience from INS Gomantak, Goa

Lieutenant Commander Aalampreet Singh Mamik

1. **Introduction**. Modern hydrography relies on precise elevation data to support flood control, marine planning, infrastructure design, and environmental management. For coastal regions in India, where rapid development and natural forces continuously change the landscape, existing digital elevation models (DEMs) from satellite sources often lack the necessary detail. Generating a high-resolution, accurate DEM for INS Gomantak, Goa - a naval base with complex topography - demonstrated how combining satellite imagery with ground-based surveys can deliver the results hydrographers need for real-world operations.

2. **The Study Area: Geography and Challenges**. INS Gomantak is situated on the Mormugao Peninsula, overlooking the Arabian Sea and the Zuari River estuary. The surrounding landscape features rocky cliffs, estuarine flats, mangroves, gentle slopes, and densely vegetated regions. These coastal and environmental variations present unique data challenges, such as poor coverage and vertical accuracy in freely available DEMs, as well as logistical barriers to dense field survey coverage. For hydrographers, capturing this complexity is vital for disaster risk assessment and nautical charting, yet traditional methods either miss critical features or require prohibitive resources.

3. **Methodology: Integrating Satellite and Ground Data**. The case study followed a structured five-stage workflow to build a robust and validated DEM: -

4. **Data Collection**. High-resolution satellite imagery (Google Earth, ~1.57 m per pixel) provided extensive coverage, while precise elevation data came from GPS and total station surveys. Over 27 ground control points (GCPs) and 14,000 field measurement spots ensured a strong validation network.

5. **Georeferencing and Data Preparation**. Survey coordinates and satellite data were cross-checked, geo-referenced, and transformed to a common datum. The dense grid of GCPs enabled precise adjustment of satellite images to real-world positions, minimizing distortions and measurement errors.

6. **DEM Construction**. Using GIS software (Global Mapper v15.0, CARIS HIPS v12), elevation points from both sources were imported, processed, and interpolated into a Triangulated Elevation Grid (TEG) at 1m resolution and detailed contours. Global Mapper and CARIS variable resolution algorithms supported the merging of raster and vector datasets, while building height artifacts were manually removed for bare-earth modelling.

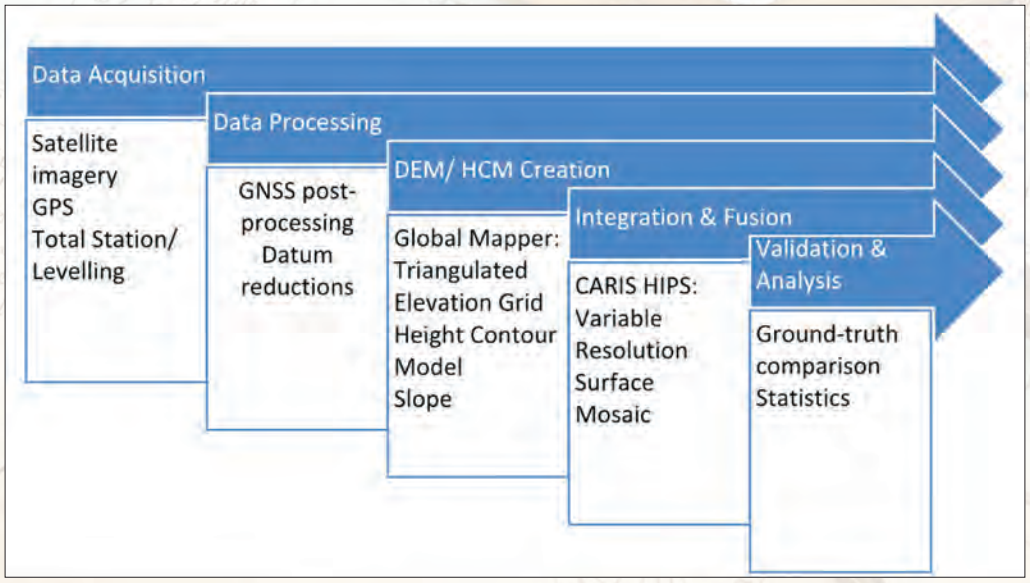


Figure 1: Methodology

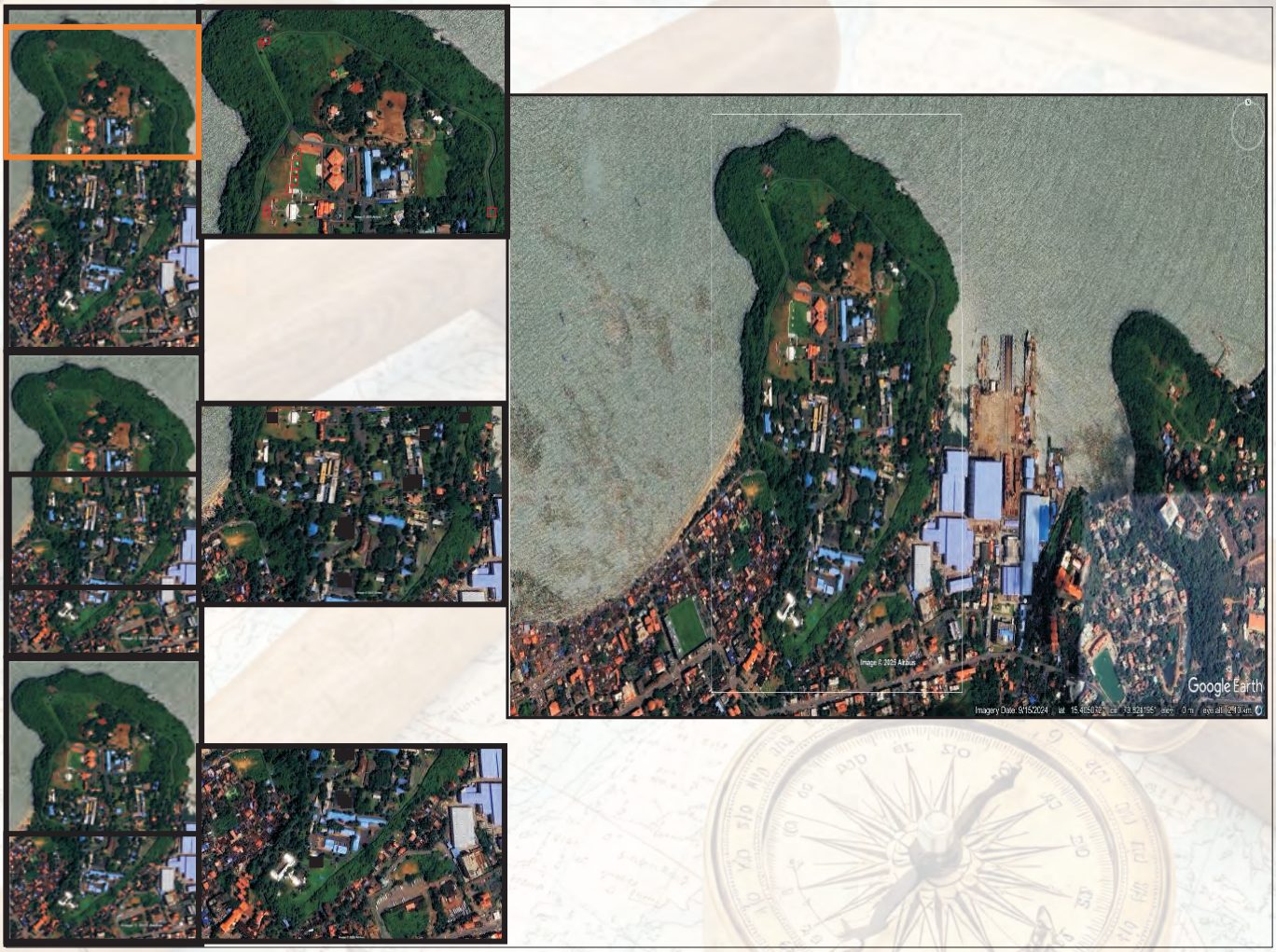


Figure 2: High resolution of satellite image

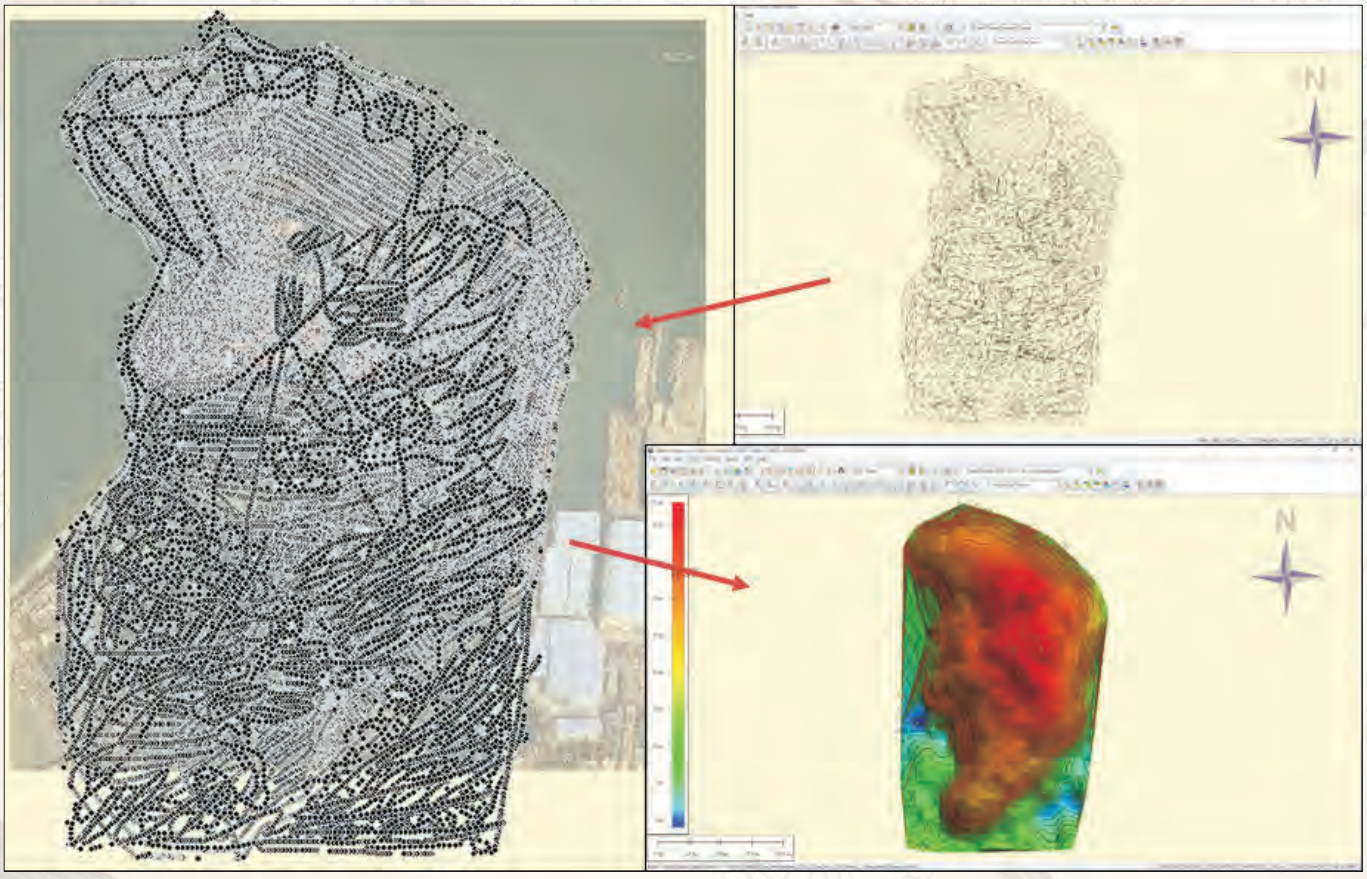
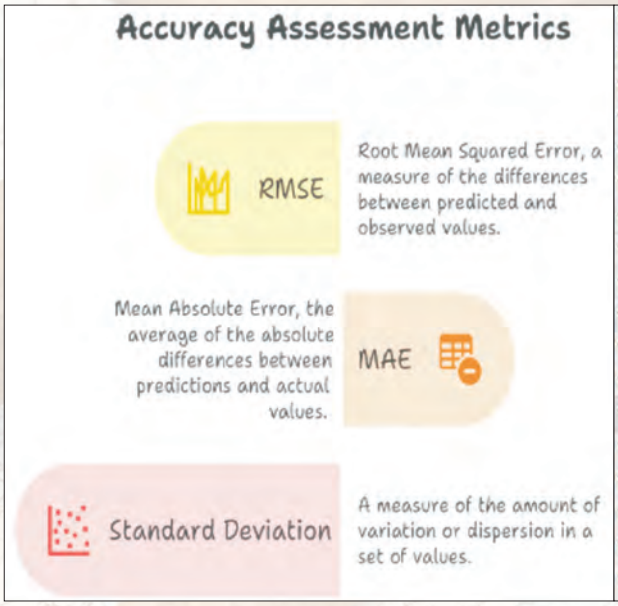


Figure 3: DEM construction

7. **Fusion and Quality Control**. Satellite-derived data was fused with field control measurements in CARIS HIPS using mosaic routines. Accuracy was systematically validated against independent ground points and error statistics (RMSE, MAE, error distribution) were computed and visualized.



145	26.303	24.577	-1.726
146	26.12	23.244	-2.876
147	25.908	23.096	-2.812
148	25.842	22.498	-3.344
149	25.343	22.645	-2.698
150	25.1	21.145	-3.955
151	24.148	21.1	-3.048
152	21.637	19.393	-2.244
153	19.966	18.017	-1.949
154	18.383	21.172	2.789
155			
156	Mean Error ME	-0.924	
157			
158	Mean Absolute Error MAE	2.1602	
159			
160	Root Mean Square RMSE	2.5097	
161			
162	Standard Deviation SD	2.3409	

Figure 4: Fusion and Quality control

8. **Results: Improvements in DEM Quality**. The final DEM achieved an RMSE of 2.51 meters and MAE of 2.16 meters, a substantial improvement over widely available remote sensing DEMs, which typically show 10–25 metre errors in comparable settings. Over 80% of the validation points fell within 3 meters of ground truth, and the high point density allowed for accurate representation of local slopes and ridges—features essential for flood modelling and engineering designs.

Comparative figures showed how the integrated model captured richer terrain detail, corrected bias from building heights, and supported site-specific hydrographic analyses not possible with coarse DEMs.

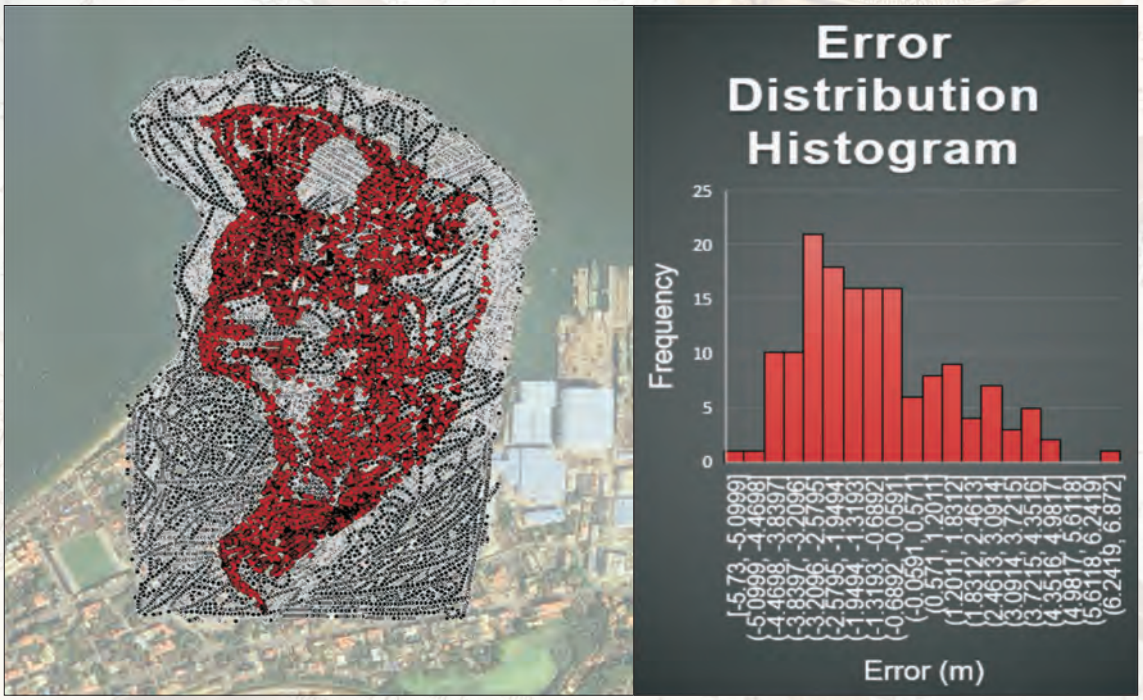


Figure 5: Error distribution Histogram

9. **Operational and Practical Impact**. The new DEM has direct applications for:-
   9.1. Flood risk mapping, emergency planning, and insurance assessments
   9.2. Coastal and port infrastructure layout, including storm water drains and embankments

9.3. Accurate shoreline and bathymetric delineation for nautical charting and surveying

9.4. Environmental management, supporting mangrove and erosion studies

This hybrid data integration methodology balances cost and practicality against the need for precision, making it highly relevant for hydrographers working in diverse, dynamic Indian coastal areas. While sub-meter vertical accuracy requires even denser control or advanced sensors, the results far outstrip those of satellite-only approaches and bring actionable improvements for both field survey teams and desk analysts.

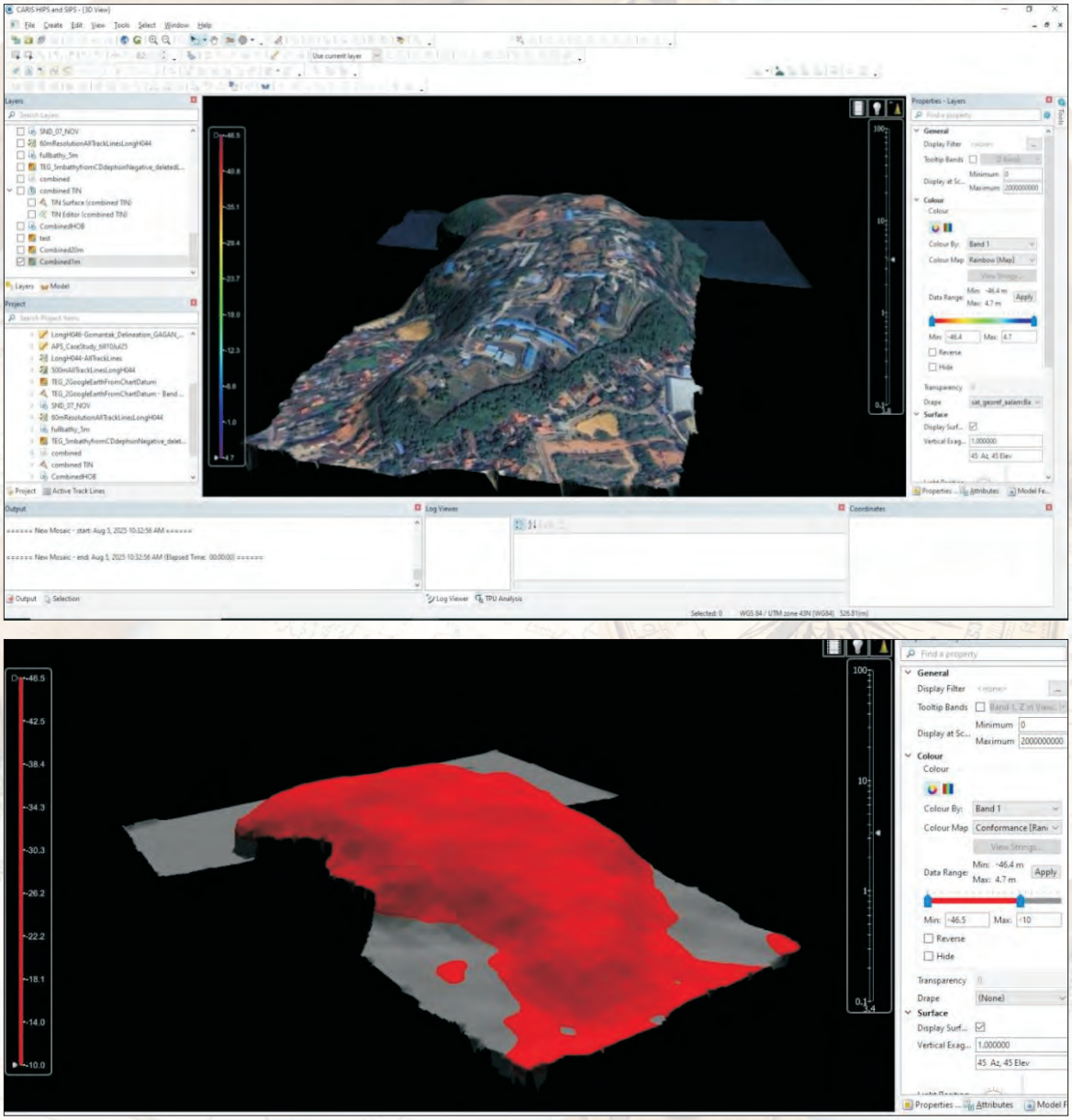


Figure 6: Terrain model using Caris HIPS and SIPS

10. **Lessons and Future Directions**. This case study establishes a transparent workflow for elevating DEM quality in operational hydrography. It shows how strategic fusion of satellite coverage and ground truthing is feasible, effective, and scalable under typical resource constraints. For broader deployment, further integration with UAV-based LiDAR and cloud-processing is recommended, as is collaboration with national agencies to standardize DEM resolutions and update protocols with local ground truth.



Lieutenant Commander Aalampreet Singh Mamik, an alumnus of the 94 INAC course at the Indian Naval Academy, has served as Assistant Hydrographic Surveyor onboard INS Jamuna. Having completed the Long Hydrography Course in 2026, he is currently posted onboard Sanshodhak as part of the commissioning crew, serving as Assistant Hydrographic Surveyor.

Comparative Evaluation of Direct and Trigonometric Levelling in Hydrographic Surveying with Reference to IHO S-44 (6th Edition)

Lieutenant Commander S Aditya

1. Accurate determination of vertical heights is fundamental to hydrographic surveying, forming the basis for safe navigation, coastal engineering, dredging operations, and marine spatial planning. Levelling techniques establish reliable vertical datums against which bathymetric measurements are referenced. Among the various methods employed, direct (spirit) levelling and trigonometric levelling remain the most widely used. This article presents a comparative evaluation of these two methods, analysing their accuracy, sources of error, operational efficiency, and conformity with the International Hydrographic Organization (IHO) S-44 (6th Edition) standards.

2. Direct levelling is traditionally regarded as the most precise method for determining height differences. It relies on establishing a horizontal line of sight using optical or digital levels and graduated staffs. Height differences are computed from back sight and fore sight readings, and systematic procedures such as closed-loop levelling are used to minimise cumulative error. In contrast, trigonometric levelling derives height differences from measured vertical angles and slope distances using total stations. This method offers greater flexibility and operational reach, especially in difficult terrain or inaccessible areas, but is more sensitive to atmospheric and instrumental errors.

3. The study was conducted in two phases. The primary field investigation took place at INS Gomantak, Goa, over a baseline of approximately 800 m between the National Institute of Hydrography (NIH) rooftop benchmark and Watch Tower-4. A secondary validation phase was carried out at NAD Jetty, Goa, to assess repeatability and inter-method consistency under stable coastal conditions. Instruments used included a Leica DNA03 digital level for precise levelling, a Leica TS15 total station for trigonometric levelling, and a Leica Viva GNSS receiver for supplementary vertical assessment.

4. Results from direct levelling demonstrated consistently high accuracy and repeatability. Over the 800 m baseline, the Leica DNA03 achieved a misclosure of approximately 2.8 mm, satisfying First-Order levelling criteria and comfortably conforming to IHO S-44 vertical uncertainty requirements for high-precision hydrographic surveys. The method proved stable across repeated observations and was minimally influenced by atmospheric variability, confirming its suitability for establishing primary vertical control.

5. Trigonometric levelling results, however, exhibited greater variability. Observed height differences ranged from 14.924 m to 15.104 m, with misclosures reaching up to 0.175 m during certain observation days. While some sessions produced acceptable results under favourable conditions, the overall accuracy fell short of IHO S-44 requirements for higher-order surveys. The NAD Jetty validation phase showed improved performance over a shorter baseline, yet misclosures remained significantly larger than those obtained through direct levelling. These findings underscore the sensitivity of trigonometric levelling to baseline length, instrument setup geometry, and atmospheric conditions.

6. Atmospheric refraction emerged as a critical source of error in trigonometric levelling. Variations in temperature, humidity, and pressure altered the refractive index, introducing measurable vertical errors when corrections were not applied. Calculations showed that uncorrected refraction over a 658 m slope distance could introduce vertical errors of approximately 4–5 mm, compounding across multiple legs. While

correction models reduced this effect, residual errors persisted, highlighting the limitations of the method in precision-critical applications.

7. Operational efficiency was a notable strength of trigonometric levelling. Field records showed that trigonometric surveys could be completed in 60–120 minutes, compared to approximately 180 minutes for closed-loop direct levelling over similar distances. GNSS heighting proved the fastest method but yielded unreliable vertical results due to poor satellite geometry and multipath effects in coastal environments. These findings confirm that speed alone does not equate to suitability for high-accuracy hydrographic control.

8. When evaluated against IHO S-44 (6th Edition) standards, direct levelling consistently met the vertical uncertainty thresholds for Special Order and Order 1 surveys, making it indispensable for critical hydrographic control. Trigonometric levelling, while efficient and operationally flexible, did not reliably meet these stringent requirements without rigorous corrections and favourable conditions. GNSS heighting, in its unadjusted form, was unsuitable for precise vertical control.

9. In conclusion, the study demonstrates that direct levelling remains the most reliable method for high-precision hydrographic vertical control, despite its higher time and labour requirements. Trigonometric levelling is best suited for reconnaissance surveys, difficult terrain, or scenarios where speed and accessibility outweigh strict accuracy demands. A hybrid approach, combining direct levelling for control benchmarks with trigonometric levelling for network extension, offers a practical balance between accuracy and efficiency. Such an approach aligns with modern hydrographic practice and ensures compliance with international standards while maintaining operational flexibility.



Lieutenant Commander S Aditya, a Hydrography specialist from the 26 NOC Extended course of the Indian Naval Academy. He has tenated appointments as Assistant Hydrographic Surveyor onboard IN ships Nirupak and Jamuna and is presently appointed as Watch Keeping Officer onboard INS Makar.

Sound Velocity Profile Error in MBES Survey, A Study in Malaysian Waters

Lt Yeganraj Sivalingam

1. The advancement of Multibeam Echo Sounders (MBES) is prompting frameworks with upgraded capacities in their conventional business sectors, yet in addition gives highlights to permit the development of their utilisation into new regions and submissions. This short audit features a portion of the highlights of the most recent age of frameworks. The credits of a MBES framework are generally characterized through specialized particulars, alongside working recurrence, beam length, beam width, range of beams and coverage.

2. Bathymetric surveys play a crucial role in marine navigation, coastal management, and resource planning. Accurate mapping of the seafloor depends heavily on Multibeam Echo Sounders (MBES) and the precision of sound velocity measurements within the water column. The sound velocity profile (SVP) directly affects how acoustic beams are refracted, impacting the reliability of depth measurements. In the coastal shallow waters of Malaysia, SVP can fluctuate significantly due to variations in temperature, salinity, and pressure, creating ongoing challenges for maintaining compliance with International Hydrographic Organization (IHO) S-44 standards.

Site and Environmental Conditions.

3. Generally, coastal waters near low latitudes consist of frequent river inflows, tropical climate, and seasonal monsoons, all contributing to unpredictable SVP changes. Salinity levels decrease near river mouths, resulting in significant variations in water column sound velocity. Measurements collected off the coast of Tanjung Tuan, Malaysia demonstrates SVP changes up to 8 m/sec, even outside monsoon periods. Such environmental variability makes the application of SVP corrections a complex but essential process for ensuring accuracy in bathymetric data.

The Role of Sound Velocity in MBES.

4. Water temperature, salinity, and pressure each influence sound velocity, especially within shallow waters up to 50 meters depth. MBES systems depend on two sound velocity measures, Surface sound speed, measured directly at the transducer for beam forming and correct beam steering. Second is sound velocity profile, measuring changes throughout the water column, used for ray tracing and acoustic signals refraction correction.

5. Errors in SVP can lead to distortions in depth estimates and swath patterns. These errors tend to have the greatest effect on the outer beams of MBES, where distortions appear as “smiley” or “frowny” curves, depending on the direction of SVP miscalculation. For example, using an SVP that is too high causes under-refraction, and outer beams appear shallower than reality. Conversely, a low SVP exaggerates refraction, resulting in deeper readings.

Effects of SVP Error.

6. Refraction errors occur when an incorrect sound velocity profile is used during data processing. These errors become more significant the further the beam is from the nadir, making them most noticeable in the outer beams. Sound velocity profile errors have distinct impacts on survey outcomes: -

6.1. **Depth accuracy**: Incorrect SVP causes depth readings to deviate from actual values, especially noticeable in the outer beams of MBES swaths.

6.2. **Survey precision**: The overall precision of bathymetric data diminishes as SVP error increases, particularly for standards demanding the highest accuracy.

6.3. **Pattern distortion**: Swath patterns show notable distortion or curvature dependent on SVP error, affecting the interpretability and reliability of mapped surfaces.

7. The following SVP error thresholds support compliance for various IHO S-44 survey orders in 50-metre deep waters: -

Table 1: Allowable SVP error to meet S-44 Survey Standards

IHO S-44 Survey Orders	SVP Error Threshold
Exclusive Order	< ±5 ms-1
Special Order	< ± 10 ms-1
Order 1a	< ± 10 ms-1
Order 1b	< ± 15 ms-1
Order 2	< ± 20 ms-1

8. Confidence levels in MBES data remain within acceptable limits at lower SVP error values. However, higher SVP errors result in decreased beam reliability, especially along the swath edges, potentially necessitating additional quality assurance measures before data acceptance. The following are the recommendations for hydrographic surveyors to mitigate sounding discrepancies and reduced data quality due to errors in SVP: -

8.1. A maximum of ±5 ms-1 Sound Velocity varies threshold to be set in the acquisition system during commencement of a survey. In other words, difference between Surface Sound Velocity and Sound Velocity profile used should not exceed ±5 m/sec to minimise effect of SVP error on data quality.

8.2. If situation as in environmental variations permits and with no logistical constraints, continuous updates of SVP data should be done through the survey. It is also recommended to cast for SVP in case of prominent changes in weather which could cause variation in temperature and salinity of water.

8.3. The outer beams of swath survey systems are more susceptible to SVP errors as inaccuracies amplified further from nadir. Real-time monitoring for smiley and frowning shape in the data should be done via the acquisition software.

8.4. Frequent and consistent quality control check must be performed with respect to IHO Survey Standards during as well as after data acquisition to avoid time wastage due to requirement to resurvey.

9. Sound velocity profile errors are a critical factor in the reliability of bathymetric surveys using MBES in Malaysian shallow waters. Defined error thresholds provide hydrographers with actionable limits that enable efficient data collection without compromising the quality required for marine navigation and coastal development. On-going attention to environmental changes and strict adherence to SVP correction procedures ensure that mapped surfaces retain the accuracy and reliability demanded for safe and effective maritime operations.



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Semi-Autonomous Multibeam Data Processing Using Caris Hips & Sips Software

Lt Pham Ha Huy

Introduction.

1. Modern hydrography increasingly demands rapid, accurate seabed mapping to support navigation safety, coastal development, and scientific study. Multibeam echosounders (MBES) produce dense bathymetric data, but traditional workflows rely heavily on manual steps - vessel configuration, tide corrections, and filtering - which are repetitive and prone to inconsistency.

Teledyne CARIS' HIPS & SIPS software is widely used to process such data, offering complete tools for data import, georeferencing, uncertainty calculation, and surface generation. A key advancement within this software is the Process Designer module, which allows users to automate processing workflows. Instead of manually executing each stage, hydrographers can design a semi-autonomous pipeline that executes predefined steps with minimal supervision.

This study evaluates the benefits and limitations of using Process Designer for semiautonomous multibeam data processing, benchmarked against traditional manual methods.

Methodology.

2. The experiment utilized MBES data collected by a Norbit iWBMS system mounted on a 24- ft vessel. Positioning and motion were provided by an integrated Applanix INS, with sound velocity measured through a Norbit profiler and validated using a Valeport MiniSVS. The survey achieved IHO Order 1a accuracy, suitable for coastal and harbour approaches.

Data were processed in CARIS HIPS & SIPS through two workflows: -

2.1. **Traditional Step-by-Step Processing** - manual data import, editing, and surface generation.

2.2. **Semi-Autonomous Workflow** - created in Process Designer, integrating major stages such as data loading, geo-referencing, Total Propagated Uncertainty (TPU) computation, CUBE surface generation, and quality control.

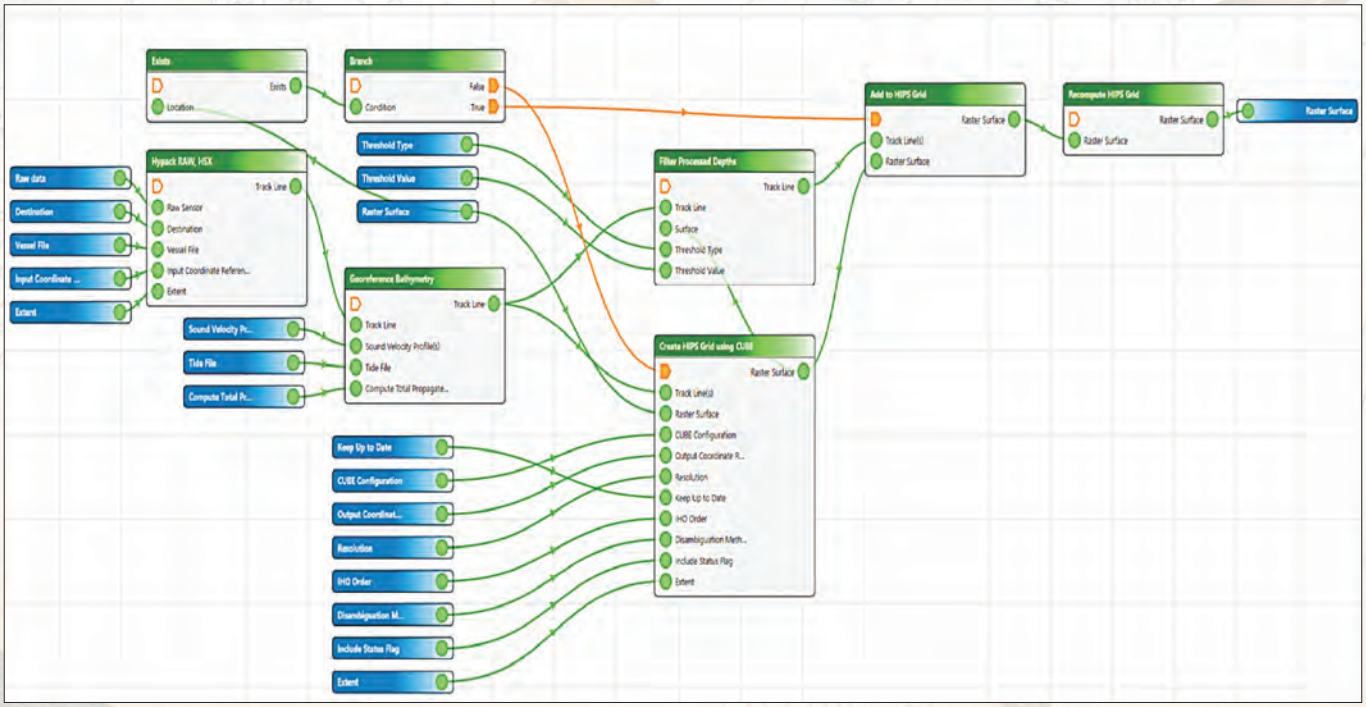


Figure 1: Process Designer Module for CUBE processing

3. The Combined Uncertainty and Bathymetry Estimator (CUBE) algorithm served as the foundation for surface creation. It treats each grid node statistically, estimating both depth and uncertainty using soundings weighted by their error sources. The Parameter Group Optimization (PGO) method was applied to determine the optimal combination of CUBE parameters, tested on representative subsets before applying to the full dataset.

The CUBE and PGO Approach.

4. CUBE converts raw soundings into gridded depth estimates through three key phases:

   4.1. **Assimilation.** – distributes each sounding's uncertainty to nearby nodes.
   4.2. **Intervention.** – creates new hypotheses when soundings deviate significantly.
   4.3. **Disambiguation.** – selects the most probable seafloor representation.

5. CARIS provides three parameter presets: Deep, Default, and Shallow, each tuned for varying depth and seabed conditions. This study found that the Default configuration achieved the best balance between accuracy and noise suppression.

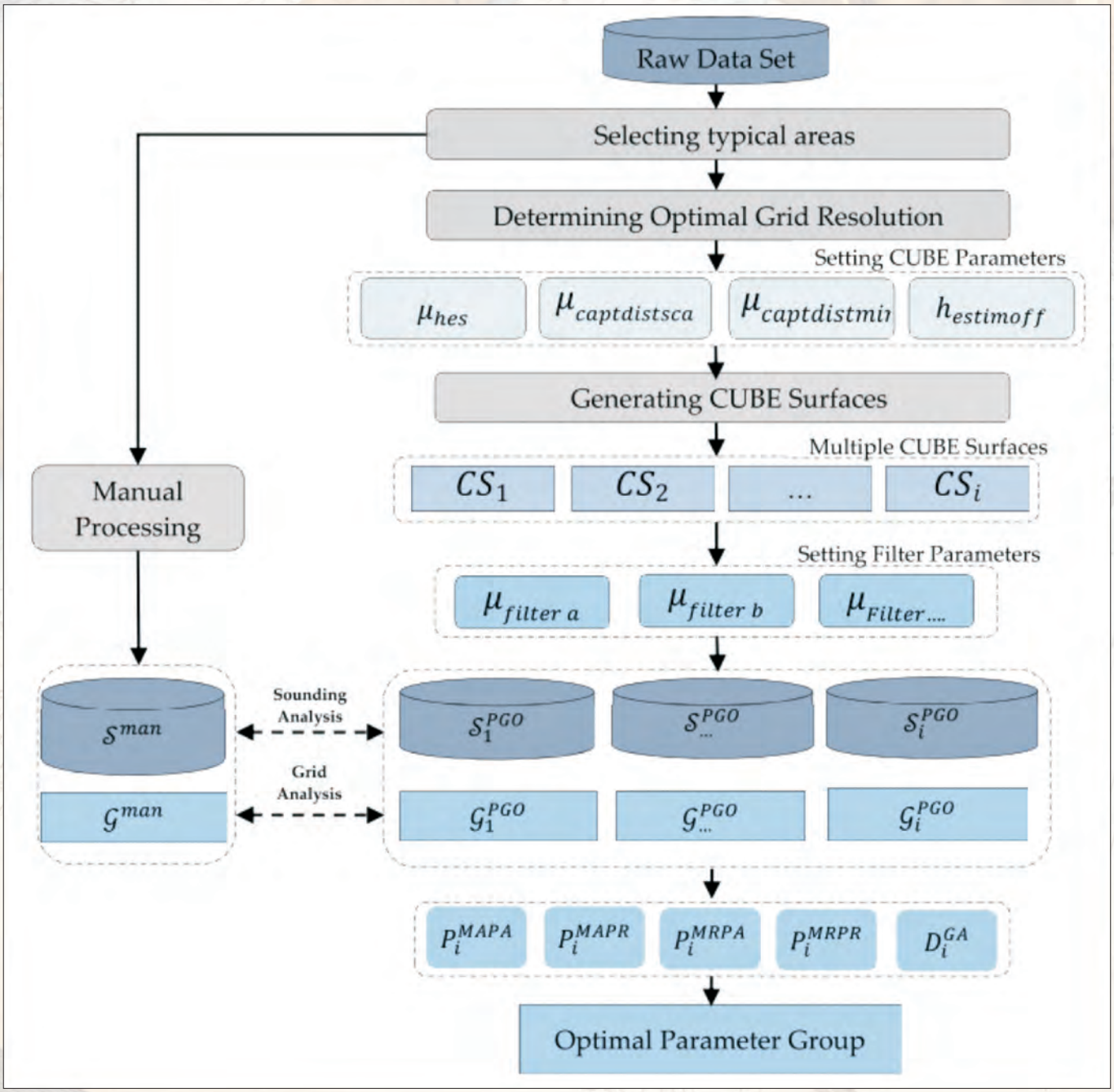


Figure 2: PGO method procedure (AL, 2021)

6. The PGO method systematically varied CUBE parameters (Horizontal Error Scale, Capture Distance, Hypothesis Offset, and Filtering Threshold) to minimize uncertainty and match manual reference surfaces. This process greatly improved consistency and reduced the need for iterative editing.

7. **Experimental Findings**.

7.1. **Data Quality**.

The semi-autonomous workflow produced a 1 m resolution CUBE surface that met IHO S- 44 Order 1a standards, with 98.32 % of nodes within tolerance (mean residual –0.378 m). In contrast, the manually processed surface achieved 95.59 % Order 1a compliance. The CUBE surface displayed slightly higher precision but a modest deep bias along steep slopes due to the algorithm's uncertainty weighting.

7.2. **Time Efficiency**.

Processing time dropped dramatically:

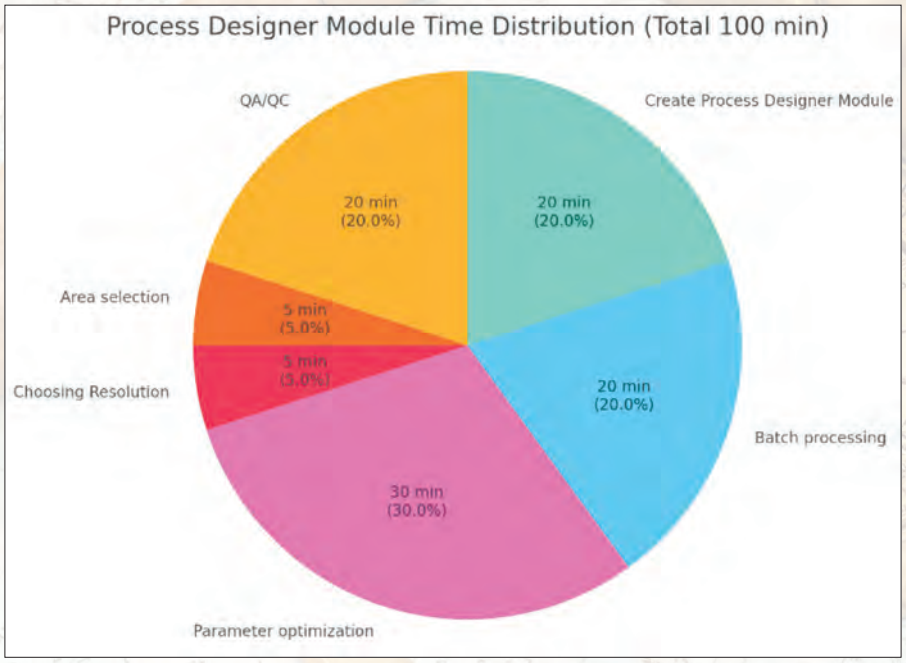


Figure 3: Process Designer Module Time Distribution

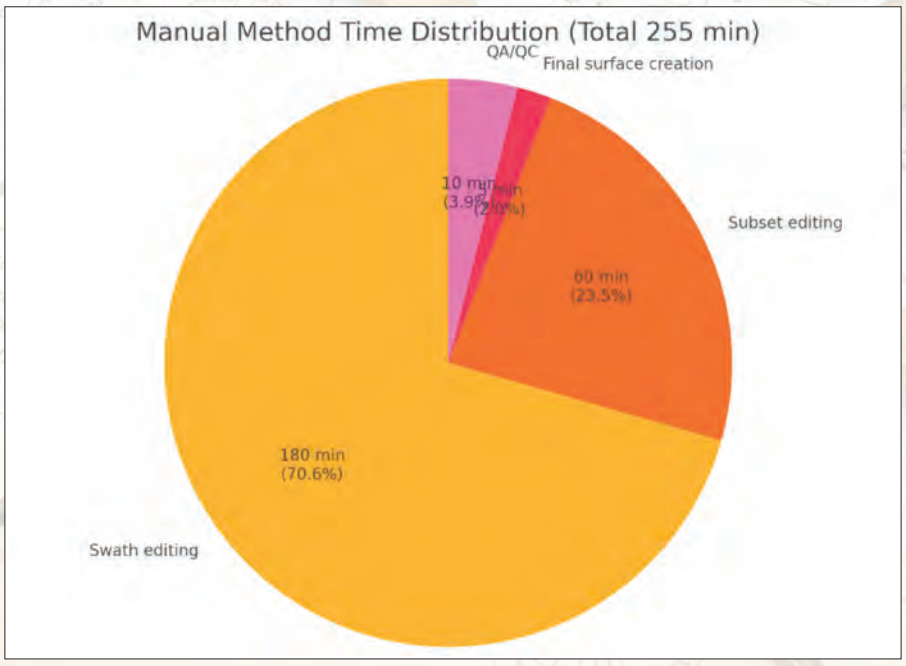


Figure 4: Manual Method Time Distribution

7.2.1. **Manual workflow**: 255 minutes (70% spent on swath editing).
7.2.2. **Process Designer workflow**: 100 minutes total - a 60% reduction.

Automation eliminated repetitive editing, allowing operators to focus on parameter tuning and quality control instead of mechanical tasks.

7.3. **Quality Control (QC)**.

Even with automation, QC remained essential. CARIS QC-Tools and Pydro visualization were used to examine sounding density, uncertainty, and potential spikes. Visual 3D inspection confirmed accurate seabed morphology, with minor artifacts traceable to motion transients. The workflow achieved compliance with the General 1 (Order 1a) hydrographic standard.

8. **Discussion**. The study highlighted several key insights:-

8.1. **Process Designer as a workflow orchestrator**: It automates predefined steps but relies on well-designed logic. Quality depends on the operator's parameter choices and understanding of CUBE behaviour.

8.2. **Human expertise remains crucial**: Automation reduces labor but cannot replace hydrographer judgment. Operators must understand how parameters interact with factors like water depth, seabed type, and sensor accuracy.

8.3. **QA/QC integration is mandatory**: 3D visualization and difference-surface analysis are vital to detect residual artifacts before chart production.

8.4. **Limitations of CUBE**: The algorithm performs excellently in uniform seafloor conditions but may over-smooth or over-deepen steep slopes. Adaptive segmentation-dividing survey areas into morphologically consistent zones with tailored parameters-improves accuracy.

8.5. **Parameter Group Optimization (PGO)**: When combined with Process Designer,

PGO provides an effective semi-autonomous workflow adaptable to various terrains while maintaining IHO compliance.

9. **Conclusion**. The semi-autonomous multibeam processing model using CARIS HIPS & SIPS offers significant efficiency gains without compromising quality. It transforms the hydrographer's role from manual editing to supervisory control and parameter optimization, while ensuring reproducibility and data integrity.

9.1. **Automation benefit**: Over 60 % reduction in processing time.

9.2. **Quality**: Achieved 98 % IHO Order 1a compliance.

9.3. **Scalability**: Suitable for operational adoption in naval and civil hydrographic agencies.

However, full autonomy remains unattainable until algorithms can adapt dynamically to complex seabed morphologies. Future improvements should include machine-learning driven parameter tuning, integration of real-time QC feedback, and adaptive surface modelling that switches presets based on terrain classification.

10. **Recommendations**.

10.1. **Develop Standard Parameter Libraries**: Establish tested CUBE and filter presets for typical seabed types to ensure consistency across surveys.

10.2. **Adopt PGO Tuning Protocols**: Systematically calibrate parameters using representative subsets before full-scale processing.

10.3. **Implement Mandatory 3D QC Checks**: Use uncertainty visualization and cross surface comparison before chart submission.

10.4. **Maintain Balanced Automation**: Use Process Designer for efficiency but retain manual review for steep, irregular, or artifact-prone zones.

10.5. **Invest in Training**: Hydrographers should be proficient in CUBE theory and Process Designer model creation to ensure reliable semi-autonomous workflows.

11. **Key Takeaway**. Semi-autonomous data processing marks a pivotal step toward modernized hydrography. By combining the CARIS Process Designer, CUBE algorithms, and PGO optimization, hydrographic institutions can accelerate data delivery, reduce operator fatigue, and maintain internationally recognized accuracy standards - achieving the ideal balance between automation and expert oversight.



Lt Pham Ha Huy serves in the Viet Nam People's Navy. He successfully completed the Long Hydrography Course (83:047) at the National Institute of Hydrography (NIH) in year 2025. He is currently assigned to a hydrographic survey vessel under the Viet Nam Hydrographic and Oceanographic Department, where he holds the appointment of Executive Officer (Hydrography) [EXO(H)].

Precision in Positioning: A Comparative Study of Network Adjustment and Baseline Processing Techniques

Lt Cdr Nitin Yadav

1. Accurate positioning forms the foundation of modern hydrographic and geodetic surveying. Every stage of hydrographic operations from the establishment of control networks to the final production of nautical charts depends on the reliability of positional data. With the evolution of Global Navigation Satellite Systems (GNSS), surveyors now routinely achieve centimetre-level accuracy using satellite-based techniques. However, the choice of data processing methodology plays a critical role in determining the final quality of derived coordinates. Two commonly adopted GNSS processing approaches are Baseline Processing and Network Adjustment, each with distinct advantages and limitations. This article presents a comparative case study conducted at the National Institute of Hydrography (NIH), Goa, to evaluate the effectiveness of these two methods in establishing horizontal control.

2. The primary objective of the study was to establish four unknown control stations using network adjustment and to compare the resulting coordinates with those obtained through the baseline processing method. The study aimed to assess differences in positional accuracy, internal consistency, and overall reliability, while examining their suitability for hydrographic control extension in accordance with IHO S-44 (6th Edition) standards.

3. To establish a highly accurate reference framework, a 25-hour static GNSS observation was conducted at NIH Rooftop Station I, which served as the origin of the survey. A scientific-grade Leica GS25 GNSS receiver was employed, logging observations at one-second intervals. The station was connected to four International GNSS Service (IGS) reference stations-POL2, BHR3, CUSV, and DGAR-using precise ephemeris data. This configuration ensured a robust geodetic framework and minimized orbit-related uncertainties. The extended observation duration further improved the reliability of the reference coordinates by averaging out short-term atmospheric and multipath effects.

4. Following the establishment of the origin, simultaneous static GNSS observations were carried out at four unknown stations located within the survey area: NCPOR, NOFRA, INS Hansa, and Watch Tower 4 (WT4). These stations were selected based on accessibility, geometry, and relevance to operational hydrographic control. Leica Viva GNSS receivers were deployed at each site, maintaining consistent observation parameters across all stations.

5. All collected data were processed using Leica Infinity software, ensuring a consistent computational environment. Two independent processing workflows were adopted. In the first approach, baseline processing was carried out by computing individual baseline vectors between the reference station and each rover station. This method relies on double-differenced carrier-phase observations to eliminate common errors such as satellite clock bias and atmospheric delays. While baseline processing is computationally efficient and widely used in operational surveys, it treats each baseline independently does not account for network-wide error distribution.

6. In the second approach, a network adjustment was performed by processing all baselines simultaneously within a least-squares adjustment framework. This method incorporates redundancy and statistical optimisation, redistributing observational errors across the entire network to achieve an internally consistent solution. Network adjustment also enables the application of statistical tests such as the Chi-square and F-test, allowing the surveyor to assess the reliability and validity of the results.

7. The comparison between the two methods revealed measurable coordinate differences at all four stations. Horizontal shifts ranged from approximately 8 cm to 50 cm, while vertical differences varied between 6 cm and 44 cm. At the NCPOR station, the differences were minimal, indicating strong agreement between the two methods. This can be attributed to the short baseline length and favourable observation geometry, which allowed baseline processing to effectively cancel systematic errors.

8. In contrast, the NOFRA and WT4 stations exhibited larger horizontal and vertical corrections in the network-adjusted results. These differences highlight the limitations of independent baseline processing, particularly when subtle atmospheric variations, geometric weaknesses, or unbalanced residuals are present. Network adjustment compensated for these effects by redistributing errors across multiple baselines, resulting in improved positional consistency. The INS Hansa station showed moderate corrections, reinforcing the importance of redundancy even in medium-length baselines.

9. From a hydrographic perspective, all derived coordinates met the horizontal accuracy requirements prescribed by IHO S-44, confirming that both methods are operationally acceptable. However, network adjustment consistently produced a more reliable and statistically defensible solution. The ability to quantify uncertainty through covariance matrices, confidence ellipses, and reliability measures provides a significant advantage when establishing permanent ? ? semi-permanent control networks. The study highlights an important operational trade-off. Baseline processing offers speed, simplicity, and efficiency, making it suitable for small-scale surveys, rapid deployments, or temporary control extension. Network adjustment, while requiring greater planning, redundancy, and computational effort, delivers superior accuracy and long-term stability. For projects involving multiple control points, extended survey areas, or integration into national geodetic frameworks, network adjustment is clearly the preferred approach.

10. In conclusion, this case study demonstrates that network adjustment provides a more robust and internally consistent solution for establishing horizontal control in hydrographic surveys. While baseline processing remains a valuable tool for localized applications, network adjustment ensures higher confidence in positional integrity and supports rigorous quality assurance. The findings validate the hypothesis that unknown stations within a survey area can be reliably established using network adjustment techniques, reinforcing their importance in modern hydrographic and geodetic practice.



Lt Cdr Nitin Yadav, an alumnus of the 94 INAC course at the Indian Naval Academy, has served as Assistant Hydrographic Surveyor onboard INS Sarvekshak and Sandhayak. He successfully completed the Long Hydrography Course (83:047) at the National Institute of Hydrography (NIH) in year 2026.

Flexibility in IHO S-44 (6th Edition)

Lt Cdr Rakesh Samal

1. The sixth edition of IHO S-44, Standards for Hydrographic Surveys, represents a major evolution in the way hydrographic surveys are designed and evaluated. One of its most significant features is the emphasis on flexibility, which allows surveys to be tailored according to navigational risk, intended use, and available resources. Unlike earlier, more prescriptive approaches, the 6th edition moves away from rigid rules and instead promotes professional judgment within clearly defined safety limits.

2. At the core of this flexibility is the principle of fitness for purpose. The standard recognises that not all sea areas present the same level of navigational risk and therefore should not be surveyed to the same level of detail. High-risk areas such as ports, harbours, and narrow channels demand very stringent survey standards, while offshore or low-traffic areas may safely be surveyed to less demanding requirements. This approach ensures that survey effort is focused where it is most needed without compromising safety of navigation.

3. Flexibility is also evident in the way survey orders are applied. Although S-44 defines different orders such as Special Order, Order 1a, Order 1b, and Order 2, the 6th edition does not require a single order to be applied uniformly over an entire survey area. Instead, it allows different orders and standards to be used within the same area based on variations in risk and navigational importance. This layered application of survey orders makes surveys more efficient and better aligned with real-world conditions.

4. The flexibility of IHO S-44 (6th Edition) is clearly demonstrated through its technology-neutral approach, which represents a significant departure from traditional, equipment-specific standards. Instead of prescribing the use of particular instruments such as multibeam echo sounders or specific positioning systems, S-44 focuses on the quality of the final survey output. The standard evaluates compliance based on whether required levels of accuracy, uncertainty, and seabed coverage are achieved. This allows surveyors to select technologies that are best suited to local conditions, operational constraints, and available resources. Such an approach encourages innovation and ensures that surveys remain compliant even as new technologies emerge, making the standard globally applicable and future-proof.

5. Another important dimension of flexibility in the 6th edition is the strong emphasis on risk-based survey planning. Survey design is no longer driven solely by fixed rules or traditional practices but is guided by a structured assessment of navigational risk. Factors such as traffic density, under-keel clearance, seabed morphology, and the consequences of grounding are carefully evaluated before determining survey parameters. Based on this assessment, decisions regarding survey order, line spacing, and coverage method can be adjusted to suit the actual level of risk. This approach places greater responsibility on professional judgment but results in surveys that are more relevant, efficient, and aligned with navigational safety requirements.

6. Flexibility is further reflected in the treatment of horizontal and vertical uncertainties within S-44. While the standard specifies strict limits for Total Horizontal Uncertainty and Total Vertical Uncertainty, it allows surveyors freedom in how these limits are met. Different combinations of positioning systems, sensors, calibration methods, and data processing techniques may be used, provided the resulting uncertainties are quantified and shownay comply with the specified thresholds. This acknowledges the practical reality that measurement errors cannot be entirely eliminated, especially in challenging marine environments. Instead, S-44 requires uncertainties to be understood, managed, and transparently reported, ensuring confidence in the final survey data.

7. Environmental and operational conditions also play a critical role in the flexible framework of the 6th edition. S-44 recognises that factors such as sea state, weather conditions, sound velocity variations, and seabed composition can significantly affect survey performance and data quality. Rather than enforcing rigid survey execution requirements, the standard allows surveyors to adapt survey plans in response to these

conditions. This may include modifying survey speed, repeating critical lines, or applying additional quality control measures. However, any such adaptations must be properly assessed and documented so that their impact on data quality is clearly understood. In this way, S-44 balances operational flexibility with the need for transparency and reliability.

8. However, flexibility in S-44 is not unlimited. It is carefully balanced by strong requirements for documentation and quality assurance. Surveyors must clearly record survey methods, limitations, assumptions, and any deviations from standard requirements. This documentation allows hydrographic offices and chart users to evaluate the reliability of the data and apply appropriate caution where necessary. In this way, flexibility is controlled and accountable rather than arbitrary.

9. In conclusion, flexibility in IHO S-44 (6th Edition) reflects a modern and realistic approach to hydrographic surveying. By adopting a risk-based, outcome-focused framework, the standard allows surveys to be adapted to real navigational needs while maintaining safety and data integrity. This balance between professional freedom and responsibility makes flexibility one of the most important and complex



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Assessing the Feasibility of Establishing MSL and CD at Colombo Harbour Using 9.3 Years of Tidal Data and Comparison with Existing MSL and CD

Lt Cdr CD Obeysinghe

Introduction.

1. Mean Sea Level (MSL) is a fundamental reference for hydrographic surveying, coastal management, and maritime navigation. Traditionally, MSL is determined using an 18.6-year tidal cycle to account for long-term tidal variations. However, Sri Lanka currently relies on an MSL and CD references which has given by UKHO long time back. This study assesses the feasibility of establishing MSL and Chart Datum (CD) at Colombo Harbour using own (Sri Lanka Navy Hydrographic Service) 9 years of tidal dataset (2015–2024) and evaluates whether this shorter period provides a reliable alternative to the conventional 18.6-year cycle.

2. The research involves statistical analysis of the 9.3 years of tidal dataset to identify trends, seasonal variations, and deviations from the existing MSL and CD. This research tests a methodology giving scientific evidence as to whether Sri Lanka can use a shorter tidal observation period but with hydrographic reliability. The primary objective of this research is to assess the feasibility of establishing MSL with reasonable accuracy by using 9.3 years of the tidal data set at Colombo Harbour. The secondary objective is to revalidate the existing MSL and CD based on the latest tidal data.

Methodology.

3. This study will make use of a mix of qualitative and quantitative methodologies and the scope of the study will be as follows: -

3.1. Analyse 9.3 years of tidal dataset from Colombo Harbour to assess variations in MSL.
3.2. Compare the results with existing MSL values.
3.3. Determine whether a 9.3 year dataset is sufficient for reliable MSL estimations.
3.4. Recommendations on whether shorter datasets can be reliably used for MSL/CD determination in Sri Lankan waters (Specifically for Colombo Harbour).

4. The primary data will be 9.3 years of tidal dataset of Colombo Harbour (Colombo harbour is located in a Semi-diurnal, Micro tide region) and details about existing MSL and CD values. Tidal data for the period of 9,3 years obtained by the SLNHS and they have collected these data using Tide pole located at Colombo harbour. In addition to that information collected from various sources such as previously published research articles, Web documents, books and journals related to the subject also referred.

Analysis.

5. MSL can be established by considering the various effects of astronomical conditions that have influenced periodically.

5.1. 25 hours of observation
5.2. 39 hours of observation
5.3. 29 days of observation
5.4. 1 year of observation
5.5. 18.6 years of observation

6. Traditionally, MSL is determined using an 18.6-year tidal cycle to account for long-term tidal variations. The reason for conducting of observation over 18.6-year period is the Regression of the nodes.

Collaboration with the Sun causes these nodes to move toward the western side of Earth at a pace of around 18.6 years for each complete cycle. Because of this, the orientation of the Moon's orbit changes gradually. The fundamental reason for selecting 9.3 years (Half of 18.6 years) is the repetitive nature of this nodal cycle every after 9.3 years of period as these nodes are revolving around the Earth.

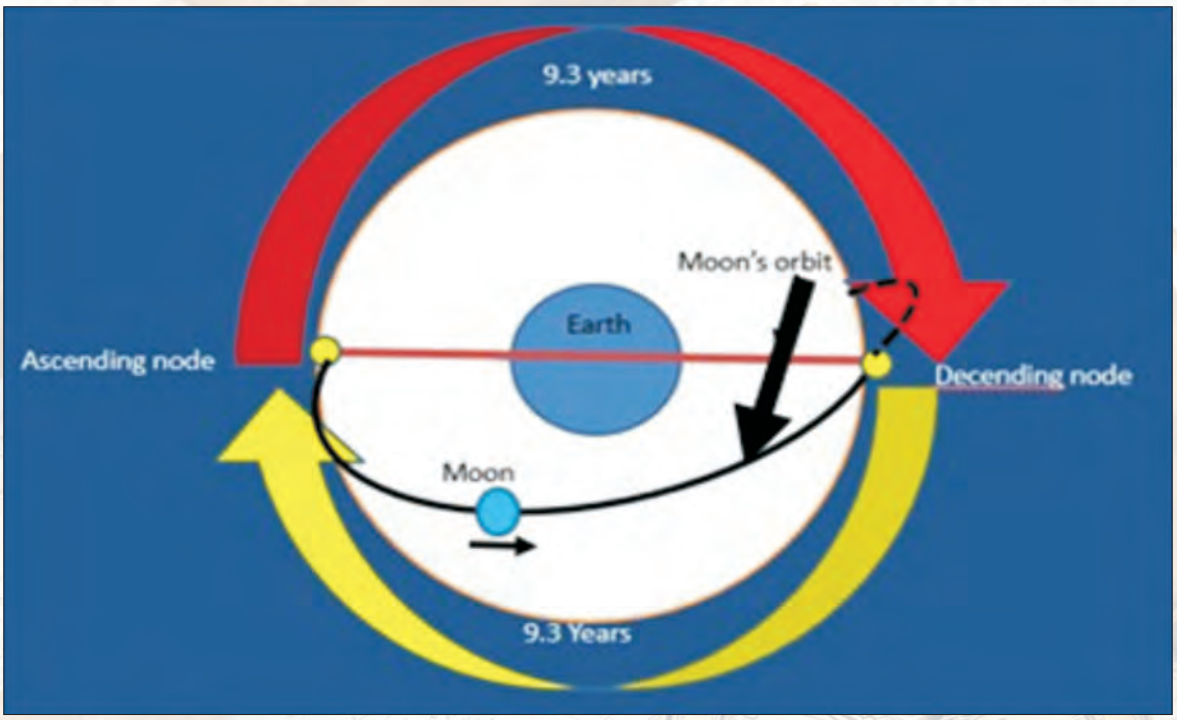


Figure 1: The nodes movement around the Earth (Top view)

7. The MSL value for the entire 9.3 years of observation is coming as 1.734 m as per the analysis of the data. , The existing MSL value established in 1930's by UKHO for the Colombo is 1.5448 m. The difference between the existing MSL value at Colombo and the calculated value for the same area by using new data is 0.1892 m. Sri Lanka is an island that experiences Semi-diurnal micro tides and the range of tide is typically, about 0.6 m in average meteorological conditions. Though the 0.1892 m is a small height in terms of safety of navigation, compared to the tide range experienced in the area of concern, the MSL has increased above 30% of its existing value over the period.

8. The Lowest Astronomical Tide (LAT) observed during the observation period is 1.140 m (September 2016). As stated in AMHS Vol. II, the Chart Datum (CD) should not be established more than 0.3 ft (0.091 m) above LAT. However, some hydrographic offices directly use LAT as the CD. Considering the observed LAT, if a new CD is established, it should not be less than 1.049 m from the established Benchmark (BM) at Colombo (1.140 m – 0.091 m). Therefore, the new CD is to be established within 1.049 m – 1.140 m from the established BM at Colombo. The existing CD for Colombo is 1.1648 m. Based on the findings of the study, the minimum and maximum differences between the new and existing CDs are 0.0248 m (1.1648 m – 1.140 m) and 0.1158 m (1.1648 m – 1.049 m) respectively. As the sea level is rising, using the existing CD allows a greater safety margin, and that margin is negligible compared to navigational requirements. Hence, changing the CD based on the new findings will not have much impact on navigation.

Causes leads to the Deviation.

9. **The Cyclic Variation of the Inclination of Lunar Orbit**. The effect of the Moon's gravitational force on the Earth's surface varies over an 18.6-year of period due to Regression of the Nodes. The effect of the incident can be divided into components. As the Nodes are moving westward around the Earth, the orientation of the Lunar orbit shifts over time, causing changes in the gravity of the Moon towards the Earth. This is one component. The orientation of the Lunar orbit will repeat after of a 9.3-year period. In that perspective, the tide generating force by the Moon is to be the same as last 9.3 years of period. However, there is another effect caused by during this 18.6 years of period. The Moon's orbit is tilled about 50 9' to the plane of Earth's equator, but it's inclination to the Earth's orbit has changed over time and it is vary between 180 18' and 280 36'. This

nodal cycle affects the inclination of the Lunar orbit, which it modulates the amplitude of the tides. In other word, it takes 18.6-year of period for the tilt of the Moon's orbit to oscillate between its extreme values, meaning from one maximum (±28°36') to the next maximum (±28°36'). Imagine that the lunar orbit is now at its northernmost or southernmost extreme of ±28°36'. It will reaches ±18°18' in 9.3 years. In next 9.3 years, again it will reach the position of ±28°36. However, other than these extreme positions, if we start at any given position, the tilt of the Moon's orbit will not touch both maximum and minimum inclination during a 9.3-year of period. Suppose, if we start counting at the Mid-point (230 27') of lunar orbit inclination range, in a 9.3-year of period, it will reach its maximum/ minimum inclination and return back to its same inclination of 230 27' only. Therefore, a 9.3-year period may not account for all the possible effects due to changes in the inclination of the lunar orbit. Analyzing this entire cycle will only enable if we observe the tide for a period of 18.6-year only.

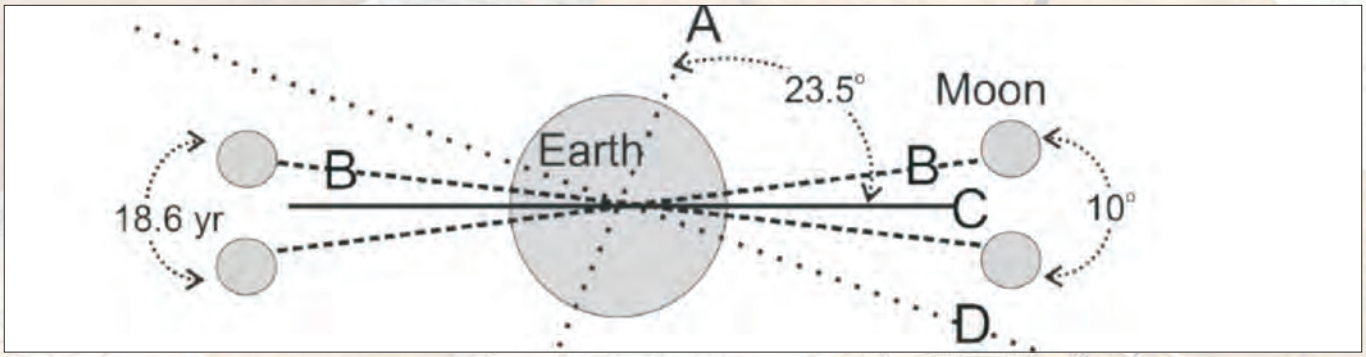


Figure 2: Lunar Declination variation over 18.6 years

10. **Non-astronomical Influences**. MSL is not only affected by astronomical factors, but some other factors like Plate tectonic activities, global sea level rising due to melting of glaciers at the poles, and meteorological conditions also influence. These are mostly random in nature and difficult to predict.

10.1. **Tectonic activities**. Earthquakes, seduction, uplift and subsidence are examples of tectonic activity that can impact the MSL. It causes changes in the earth's land, shifting up or down.

10.2. **Melting of Glaciers at Poles**. Melting glaciers are one of the main contributors to global sea level.Melted glaciers and ice caps cause water to be released to the oceans which increases the world's total seawater. As per the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report (2021), the mean rate of sea level rise was 1.3 (0.6 – 2.1) mmyr-1 from 1901 to 1971. From 1971 to 2006, it increased by 1.9 (0.8 – 2.9) mmyr-1 and from 2006 to 2018, it has drastically increased by 3.7 (3.2 – 4.2) mmyr-1 causing greater than ever in history. Human activities are very likely what caused these increases starting as far back as 1971.

10.3. **Meteorological influences**. These effects are typically highly irregular, short to medium term effect and have relatively less impact on long term tide variations. Changes in the atmospheric pressure, winds, evaporation and precipitation pattern in the area, river discharge and storms.

Conclusion.

11. This paper investigate the feasibility of establishing MSL and CD at Colombo harbour, by using of 9.3 years of the tidal data that was gathered from January 2015 to April 2024. During the course of study, it is observed that the 9.3 years of tidal data set is not suitable for the determining all the possible effects due to changes in the inclination of the lunar orbit. It will be accounted by the period of 18.6 years only. 9.3 years of tidal data set at Colombo harbour, shows more than 30% of increment compared to the existing MSL value. Hence, it is proves that periodic updates to MSL are necessary rather than relying on existing datum.



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Section - 2

Shared Horizons

Hydrography: Charting The Blue Future – Leadership and Lessons from a Beach Gradient Survey off Madhavpur

Lt Cdr C Pradeep

1. Hydrography is often perceived as a technical discipline defined by soundings, profiles, and charts. However, when conducted in complex operational environments, it transforms into a demanding exercise in leadership, coordination, and situational awareness. One such defining experience for me was while serving on board INS Sutlej. I was the Officer-in-Charge (OiC) of a detached survey team during the Beach gradient survey off Madhavpur, Gujarat, conducted at a time when Op Sindoor was in progress and national security concerns were at the forefront. What was planned as a routine coastal hydrographic task evolved into a challenging operation carried out under heightened border tensions, intense public attention, and severe time and environmental constraints - yet it reinforced the crucial role hydrography plays in charting India's blue future?

Operational Backdrop: Surveying Amidst Tensions.

2. The timing of the survey coincided with Op Sindoor, a period marked by elevated alertness and heightened sensitivity along the coast. The presence of a naval warship operating close to shore and deploying multiple assets such as Survey Motor Boats, RHIBs, Gemini crafts, and helicopter, naturally drew the attention of local civilians.

3. For many coastal residents, unfamiliar with hydrographic operations, the sight of military assets being deployed so close to the shoreline created a strong perception that preparations for war were underway. As the beach gradient survey required sustained activity close to inhabited areas, with survey personnel operating openly on the beach, this added a unique layer of complexity to the task. Managing civilian curiosity, misconceptions, and media interest, while maintaining operational focus and security, became as critical as the survey itself.



Figure 1: Beach Gradient Survey: A Task at the Land-Sea Interface

4. Beach gradient surveys are inherently demanding. They are conducted at the narrow interface between land and sea, where tidal windows are short and environmental conditions change rapidly. In Madhavpur, the task primarily involved measuring the beach slope and near shore gradients, a vital input for coastal studies, amphibious planning, and safe navigation.

5. The survey spanned five days, with the major workload falling on the deployed beach survey team, operating entirely exposed to the public view. As OiC of the detached team, ensuring accuracy, safety, discipline, and morale under these circumstances was a constant responsibility.

Helicopter-Borne Survey Operations: Precision under Constraint.

6. One of the defining aspects of this operation was the method of deployment. Due to the absence of a suitable helicopter landing site during high water, all survey activity had to be compressed within narrow tidal windows.

7. Each day, the team was inserted by helicopter during the morning low water and extracted at the second low water before sunset. This imposed strict time discipline and demanded flawless coordination between aircrew, ship, and survey personnel. On certain days, operational constraints required winching down the team, to access the survey area. These moments underscored the unique nature of hydrographic operations - where precision surveying intersects with military aviation and seamanship. Any delay or miscalculation could have resulted in incomplete profiles or compromised safety. Yet, the team adapted seamlessly, demonstrating professionalism and confidence under pressure.



Figure 2: Helicopter-Borne Survey Operations

Human Factors, Media Attention and Operational Fatigue.

8. Op Sindoor had heightened public and media interest in naval activity. The visible nature of beach gradient surveys meant that our task attracted attention not only from locals but also from media personnel seeking operational snippets. Balancing operational security, public perception, and survey efficiency became an additional challenge. For the survey team which was already engaged in physically demanding work under the sun. The added pressure made an already tiring task even more tedious and mentally exhausting. Despite these factors, the team maintained focus, adhered to timelines, and ensured data integrity. Their resilience and commitment were a testament to the ethos of hydrographic professionals.

Leadership and Completion of Task against the Odds.

9. Conducting and completing a detached survey during a period of national emergency reinforced key leadership lessons such as clear communication, adaptability, and trust in the team. As OiC, coordinating across multiple agencies while safeguarding the welfare of personnel remained paramount. Against all odds such as operational constraints, environmental challenges and civilian perceptions the survey was completed successfully. Accurate beach profiles were established, objectives met, and the team recovered safely after each sortie.

Hydrography and the Blue Future.

10. This experience at Madhavpur reaffirmed that hydrography is far more than a technical discipline. It is a quiet enabler of national maritime capability. Each beach gradient measured contributes to coastal resilience, informed planning, and safer operations i.e. pillars of India's growing Blue Economy. Even amid national tension, hydrographic tasks must continue - often unnoticed, yet indispensable. The Madhavpur beach gradient survey was a defining professional experience. One that blended hydrography, leadership, and operational realism. It demonstrated how, even in the most challenging circumstances, hydrographers continue to chart the seas with precision, perseverance, and purpose. Behind every contour line lies not just data, but dedication and sometimes, a story of service carried out under extraordinary conditions.



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Battling The Swells: A Beach Gradient Survey Experience

Nakka Chiranjeevi, AVR SEA (HY)

Introduction.

1. Hydrographic surveying plays a crucial role in coastal management, navigation safety, and marine infrastructure development. One important aspect of hydrographic operations is beach gradient surveys, which help determine the slope and morphological characteristics of coastal beaches. These surveys demand a combination of technical expertise, physical endurance and teamwork, when operations are conducted in challenging marine environment.

2. One such professional challenge was encountered during a beach survey conducted at Madhavpur, Gujarat. During my survey experience, the presence of strong swells transformed a routine operation into a physically demanding and mentally challenging task. Each stage of the survey from landing to setup as directly impacted by the relentless motion of the sea.



Figure 1: Beach Gradient Survey

Study Area and Environmental Conditions.

3. The survey was conducted along an open sandy coastline characterized by a gentle to moderate beach slope. The operational period experienced continuous incoming swells with variable height and frequency, influenced by offshore wind patterns and prevailing sea state.

4. These swells generated strong orbital motion within the surf zone, producing both horizontal force and rotational water movement. Such conditions created instability for personnel and equipment, particularly during nearshore operations and data collection activities.

5. **Reaching the Shore: A Stuggle against Swells**. Approaching the beach was far more difficult than anticipated. The swells rose unpredictably, lifting the gemini craft and dropping it with force, making it challenging to maintain misjudgement could push the vessel sideways or pull it back into deeper waters. As I attempted to step off the boat, maintaining balance became extremely difficult. The force of the incoming

waves frequently disrupted footing, and at times, the water motion caused involuntary rotation of the body. Reaching the shore safely required multiple attempts, careful coordination, and constant alertness under rapidly changing conditions.

Landing Operations: Fighting Instability.

6. Once near the shoreline, the challenges intensified. The continuous movement of the waves made it difficult to secure the gemini and unload equipment. Each incoming swell would push the team backward or alter body posture, forcing repeated pauses to regain stability.

7. During equipment handling, the water currents occasionally tilted my body unexpectedly, making it difficult to maintain control while carrying equipment. Even simple movements such as stepping forward or holding position became physically demanding tasks, requiring strength, balance, and precise timing.

Equipment Deployment and Setup challenges.

8. Accurate beach gradient surveys depend on stable and properly aligned equipment, including levelling instrument and GNSS systems. However, the swash zone conditions posed significant challenges.

9. The wet, shifting sand reduced tripod stability, causing instruments to sink or tilt slightly. Repeated adjustments were necessary to achieve proper alignment. The constant intrusion of waves further interrupted the setup process, forcing frequent pauses and rechecks.

10. Even after positioning the equipment, maintaining accuracy remained difficult due to subtle ground movement caused by receding water. Handling equipment under these conditions required continuous effort, as incoming swells exerted sudden force while outgoing water currents affected footing and balance.



Figure 2: Spot Sounding - Beach Gradient Survey

Survey Execution: Maintaining Precision in Motion.

11. The survey was conducted using standard beach profiling techniques, with measurements taken along transects perpendicular to the shoreline. Elevation data points were collected at regular intervals from the backshore to the lowest accessible depth, in accordance with IHO standards.

12. Field execution was physically demanding. Walking along the gradient line was not straightforward - the receding water pulled at the legs, while incoming swells disrupted balance. At several instances, the force of the waves caused involuntary rotation of the body, making it difficult to maintain a straight survey line.

13. Despite these interruptions, maintaining precision was critical. Each observation required concentration, coordination, and repeated verification to ensure data reliability under unstable conditions.

Environmental Exposure and Operational Endurance.

14. Survey operations commenced in the early morning hours and continued until late evening to maximize productivity within the available working window. The absence of any shelter along the survey area exposed the team to continuous environmental stress.

15. Prolonged exposure to intense sunlight resulted in significant heat stress and physical fatigue. The lack of shaded areas limited opportunities for rest, while constant contact with saline water further intensified discomfort. The combined effect of strong solar radiation and saltwater exposure led to skin irritation and noticeable darkening over time.

16. Despite these physically demanding conditions, the survey continued with determination. Maintaining focus and efficiency required patience, endurance, and mental resilience.

Physical and Mental Challenges.

17. Beyond the technical difficulties, the survey tested both physical endurance and mental strength. Continuous exposure to wave motion drained energy, while maintaining concentration under such dynamic conditions proved equally challenging.

18. However, these hardships fostered resilience. The experience emphasized the importance of teamwork, communication, and composure under pressure.



Figure 3: Beach Gradient Survey

Recommendations.

19. **Need for Improved Equipment Handling**. Future beach gradient surveys could benefit from specialised waterproof equipment cases and portable survey setups to minimize risk during landing operations.

20. **Integration of Advanced Survey Technology**. Modern technologies such as Unmanned Surface Vehicles (USVs), Drone-based photogrammetry, GNSS-enabled survey equipment can significantly enhance efficiency and safety during coastal surveys.

Conclusion.

21. The beach gradient survey at Madhavpur, Gujarat, demonstrated the practical challenges associated with coastal hydrographic operations. Despite heavy swell conditions and equipment handling difficulties, adherence to established standards, combined with teamwork and perseverance, ensured successful survey completion.

22. This field experience highlights the importance of adaptability, proper survey methodology and operational coordination in conducting hydrographic surveys in challenging coastal environments.

23. With the integration of advanced technologies and improved operational practices, future beach gradient surveys can be conducted with greater efficiency, accuracy and safety.



Nakka Chiranjeevi, AVR SEA (HY) from INS Sutlej

Tense Encounter During Hydrographic Survey – Middle Andaman (West Coast)

Cdr C.K. Singh (Retd.)



1. During a hydrographic survey operation on the west coast of Middle Andaman onboard INS Nirupak in early 2020, an area traditionally inhabited by the Jarawa tribe, there was requirement for installing a tidal pole on the shoreline to obtain accurate tidal observations.

2. While the tide party was in the process of rigging the tide pole, the team was suddenly confronted by two Jarawa tribesmen in a country boat. They appeared aggressive and pointed arrows towards the tide party, creating a highly tense and unpredictable situation.

3. Efforts were immediately made to de-escalate the situation by involving Forest Department representatives to initiate dialogue with the Jarawas. However, initial attempts at negotiation did not yield positive results. Considering the safety of personnel, a reinforcement team was promptly dispatched from the ship to the shore to stabilize the situation and provide support.

4. After several hours of calm communication and confidence-building measures, the tension gradually eased and the situation was brought under control. Remarkably, the interaction later turned positive, and as a gesture of goodwill, the Jarawa tribesmen offered a hunted deer to the team - reflecting the restoration of mutual trust and respect.

5. This incident remains a strong reminder of the challenges and responsibilities involved while conducting survey operations in sensitive and protected tribal regions.



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Crossing Coast – Makar's Saga Across the Oceans

Lieutenant Commander Shibin Babu

1. For what was meant to be a crisp, well-timed departure for the International Fleet review-2026, it turned into a two and a half hour master class in "naval flexibility." First came engine control defects, then a stubborn switchboard, and finally a sulking sewage treatment plant-because why suffer one defect when three can join the party? Still, once the gremlins were banished, Makar did cast off with the sort of optimism only a seasoned hydrographic vessel can muster.

2. The onward passage through the Arabian Sea hugged routine-until it wasn't. Off Kochi, the ship encountered a veritable metropolis of fishing craft, all darting about with the confidence of road traffic in peak office hours. However, Makar glided through this chaos with the practiced patience of a hydrographer fathoming uncharted waters. We entered Kochi for a day to embark hydrographic stores-a pit stop that offered the brief illusion of calm before the voyage's true theatrics began.

3. When the ship casted off from Kochi, the low pressure brewing in the southwest Indian Ocean made itself known. As she approached the funnel of Gulf of Mannar, long and lofty swells began slamming the ship beam-on. As Officer of the watch in Dondra Head TSS, my heart skipped a beat when a call from Survey Ops room brought to my knowledge, the uprooting of fairsheet plotter from its securing arrangement, fortunately, without incurring any major damages. Just as the gloomy news of the plotter had begun to wane off, the Quartermaster would report an unresponsive wheel, only for me to realize that the thundering waves had gotten the best of starboard steering ram control relay which was found to be uprooted. The engine room crew, toiled at the aft steering post unflustered, as the twin hulled catamaran rolled, pitched, and bucked in the tall waters. The crew-seasoned mariners with spirits as sturdy as their ship-addressed the defect within a short span of time, restoring the ship's course toward Chennai.

4. The seas turned ferocious as the ship rounded Sri Lanka. Her speed dropped from a confident 12 knots to a reluctant 7, her bows pounded by towering waves and sea spray that engulfed the focsle sweeping across the bridge. Yet she pressed on. Designed primarily for littoral operations, this compact catamaran now proved that she could stare down the wrath of the sea gods without flinching. For the crew, those hours skirting Sri Lanka became an unforgettable chapter-equal parts challenge, camaraderie, and awe.

5. North of Trincomalee, signs of mercy finally appeared. Clear patches of waterworn fishing nets offered brief relief from the earlier chaos. Then, as though Lord Varuna himself acknowledged the perseverance of the small but mighty Makar, the skies began to lighten. Seas calmed. And with a gentle rumble of approval, the ship's propellers regained their zest, restoring her planned passage speed. The crew had earned their respite, and they savored every moment of it.

6. The ship eneterd Chennai after days of battling unruly seas, the quiet break ashore was nothing short of rejuvenating. Here the officers enjoyed a warm and lively deck reception hosted by INS Sarvekshak, mingling with hydrographers from Sarvekshak, Darshak, Sutlej, and, of course, Makar. It was a rare gathering, a buoyant meeting of people who spent much of their careers measuring oceans but seldom found time to share stories on land.

7. With spirits refreshed, Makar sailed towards Visakhapatnam and reached the anchorage in the early hours of 13 February and was assigned a berth in the lead column. Hydrographic survey motorboats were standing by to assist ships in anchoring within 100 yards. But "Trailblazer in Surveying" is not a tagline earned lightly. Makar dropped anchor with pinpoint precision within a mere five meters, quietly demonstrating the impeccable skill of the Indian Naval Hydrographic Department.

8. Between 13 and 19 February, the ship remained at anchorage, rehearsing daily for the International

Fleet Review. Each day she adjusted her head using engines, swinging around her anchor akin to a trained dancer poised for a grand performance. On 18 February, during the Presidential Fleet Review, the crew of Makar stood tall in immaculate whites, manning the ship's side, their synchronized "Teen Jais" resounding across the water as the Presidential Column steamed past. Later, at sunset, the anchored fleet lit up in a stunning display off RK Beach-an ethereal spectacle that defied description.

9. To cap off these ceremonial duties, the ship sailed into the Naval Harbour of Visakhapatnam on the morning of 20 February for operational turn around. She was to begin her return passage the next day-until the persistently loyal low pressure system reappeared, delaying the departure once again. The sea gods, it seemed, were not done toying with the ship that had dared to defy their earlier tantrums. However, this time the reappearance of the low pressure system turned out to be a blessing in disguise, as it afforded the ship the unique privilege of hosting the Chief Hydrographer onboard. It was followed by a joyful gathering of hydrographers of all participating Survey ships onboard Nirdeshak in the honour of Chief Hydrographer, which turned out to be the perfect opportunity to rekindle bonds, reminisce shared memories and revel in the spirit of bonhomie.

10. Finally, on 24 February after waiting out the storm, Makar set out, this time with fervent prayers for calm seas and for once, the sea gods obliged wholeheartedly. The waters remained blissfully placid and around Dondra Head all the way to Kochi. After the turbulence of the onward journey, this serene return felt like a gracious apology from the ocean. Makar stopped for a brief pause at Kochi on the 01st of March to refuel for the final leg of passage to her homeport. While leaving harbour the following day, the ship greeted her home bound fellow survey ship Ikshak at the mouth of Kochi channel with a shared sense of gratitude felt in the success of the prestigious IFR 26 deployment.

11. Exactly after a month after casting off from Karwar, INS Makar returned to her base port. She arrived not just as a ship completing a deployment, but as a vessel carrying a month's worth of memories of heavy seas conquered, defects defeated, friendships strengthened, pride reaffirmed, and horizons crossed. Her twin hulls, having sliced through tempest and tranquility alike, bore testimony to the resilience and professionalism of her crew.

12. The saga of Makar across the oceans is not merely a record of miles steamed or events attended. It is a celebration of grit wrapped in humor, of precision hidden beneath simplicity, of a small ship with a large heart proving-yet again-that courage on the seas is measured not by tonnage, but by tenacity.

13. And so, Makar's voyage stands complete, a chapter inked with salt spray, laughter, challenge, and triumph. A tale worth telling. A journey worth remembering.









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Struggle of Hydrographic Sailors

Ravish Pandey LS (HY), PO 'Q' (HY)

1. Hydrographic sailors play a crucial yet often overlooked role in ensuring safe navigation and maritime operations. Their work involves surveying oceans, seas, rivers, and coastal areas to produce accurate nautical charts. Despite their importance, the life of hydrographic sailors is filled with numerous challenges and hardships that demand resilience, dedication, and technical expertise. One of the primary struggles faced by hydrographic sailors is the harsh and unpredictable marine environment. They often operate in extreme weather conditions, including rough seas, storms, and intense heat or cold. These conditions not only make their work physically demanding but also increase the risk involved in conducting precise surveys. Long hours on deck handling equipment such as echo sounders, GPS systems, and sonar devices require constant attention and endurance.

2. Another significant challenge is the prolonged separation from family. Hydrographic missions can last for weeks or even months, during which sailors remain at sea with limited communication. This isolation can lead to emotional stress and requires strong mental resilience. Missing important family events and responsibilities adds to the personal sacrifices they make in service of their duty. Technical complexity is also a major aspect of their struggle. Hydrographic surveying demands high accuracy, and even minor errors can lead to serious consequences for navigation safety. Sailors must be well-trained in operating advanced instruments, data processing systems, and software. Continuous learning and adaptation to new technologies are essential, making their job intellectually demanding as well.

3. In addition, hydrographic sailors often work in remote and less accessible regions. Survey areas may include uncharted waters, shallow coastal zones, or areas with underwater hazards. These conditions make operations more challenging and sometimes dangerous. Limited resources and logistical difficulties further complicate their tasks. Despite these struggles, hydrographic sailors remain committed to their mission. Their work ensures safe passage for ships, supports naval operations, aids in disaster management, and contributes to scientific research. Their dedication often goes unnoticed, yet it forms the backbone of maritime safety and development.

4. In conclusion, the life of a hydrographic sailor is a blend of physical hardship, emotional sacrifice, and technical challenges. Their struggles highlight their courage and professionalism. Recognizing and appreciating their contributions is essential, as they silently serve to make the seas safer for everyone.



Ravish Pandey LS (HY), PO 'Q' (HY) – 83:650 trainee of NIH, Goa

Section - 3

The Deep Dive

Blueprint of the Digital Sea: Why Hydrography Matters More Than Ever

Vice Admiral SK Jha, PVSM, AVSM, NM (Retd)

Abstract.

1. The transformation of maritime navigation and ocean governance in the twenty-first century is being driven by the convergence of high-resolution hydrographic science and the International Hydrographic Organization's S-100 Universal Hydrographic Data Model. While S-100 represents a structural shift in marine geospatial standardization, its effectiveness depends fundamentally on hydrographic measurement. This paper explores the interdependence between hydrography and the S-100 framework, examining how hydrographic data forms the foundational intelligence layer that enables dynamic navigation systems, e-navigation, marine spatial governance, and the future development of digital ocean ecosystems. Through institutional analysis, operational insights, and applied examples, the study demonstrates that hydrography is not merely a contributor to S-100 but the primary generator of authoritative marine spatial knowledge.

Introduction: From Nautical Charts to Digital Oceans.

2. For centuries, hydrography has served as the silent guarantor of maritime safety. Early navigators relied on rudimentary depth measurements and hand-drawn coastal sketches, gradually evolving into systematic surveys and printed nautical charts. Although technologies advanced - from lead lines to sonar, from sextants to satellites - the fundamental objective remained constant: to understand the sea well enough to enable safe passage.

3. In the twenty-first century, however, the maritime domain has expanded far beyond navigation alone. Oceans are now central to global trade, offshore energy development, environmental stewardship, climate research, and marine spatial governance. This expansion has placed new demands on marine geospatial information. Static charts, updated periodically, are no longer sufficient for a world that operates in real time.

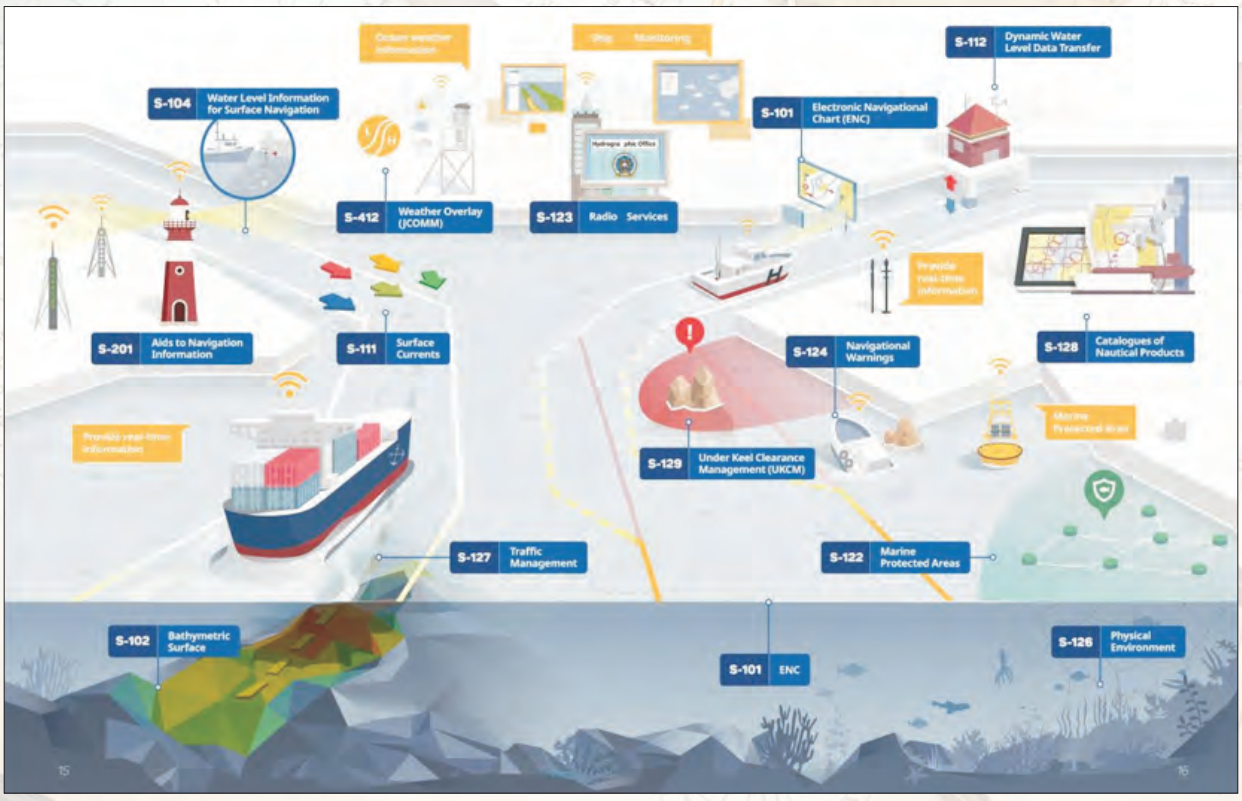


Figure 1: Image showing IHO S-1xx concept

4. It is within this evolving landscape that the International Hydrographic Organization introduced the S-100 framework, formally recognized as the Universal Hydrographic Data Model. S-100 represents more than a technical revision of charting standards; it embodies a conceptual transition from product-based cartography to data-driven ocean intelligence. Yet the sophistication of S-100 depends on the quality, reliability, and continuity of hydrographic measurement. The digital architecture cannot function without accurate physical observation. Hydrography supplies the measured reality that S-100 structures, standardizes, and distributes.

The Structural Evolution of Marine Data: Understanding S-100.

5. The S-100 framework was developed to address the limitations of earlier Electronic Navigational Chart standards and to align marine geospatial data management with modern international geographic information standards, particularly the ISO 19100 series. Earlier systems were primarily chart-centric, designed to reproduce traditional navigational charts in digital form. While effective for electronic display, they lacked flexibility for integrating diverse and dynamic datasets.

6. S-100 introduces a fundamentally different approach. It separates data content from data encoding, enabling the same authoritative dataset to be reused across multiple applications without redundancy. The framework is extensible, allowing new product specifications—such as S-101 for next-generation electronic navigational charts and S-102 for bathymetric surface models—to coexist within a unified structure. Its architecture accommodates gridded data, imagery, time-dependent variables, and three-dimensional spatial representations.

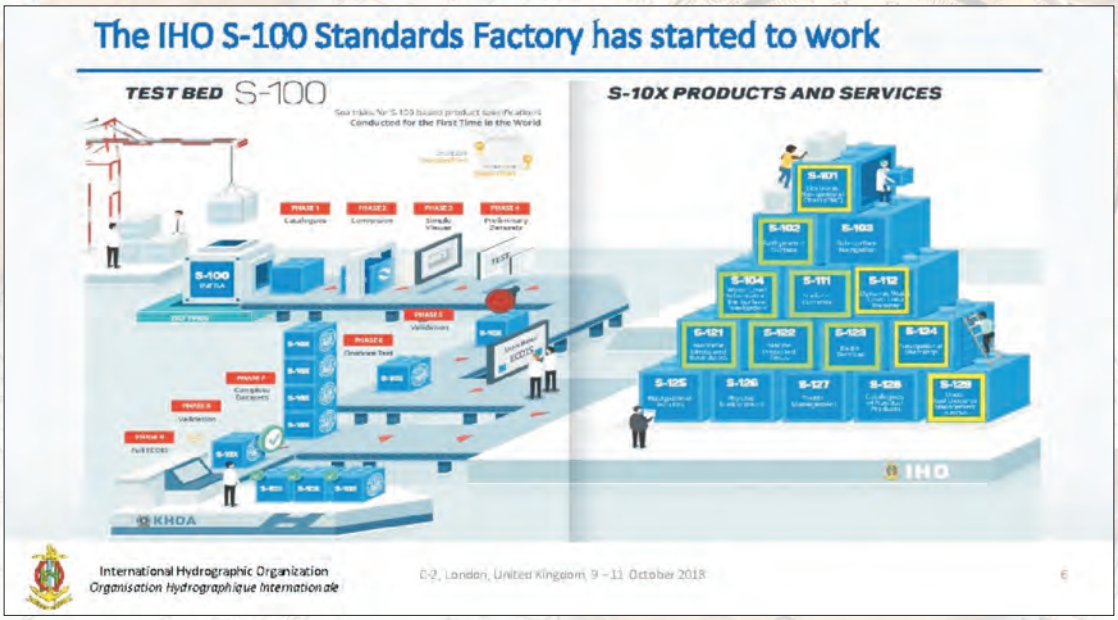


Figure 2: structure of the S-100 model and its role as a universal geospatial framework

7. This structural flexibility reflects a broader recognition: the ocean is not static. It is a dynamic, multidimensional environment influenced by tides, sediment transport, currents, meteorological forces, and human intervention. To represent such complexity, marine data systems must evolve beyond static contours and symbolic representations. S-100 provides the digital infrastructure for this transformation. However, infrastructure without accurate input remains empty. The integrity of the system ultimately depends on hydrographic science.

Hydrography as the Generator of Marine Spatial Truth.

8. Hydrography is the discipline dedicated to measuring and describing the physical features of oceans, seas, coastal areas, lakes, and rivers. Through systematic surveying techniques - multibeam echo sounding, airborne LiDAR, satellite-derived bathymetry, and autonomous surface or underwater platforms - hydrographers transform the seafloor from an unseen terrain into quantifiable spatial data.

9. Every bathymetric grid within an S-102 dataset, every navigational hazard within an S-101 chart, and

every seabed representation integrated into marine spatial planning systems originates from hydrographic measurement. S-100 does not create new knowledge; it structures and disseminates existing knowledge derived from hydrographic surveys.

10. The importance of this relationship becomes particularly evident in shallow or congested waters. In ports and approach channels, centimeter-level differences in seabed elevation can determine vessel loading capacity and grounding risk. Under-keel clearance management systems rely on high-density bathymetric models derived from repeated hydrographic surveys. Without consistent and precise measurement, digital models would lose operational credibility.

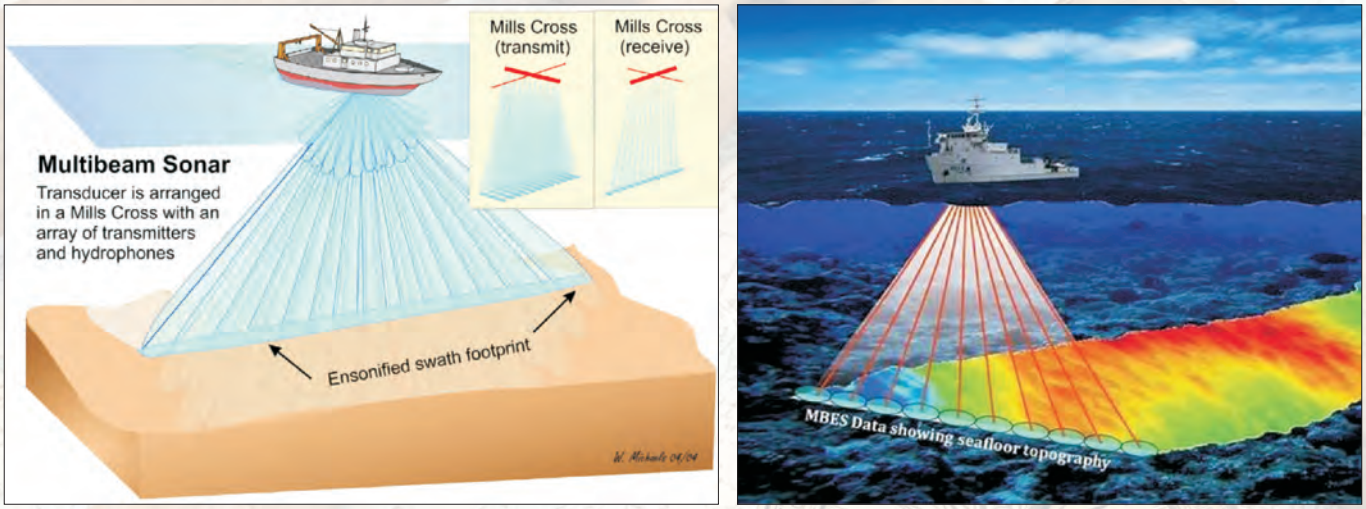


Figure 3: Hydrographic Data Acquisition

11. Hydrography therefore serves as the epistemological foundation of the digital ocean. It establishes what is physically true before that truth is encoded into interoperable standards.

The Transition from Static Representation to Dynamic Intelligence.

12. Historically, hydrographic outputs were manifested as charts—paper or electronic—representing the marine environment at a specific point in time. Updates occurred through periodic Notices to Mariners, reflecting incremental corrections. While effective for centuries, this model inherently lagged behind environmental change.

13. The S-100 framework signals a transition toward dynamic data ecosystems. Instead of representing depth as contour lines, modern systems utilize high-resolution digital elevation models capable of being updated as new survey data becomes available. Tidal predictions can be integrated as real-time water-level services. Current observations can be combined with predictive oceanographic models to provide time-sensitive route optimization.

14. In this emerging paradigm, hydrography is no longer a periodic activity but an ongoing process of spatial intelligence generation. As seabed morphology shifts due to sedimentation, dredging, coastal construction, or natural forces, hydrographic surveys feed updated information into the digital system. The result is a continuously evolving representation of the marine environment rather than a static depiction.

Interoperability and the Expansion of Hydrographic Relevance.

15. One of the most transformative implications of S-100 lies in interoperability. Hydrographic data, once primarily confined to navigational use, can now interact seamlessly with meteorological observations, oceanographic models, vessel tracking systems, and coastal infrastructure databases.

16. This convergence expands hydrography's relevance beyond navigation. Bathymetric data contributes to offshore wind farm placement, subsea cable routing, habitat conservation planning, and sediment transport analysis. Integrated marine datasets support climate resilience strategies by modelling storm surge behaviour and coastal erosion patterns.

17. Through S-100, hydrographic information becomes a foundational layer within Marine Spatial Data Infrastructure frameworks. The ocean is increasingly understood as a complex, interconnected system in which physical, environmental, and operational data coexist within a common geospatial architecture. Hydrography anchors this system in measurable reality.

Institutional Foundations and Governance.

18. The reliability of the S-100 framework depends not only on technical design but also on institutional strength. National hydrographic offices remain custodians of marine spatial data, responsible for conducting surveys, validating information, and ensuring compliance with international standards.

19. Through coordination under the International Hydrographic Organization, these offices contribute to a harmonized global marine data environment. Standardization ensures interoperability; institutional authority ensures credibility. As digital marine systems become more integrated and widely accessed, questions of data accuracy, traceability, and accountability become increasingly significant. Hydrography provides the governance foundation that sustains trust in the system.

Operational Application: Port of Rotterdam, Netherlands - Operationalising S-100 Through High-Resolution Hydrography.

20. The Port of Rotterdam in the Netherlands offers one of the most practical real-world examples of how hydrography and the S-100 framework, particularly S-102 bathymetric models, are being used together in active maritime operations. As one of the world's busiest ports handling large deep-draft vessels, even small variations in seabed depth can affect safety and cargo capacity. To address this, the port regularly conducts high-resolution hydrographic surveys using multibeam echo sounders to capture detailed seafloor measurements. Instead of converting this data only into traditional depth charts, it is now transformed into S-102 bathymetric grids that present the seabed as a continuous digital surface. This provides a far more accurate and realistic picture of underwater terrain, helping navigators, pilots, and port authorities make safer and more informed decisions.

21. The integration of hydrographic data into the S-100 system has significantly improved operational efficiency in Rotterdam. With more precise under-keel clearance information, large vessels can safely carry more cargo while reducing grounding risks. Frequent surveys also help detect sediment build-up early, enabling targeted dredging and better port management. As seabed conditions in busy ports constantly change due to traffic and sediment movement, linking updated hydrographic inputs with standardized S-100 products ensures that navigational information remains current and reliable. This case clearly demonstrates how hydrography acts as the foundation for advanced digital navigation systems, showing a shift from static charts to dynamic, data-driven maritime operations that enhance safety, efficiency, and future readiness.

Emerging Frontiers: Autonomous Systems and Digital Twins.

22. Looking ahead, the convergence of hydrography and S-100 will play a decisive role in autonomous shipping and digital ocean modelling. Autonomous vessels will require continuous, high-confidence spatial intelligence. Static datasets will not suffice. Real-time bathymetric updates, dynamic water-level models, and integrated environmental layers will become essential components of navigational decision systems.

23. Simultaneously, the concept of digital twins - virtual replicas of marine environments - relies heavily on structured, high-resolution spatial data. Such models could support climate forecasting, infrastructure planning, disaster response, and long-term ocean sustainability initiatives. Hydrography will provide the measured foundation; S-100 will enable integration and scalability.

24. Parallel to this, several hydrographic offices and maritime administrations are actively experimenting with high-density bathymetric models under the S-102 specification. These models allow for centimetre-level accuracy in critical navigation zones such as ports, channels, and offshore terminals. The practical application of such precision is already being tested in under-keel clearance management systems, where ships can optimize loading and passage based on real-time depth conditions. This represents a major shift in operational efficiency, as vessels can safely carry more cargo while minimizing grounding risks.

25. Another emerging area of intervention is the integration of hydrographic data with predictive oceanographic modelling. Through S-100-enabled data layering, bathymetry is now being combined with tide, current, and sediment transport models to better understand how marine environments change over time. This has opened new experimental pathways in coastal resilience planning, where dynamic seabed data is used to study erosion, storm surge impacts, and shoreline migration. In the long term, such integration could support climate adaptation strategies for coastal infrastructure and port development.

26. Beyond technological innovation, the S-100 transition is also creating new institutional and economic opportunities. As maritime nations begin to adopt S-100 product specifications, there is a growing demand for professionals skilled in hydrographic data processing, marine geospatial analysis, digital cartography, and system integration. For the maritime industry, the economic implications are substantial. Ports can use S-100-enabled data to optimize vessel traffic management and improve turnaround times. Offshore energy developers can access more precise seabed intelligence for planning installations. Shipping companies can benefit from smarter route optimization based on integrated depth, current, and water-level information. These capabilities contribute to cost savings, improved safety, and reduced environmental impact.

27. Research institutions are also beginning to explore the concept of "living hydrography," where continuous data streams from fixed sensors, autonomous platforms, and satellite observations are integrated into unified marine spatial models. In the longer term, the convergence of hydrography and S-100 is expected to play a crucial role in the development of autonomous shipping. Self-navigating vessels will require highly reliable, real-time spatial data to operate safely. High-resolution bathymetric surfaces, dynamic water-level models, and integrated environmental layers will form the core intelligence upon which these systems depend.

28. Ultimately, the ongoing interventions around the S-100 ecosystem are not limited to technical upgrades. They represent a broader shift toward a digital ocean economy where marine data becomes a strategic resource. Hydrography will continue to generate the foundational knowledge, while S-100 will expand its application across sectors. Together, they are opening new pathways for innovation, employment, research, and economic development, signalling a future in which ocean intelligence is continuously generated, shared, and applied in ways that were previously unimaginable.

Challenges and Capacity Gaps.

29. Despite its promise, the integration of hydrography and S-100 presents significant challenges. High-resolution surveying requires substantial financial investment and technical expertise. Many maritime nations face limitations in digital infrastructure, workforce training, and data management capacity.

30. Ensuring consistent implementation across jurisdictions demands international cooperation, sustained funding, and knowledge sharing. Without coordinated effort, disparities in hydrographic capability could translate into uneven access to digital navigation benefits.

Role of Hydrographic Office – The early mover for S-100 Implementation.

31. The early adoption of the S-100 framework offers Hydrographic Offices (HOs) a strategic advantage that extends well beyond technical modernization. While many countries are still consolidating full implementation of S-57 Electronic Navigational Charts, S-100 represents a structural evolution from chart production to data ecosystem management. It is not simply a new format, but a digital architecture designed to integrate hydrographic, oceanographic, meteorological, and navigational datasets within a unified geospatial framework. Hydrographic offices that move early into this environment position themselves not merely as standard adopters, but as architects of national marine data infrastructure.

32. One of the most significant early-mover advantages lies in institutional positioning. By developing S-100 competencies ahead of widespread global adoption, hydrographic offices can shape national marine spatial data strategies, influence regional implementation models, and strengthen their role within international forums led by the International Hydrographic Organization. Early engagement also accelerates workforce transformation, enabling hydrographers to transition from product-centric chart production toward data modelling, service delivery, and interoperable geospatial system management. This human capital

advantage may prove more valuable than technology itself.

33. Operationally, early adoption enables hydrographic offices to pilot next-generation services such as high-resolution bathymetric grids, real-time water level integration, and dynamic current modelling. These capabilities support safer navigation, optimized port operations, and improved under-keel clearance management. In an era where maritime operations are becoming increasingly digital and semi-automated, having structured, high-confidence spatial data ready within an S-100 framework enhances readiness for e-navigation systems and future autonomous vessel operations.

34. Importantly, the slow global rollout of S-57 offers a cautionary lesson: standards succeed not merely through publication, but through ecosystem readiness—tools, training, governance, and stakeholder alignment. Early S-100 adopters can avoid repeating past delays by implementing use-case-driven pilots rather than waiting for full-scale conversion mandates. By starting with high-impact product specifications and gradually expanding integration, hydrographic offices can demonstrate tangible operational value while building scalable digital infrastructure.

35. In strategic terms, the true early-mover advantage is future-proofing. As the maritime domain evolves toward integrated digital twins, predictive ocean modelling, and cross-sector marine spatial governance, S-100 will likely become the backbone of ocean intelligence systems. Hydrographic offices that begin transitioning now will be better positioned to lead rather than follow, to provide data services rather than static products, and to anchor their national maritime ecosystems in structured, interoperable spatial truth.

Conclusion: Anchoring the Digital Ocean.

36. The evolution of the S-100 framework represents a defining moment in marine geospatial science. Yet its success is inseparable from hydrography. Hydrography measures the physical world; S-100 organizes that measurement into interoperable digital intelligence.

37. Together, they transform static charts into living data systems, enabling safer navigation, smarter port management, and more informed ocean governance. As global dependence on maritime trade and coastal resilience intensifies, this partnership will become increasingly central to economic stability and environmental sustainability.

38. In the era of the digital ocean, hydrography remains the anchor of spatial truth. The S-100 framework ensures that this truth can be shared, integrated, and applied across disciplines. The future of maritime intelligence will not be built on abstraction, but on measured reality - structured for a connected world.



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Charting The Blue Economy: Hydrography, Technology, and Sustainable Ocean Governance in a Changing World

Cmde Ajay Kumar Jolly, IN (Retd)

Introduction: Oceans, Economy, and the Imperative of Knowledge.

1. The oceans form the planet's largest life-support system, covering more than 70 percent of Earth's surface and sustaining climate regulation, biodiversity, food security, trade, and cultural heritage. In the twenty-first century, as pressures on terrestrial resources intensify, nations increasingly look seaward for economic opportunity. This shift has given rise to the concept of the Blue Economy, defined as the sustainable use of ocean resources for economic growth, improved livelihoods, and employment, while safeguarding the health of marine ecosystems. As the world increasingly recognizes the oceans as engines of economic growth and environmental stability, the ability to understand, visualise, and govern marine space has become a strategic necessity rather than a technical luxury.

2. Despite centuries of maritime activity, oceans remain among the least explored and least mapped regions of the planet. Large portions of the global seabed are still poorly understood, limiting safe navigation, resource assessment, environmental protection, and climate resilience planning. In this context, marine charting and hydrography-the systematic measurement, mapping, and interpretation of marine environments-emerge as foundational enablers of the Blue Economy. Charting converts the ocean from an uncertain frontier into a governable, productive, and sustainable space.

The Blue Economy in Global and National Context.

3. At the global level, ocean-based industries account for trillions of dollars annually, spanning shipping, fisheries, coastal tourism, offshore energy, marine biotechnology, seabed mining, and emerging blue-carbon markets. Maritime transport alone carries the overwhelming majority of international trade by volume, making safe and efficient navigation a linchpin of economic stability. Simultaneously, climate change, overfishing, pollution, habitat destruction, and sea-level rise threaten the very ecosystems that underpin these industries.

4. The Blue Economy addresses this paradox by integrating economic ambition with ecological responsibility. However, such integration is impossible without reliable offshore marine data. Economic expansion without spatial data and knowledge leads to user conflicts, environmental degradation, and heightened operational risk. This makes charting not only a technical function but a governance instrument, critical to balancing development with sustainability.

Charting as the Foundation of the Blue Economy.

5. The author has served at INHD in various capacities for more than three decades. The department has been playing a foundational role in marine charting that underpins nearly every sector of the Blue Economy. Accurate hydrographic data ensures safe navigation, reduces groundings and accidents, and supports port efficiency and logistics planning. In fisheries, charting enables identification of fishing grounds, breeding habitats, and conservation zones, supporting sustainable harvests. Offshore energy development, whether oil and gas, offshore wind, or emerging ocean energy systems, relies on precise seabed and sub-surface information to minimize ecological impact and engineering risk. Coastal tourism, recreation, and marine conservation equally depend on reliable charts to ensure safety, environmental protection, and long-term viability.

6. Modern charting has evolved far beyond paper charts. Today's marine charts integrate bathymetry, currents, tides, weather, navigation infrastructure, and ecological overlays into dynamic, digital geospatial

systems. This shift has transformed charting into a living information environment, capable of supporting real-time decision-making, predictive modelling, and adaptive management across the Blue Economy.

Technological Advances in Marine Charting.

7. Recent decades have witnessed transformative advances in charting technologies. Advanced bathymetric and geophysical sensors as well as precise positioning services have revolutionised the world of offshore surveying. Underwater features and objects can now be located with pin-point accuracy and in faster time-frames. Autonomous Underwater Vehicles (AUVs) and remotely operated systems have revolutionised seabed mapping, enabling high-resolution surveys at depths previously unreachable. Satellite remote sensing provides large-scale observations of ocean surface conditions, supporting climate monitoring, hazard detection, and environmental surveillance. Crowd sourced bathymetry, when quality-controlled, supplements national surveys by expanding data coverage in under-mapped regions. Geographic Information Systems (GIS) integrate diverse datasets into unified analytical platforms, enabling Marine Spatial Planning, cumulative impact assessment, and ecosystem-based management.

8. Together, these advances have made ocean data more accurate, timely, and accessible, allowing a wider range of stakeholders to participate in and benefit from the Blue Economy.

The IHO S-100 Standard and Digital Transformation.

9. A major milestone in modern charting is the transition to the IHO S-100 Universal Hydrographic Data Model. Unlike earlier standards focused primarily on navigation, S 100 enables integration of multiple data layers - high resolution bathymetry, water levels, surface currents, marine protected areas, met ocean data and port infrastructure etc, within a common, interoperable framework. This capability supports dynamic navigation systems, digital twins of ports and coastal zones, and the emerging ecosystem of autonomous and semi autonomous vessels.

10. S-100 represents a paradigm shift: charts are no longer static products but dynamic services, forming part of a broader digital ocean infrastructure that supports economic efficiency, safety, and environmental stewardship.

India's Blue Economy and the Hydrographic Imperative.

11. India's Blue Economy vision is grounded in geography and history. With a coastline exceeding 7,500 kilometres and an Exclusive Economic Zone of approximately 2.4 million square kilometres, the oceans have long been central to India's trade, culture, and security. Ocean-based activities contribute roughly 4 percent to national GDP and carry the vast majority of India's merchandise trade.

12. India's maritime doctrine has evolved from the regional SAGAR framework toward the more expansive MAHA-SAGAR vision, reflecting growing ambition in ocean governance and regional leadership. Central to this transition is hydrography. India has mapped most of its EEZ, providing a critical spatial foundation for offshore energy development, fisheries management, seabed resource exploration, and Marine Spatial Planning.

Deep Ocean Mission, MSP, and Data-Driven Governance.

13. India's Deep Ocean Mission exemplifies the integration of charting with frontier science and technology. Through advanced AUVs and manned submersibles, the mission generates high-resolution bathymetric, geological, and ecological data from extreme depths, supporting responsible exploration of deep-sea minerals while enhancing understanding of ocean processes.

14. Parallel to exploration, Marine Spatial Planning (MSP) has emerged as a central governance tool. Platforms such as the SAHAV portal integrate hydrographic, oceanographic, and ecological data to support evidence-based allocation of marine space. MSP pilots in regions such as Puducherry and Lakshadweep demonstrate how detailed charting can harmonise fisheries, tourism, infrastructure, and conservation, reducing conflict and strengthening marine resilience.

Private-Sector Innovation as a Force Multiplier.

15. While state-led hydrographic programmes provide strategic baselines, the operational dynamism of the

Blue Economy increasingly depends on private-sector innovation. Professional marine survey organisations translate national vision into field-level execution, particularly for ports, offshore infrastructure, renewable energy, subsea cables, and environmental assessments. As marine datasets grow in volume and complexity, the need for integrated, intelligent data processing has become critical.

Ocean Science & Surveying Pvt Ltd (OSS): Integrated Innovation in Action.

16. Within this landscape, Ocean Science & Surveying Pvt Ltd (OSS) stands out as an important private sector contributor to India's Blue Economy. OSS operates for hydrographic surveying, offshore geophysics, and marine geospatial analytics, supporting ports and harbours, offshore energy, subsea infrastructure, environmental studies, and maritime safety.

17. A defining strength of OSS lies in its in-progress development of a cutting-edge Software Application Platform designed to revolutionise integrated multi-sensor processing of marine geo-physical data. The platform is engineered to ingest and analyse diverse datasets - multibeam and single beam bathymetry, side scan sonar imagery, seismic and sub bottom profile data, magnetometer measurements, and derived geospatial products, within a single, unified processing environment.

18. Traditionally, such datasets are processed independently, often resulting in fragmented interpretations and long delivery timelines. OSS's platform (Amphibia) breaks this siloed approach through multi-sensor data fusion, corroborating seabed morphology, acoustic texture, sub surface structures, and magnetic anomalies to achieve higher confidence interpretations. Supported by scientific modelling and selectively applied machine learning and artificial intelligence tools, the platform enables tasks that once took weeks to be completed in minutes, while remaining under close expert supervision to ensure accuracy and regulatory reliability.

19. OSS's innovation extends beyond software. The organisation demonstrates dual capability in both hardware and software innovation, combining operational expertise in survey instrumentation with advanced data processing and visualisation. This end-to-end approach ensures data integrity from acquisition to final deliverables, bridging a critical gap often seen in offshore projects.

20. Equally important is OSS's human capital. The organisation brings together experienced geophysicists, hydrographic surveyors, marine engineers, IT professionals, CAD processors, and a youthful, technically agile team adept in modern analytics. This blend of experience and innovation enables OSS to address complex marine challenges holistically, integrating science, engineering, and digital technology into a cohesive operational ecosystem.

21. From a Blue Economy perspective, OSS functions as a force multiplier, transforming raw survey data into actionable information that supports safe navigation, offshore development, environmental stewardship, and marine spatial planning.

Spotlight: Ocean Science & Surveying Pvt Ltd (OSS).

Innovation at the Seabed–Digital Interface.

22. Ocean Science & Surveying Pvt Ltd (OSS) is an Indian marine science and offshore surveying organisation contributing to the Blue Economy through integrated hydrographic, geophysical, and digital solutions.

Key Highlights.

22.1. Active R&D in an integrated multi-sensor software platform for marine geophysical data processing
22.2. Expertise across bathymetry, side scan sonar, seismic, magnetics & met ocean.
22.3. Balanced innovation in hardware operations and software analytics
22.4. A multidisciplinary team of geophysicists, surveyors, engineers, IT experts, and CAD specialists
22.5. Emphasis on AI-assisted, expert-supervised interpretation ensuring speed with precision

23. Blue Economy Relevance OSS supports safe navigation, offshore infrastructure, resource assessment, environmental monitoring, and marine spatial planning, illustrating how private innovation strengthens national ocean governance.

Conclusion: Charting the Future of the Blue Economy.

24. In the final analysis, charting is far more than a technical requirement. It is the strategic backbone of the Blue Economy. Accurate, accessible, and interoperable marine data enables safer navigation, sustainable resource use, climate resilience, and evidence based policy. As nations pursue ocean based growth, the integration of advanced charting standards, emerging technologies, state leadership, and private sector innovation will determine whether that growth remains extractive or becomes genuinely sustainable.

25. By investing in hydrography, embracing digital standards such as S 100, strengthening platforms like SAHAV, advancing deep ocean exploration, and fostering innovative private enterprises such as OSS, India and the global community can unlock the full potential of the Blue Economy, while safeguarding the oceans for generations to come.

Bibliography.

1. Blue Economy – Global Frameworks and Policy
2. World Bank. (2017). The Blue Economy: Increasing Long-Term Benefits of Marine Resources for Small Island Developing States and Coastal Least Developed Countries. Washington, DC: World Bank Group.
3. World Bank. (2024). PROBLUE: Healthy Oceans, Healthy Economies, Healthy Communities – Annual Report. Washington, DC.

   Available at: https://www.worldbank.org/en/programs/problue
4. Organisation for Economic Co operation and Development (OECD). (2023). The Blue Economy in Cities and Regions: A Territorial Approach. Paris: OECD Publishing.

   Available at: https://www.oecd.org/en/topics/sub-issues/water-governance/blue-economy.html
5. European Commission. (2012). Blue Growth: Opportunities for Marine and Maritime Sustainable Growth. Brussels.
6. United Nations Environment Programme (UNEP). (2021). Conceptual Framework for a Sustainable Blue Economy. Nairobi.
7. International Hydrographic Organization (IHO). (2010). S 100 Universal Hydrographic Data Model. Monaco: IHO.
8. International Hydrographic Organization (IHO). (2026). S 100 Based Product Specifications (S 101, S 102, S 104, S 111, S 122).

   Available at: https://iho.int/en/s-100-based-product-specifications
9. NOAA. (2023). Hydrography and Bathymetry: Foundations for Maritime Safety. Washington, DC.

10. Marques, C. R. V. (2022). Hydrography in the Blue Economy. International Hydrographic Conference Presentation.

    Available at: https://hydrography.earth
11. Australian Hydrographic Office. (2024). S 100: Next-Generation Maritime Products and Services.

    Available at: https://www.hydro.gov.au/prodserv/S-100.htm
12. Intergovernmental Oceanographic Commission (IOC UNESCO). (2009). Marine Spatial Planning: A Step-by-Step Approach toward Ecosystem-Based Management. Paris: UNESCO.
13. IOC UNESCO & European Commission (DG MARE). (2021). MSPglobal International Guide on Marine/Maritime Spatial Planning. Paris: UNESCO.
14. Ehler, C., & Douvere, F. (2009). Marine Spatial Planning: A Step by Step Approach. UNESCO IOC Manuals and Guides No. 53.
15. Reimer, J. M., et al. (2023). “The Marine Spatial Planning Index.” npj Ocean Sustainability.
16. Economic Advisory Council to the Prime Minister (EAC PM) & Ministry of Earth Sciences (MoES). (2021). India’s Blue Economy: A Draft Policy Framework. New Delhi.

17. Ministry of Earth Sciences (MoES), Government of India. (2025). Transforming India's Blue Economy. New Delhi.
18. Ministry of Ports, Shipping and Waterways. (2023). Maritime Amrit Kaal Vision 2047. Government of India.
19. Press Information Bureau (PIB). (2021). Cabinet Approves Deep Ocean Mission. Government of India. Available at: https://pib.gov.in
20. Indian National Centre for Ocean Information Services (INCOIS). (2024). Deep Ocean Mission Overview. Hyderabad.
21. Ministry of Earth Sciences (MoES). (2021). Deep Ocean Mission: India's Gateway to the Ocean Floor. Government of India.
22. National Institute of Ocean Technology (NIOT). (2023). Technologies for Deep-Sea Exploration and Mining. Chennai.
23. International Seabed Authority (ISA). (2022). Polymetallic Nodules in the Central Indian Ocean Basin. Kingston, Jamaica.
24. Ministry of Statistics and Programme Implementation (MoSPI). (2023). Ocean Ecosystem Accounts in India: A Framework. Government of India.
25. IPCC. (2021). Sixth Assessment Report: The Ocean and Cryosphere in a Changing Climate.
26. Nature Sustainability & Nature Ocean Sustainability journals (various authors). (2023–2025). Blue Economy, Marine Governance, and Climate Resilience.
27. Ocean Science & Surveying Pvt Ltd (OSS). (2024–2026). Internal Technical Descriptions and R&D Documentation on Integrated Multi Sensor Marine Geophysical Processing Platforms.
28. Maritime Research Centre (MRC). (2024). Underwater Domain Awareness (UDA) Framework. India.
29. Raymarine Commercial & Teledyne. (2026). Practical Implementation of the IHO S 100 Standard. Available at: https://commercial.raymarine.com
30. Modak, K. C., Tiwari, K., & Sahagún, M. A. (2026). "Charting Blue Growth through SDG 14." In The Blue Economy and Environmental Sustainability. Springer
31. Earth.Org. (2026). Mapping the Blue Economy: Sectors, Policies, and Challenges.
Available at: https://earth.org



Cmde Ajay Kumar Jolly, IN (Retd) is a distinguished veteran of the Indian Navy with over 32 years of service, specializing as a Charge Hydrographic Surveyor, the highest grade in the field. During his naval career, he commanded four ships and led critical hydrographic and operational missions across the North Indian Ocean, including a joint survey of Sir Creek and disaster relief during the 2004 Tsunami. He was awarded a Mention in Dispatches for his service for his work in Op Vijay.

His leadership extended to serving as Principal Director (Operations) at the National Hydrographic Office, where he oversaw global chart distribution and maritime safety services. He also headed the National Institute of Hydrography, spearheading its international certification and modernization. Following his naval tenure, he served as the Chairman Managing Director of The Jute Corporation of India (JCI) from 2019 until his retirement in 2025, where he directed a major digital transformation and achieved record revenues.

Currently, Cmde Jolly serves as the Director of Innovation & Strategy at Ocean Science & Surveying Pvt Ltd, leveraging his extensive expertise in hydrography and charting to advance the blue economy. He holds a Master level qualification in Hydrography, an M.Sc. in Defence & Strategic Studies, and an Executive MBA besides the Certificate of Defence Management Course from IIM Lucknow. He is also a Fellow of the Institution of Surveyors.

From Hydrography to Hydrospatial Intelligence – The Liability Paradox of S-100 Data Model

Cdr Sanjeev Sharma, IN (Retd.)

Abstract.

A ship runs aground…
But no system actually "failed."
- The chart was valid.
- The tide data was correct—just slightly delayed.
- The algorithm did exactly what it was designed to do.

And yet… it still happened.

So here's the uncomfortable question in the International Hydrographic Organization S-100 world: -
- If navigation is built on multiple data layers… who owns the final decision?
- And when something goes wrong—who is accountable?

As we shift from static ENCs to real-time, fused, algorithm-driven navigation: -
- The "product" is no longer a chart
- The "authority" no longer controls all inputs
- The "truth" is now… computed

Because in the future of navigation… It's not about who made the data. It's about who owns the outcome.

This thought piece examines the emerging liability paradox of S-100, explores governance and regulatory implications, and proposes policy directions to ensure that as navigation becomes more intelligent and interconnected, it remains equally trustworthy, accountable, and safe.



Keywords.

S-100, Maritime Safety, Hydrography, e-Navigation, Autonomous Ships, Digital Maritime, Future of Shipping, Nautical Charting, Product Liability

A Grounding That Wasn't a Single Failure.

1. The vessel was inbound on a routine approach, navigating a familiar channel under seemingly benign conditions. The bridge team relied on an integrated navigation system displaying high-resolution bathymetry, real-time tidal data, and predictive under-keel clearance (UKC) calculations. Yet, within moments, the vessel touched bottom. Subsequent investigation revealed no single catastrophic failure, but rather a chain of small discrepancies: a slightly outdated bathymetric grid, a delayed tidal update, and a decision-support system that fused both into an overly optimistic UKC margin. In the era of the International Hydrographic Organization S-100 data framework, this is not a hypothetical scenario—it is an emerging reality. And it raises a fundamental question: when navigation becomes a product of multiple data sources and algorithms, who owns the outcome—and who is accountable when it fails?

Redefining the "Product ownership" and "Product" in an S-100 World.

2. Traditionally, hydrographic product ownership was clear and singular. National Hydrographic Offices (HOs) produced official Electronic Navigational Charts (ENCs), validated their contents, and stood as the authoritative source for safe navigation. Liability, while rarely tested in courts, was implicitly anchored in this centralized model of control and responsibility. However, S-100 dismantles this simplicity. It replaces a monolithic product with a modular, interoperable data ecosystem, where the "chart" is no longer a standalone artifact but a dynamic aggregation of datasets, services, and system-generated outputs. In doing so, it transforms not only how navigation data is delivered, but also how ownership and liability must be understood.

3. At the heart of the issue lies a definitional challenge: what constitutes the "product" in an S-100 environment? Is it the individual dataset—such as an S-102 bathymetric surface or an S-104 tidal stream? Is it the real-time service delivering continuous environmental updates? Or is it the final, fused representation on an ECDIS or autonomous navigation system, where multiple inputs are algorithmically processed into a single navigational recommendation? Each layer has its own creator, its own update cycle, and its own uncertainty profile. Yet to the mariner, these distinctions are invisible. What is perceived is a unified, authoritative output—an expectation inherited from the S-57 era, but increasingly misaligned with the distributed nature of S-100.

4. This fragmentation gives rise to a complex and potentially problematic data supply chain. Hydrographic offices continue to provide foundational datasets, but they are now joined by port authorities supplying high-resolution local surveys, meteorological agencies contributing environmental overlays, private firms generating commercially driven bathymetric updates, and sensor networks streaming real-time conditions. Value-added service providers further integrate and process this data into decision-support tools. The result is a federated system of interdependent contributors, none of whom individually control the full navigational picture. Ownership, in this context, becomes diffuse—shared across actors who may never directly interact, yet whose data converges at the point of use.

The Liability Paradox of S-100.

5. It is within this convergence that the liability paradox of S-100emerges. Authority remains expected, but control is distributed. Responsibility is assumed, but ownership is fragmented. In the event of an incident, such as grounding, attributing fault becomes inherently complex. Was the bathymetric data insufficiently updated? Did the tidal service fail to deliver timely information? Did the integration platform misinterpret input data? Or did the vessel operator place undue reliance on automated outputs? Existing legal and regulatory frameworks offer limited guidance for such scenarios, as they were conceived in an era where data provenance was singular and product boundaries were clearly defined.

Hydrographic Offices: Authority Without Full Control.

6. The Hydrographic Offices find themselves at the centre of this paradox. While their traditional role as sole data producers is evolving, their position as trusted authorities persists. Mariners and regulators alike continue to associate Hydrographic Offices with the integrity of navigational information, regardless of its source. This creates an asymmetry: hydrographic offices may no longer control all contributing data, yet they remain implicitly accountable for the overall reliability of the navigational environment. The challenge, therefore, is not merely technical, but institutional - how to redefine authority in a system where control is inherently shared.

Rethinking Liability: Toward a Certified Data Ecosystem.

7. A critical step toward resolving this challenge lies in the concept of data provenance and traceability. In an S-100 ecosystem, every dataset must carry with it a transparent lineage: who produced it, when it was last updated, what are its accuracy parameters, and how it has been transformed or integrated. Such metadata is not simply informational; it is foundational to accountability. Without it, assigning responsibility in the event of failure becomes speculative at best. With it, navigation data evolves into a form of auditable digital evidence, enabling clearer attribution of both value and fault. From a governance perspective, several models for product ownership and liability can be envisioned.

7.1. The legacy model of centralized liability, where hydrographic offices bear full responsibility, is increasingly untenable in a multi-source environment.

7.2. A fully distributed model - where each data provider is independently liable—risks creating confusion and eroding user trust.

7.3. Certified data ecosystem- A more balanced approach lies in the development of a certified data ecosystem, wherein hydrographic offices transition from sole producers to validators and certifiers of data quality. In this model, third-party datasets are integrated into the navigational framework only after meeting defined standards, and liability is structured across the data chain rather than concentrated at a single point.

Regulatory Imperatives in a Multi-Source Data World.

8. The role of the International Maritime Organization becomes critical in this transition. As the custodian of maritime safety regulations, the IMO must address the implications of multi-source data environments within frameworks such as SOLAS and the e-navigation strategy. This includes defining what constitutes “official data” in an S-100 context, establishing expectations for data integrity and availability, and clarifying the responsibilities of ship operators when relying on integrated digital systems. Without such regulatory alignment, the legal ambiguity surrounding S-100 could hinder its adoption and undermine confidence in its capabilities.

Implications for Mariners: The Rise of Data Literacy.

9. For the mariner, these complexities must remain largely invisible, yet their implications are profound. The integration of multiple data sources introduces varying levels of confidence and potential inconsistency, even as systems present a seamless interface. This places new demands on both technology and training. Bridge systems must evolve to communicate not just information, but uncertainty and data quality, while mariners must develop a form of data literacy that allows them to critically interpret system outputs rather than accept them at face value.

Concluding Thoughts - Who Owns Truth at Sea?

10. Ultimately, the question of product ownership in the S-100 era is inseparable from the broader evolution of hydrography itself. As the discipline moves toward hydrospatial intelligence, the notion of a static, owned product gives way to a dynamic, shared service. In this new paradigm, ownership is less about possession and more about accountability within a networked system. Ensuring that this accountability is clearly defined, fairly distributed, and transparently communicated will be essential to realizing the full potential of S-100.

11. The grounding incident that opens this discussion is not merely a cautionary tale - it is a signal. A signal that as navigation becomes smarter, faster, and more interconnected, the frameworks that underpin trust must evolve accordingly. Because in the end, the success of S-100 will not be measured solely by the sophistication of its data models, but by the confidence with which mariners can rely on the information they receive - and the clarity with which responsibility is assigned when that confidence is tested.



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Now at Tridel Technologies, Cdr Sharma leverages his deep domain knowledge and leadership acumen to drive innovation and operational excellence in the rapidly evolving field of marine autonomy and technology.

Digital Cartography to Harness Blue Economy

Cdr Sanjeev Sharma, IN (Retd.)

Introduction.

1. Cartography has been used since ages for land revenue mapping and defence. With advancement of science and technology, it's forms and formats have changed. Raja Todarmal is credited to introduction of land reforms, the essence of which was the assessment of land revenue according to the extent of cultivation, nature of soil and quality of crops.

2. There are records in ancient history of use of maps and charts during the Maurya and Chola Period. Kautilya's Arthashastra was one of the earliest to recognize the relevance of land revenue collection from productive farmlands, in villages with settled population of farmers. The Sukra Neeti talks of revenue estimation from cultivated land according to the fact that the land is watered by tanks and lakes, by rivers, by wells and sluices apart from dry farming rainfed areas and the nature and number of crops raised in each parcel.

3. A major step taken by Shivaji in western Maharashtra for land administration was to have a survey of the lands and then to assess the rents and dues payable by the cultivators. While the land ownership in Deccan was in large land holdings, in Konkan they were in much smaller tillable plots on slopes and valley sides. Land surveys were carried out at different times and basically followed the system of Malik Ambar in Moghal Deccan. The main features of this system were the classification of land according to fertility, ascertainment of their produce and fixing the government share.

Blue Economy.

4. According to World Bank, the blue economy is the "Sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystem."

5. A United Nations representative recently defined the Blue Economy as an economy that "comprises a range of economic sectors and related policies that together determine whether the use of ocean resources is sustainable. An important challenge of the blue economy is to understand and better manage the many aspects of oceanic sustainability, ranging from sustainable fisheries to ecosystem health to preventing pollution. Secondly, the blue economy challenges us to realize that the sustainable management of ocean resources will require collaboration across borders and sectors through a variety of partnerships, and on a scale that has not been previously achieved. This is a tall order, particularly for Small Island Developing States (SIDS) and Least Developed Countries (LDCs) who face significant limitations." The UN notes that the Blue Economy will aid in achieving the UN Sustainable Development Goals, of which one goal, 14, is "Life Below Water".

6. The 'blue economy' concept provides a more holistic vision that embraces economic growth – when it is sustainable and does not damage other sectors. Similar to the 'green economy', the blue economy brings human well-being, social equity and environmental sustainability into harmony.

7. The worldwide ocean economy is valued at around $1.5 trillion per year, making it the seventh largest economy in the world. It is set to double by 2030 to $3 trillion. The total value of ocean assets (natural capital) has been estimated at $24 trillion. The blue economy embraces economic opportunities. But it also protects and develops more intangible 'Blue' resources such as traditional ways of life, carbon sequestration and coastal resilience in order to help vulnerable states mitigate the devastating effects of poverty and climate change.

Blue economy encompasses many activities, such as: -

7.1. Maritime Transport. 80% of global trade by volume is carried by sea,

7.2. Energy security. 34% of crude oil production will come from offshore oil fields by 2026

7.3. Renewable energy. Sustainable marine energy can play a vital role in social and economic development.

7.4. Fisheries and aquaculture. Marine fisheries contribute USD 270 Billion annually to global GDP. 350 million jobs worldwide are linked to fisheries and about 50% of fish for human consumption is provided by aquaculture. More sustainable fisheries can generate more revenue.

7.5. Climate Change. The impacts of climate change on ocean-rising sea levels, coastal erosion, changing ocean current patterns and acidification are staggering. At the same time, Oceans are an important Carbon Sink and help mitigate climate change.

7.6. Tourism. Ocean and coastal tourism can bring jobs and economic growth. Coastal least developed states and Small Island Developing States (SIDS) receive more than 41 million visitors per year.

7.7. Waste management. 80% of litter in the ocean is from land based sources. Better waste management on land can help oceans recover.

8. OECD (Organisation for Economic Co-operation and Development), (formed in 1961 and based in Paris,) expects the global Ocean economy to outperform the rest of global economy and double its economic contribution by 2030, reaching 3 trillion US dollars and employing 40 million people.

9. The Baseline for strengthening/ enhancing blue economy rests on Marine offshore data, which a coastal state has. This is more established in developed states than the developing OR Small Island Developing states (SIDS) and efforts to harness Blue economy in these states has just begun.

10. The Indian Hydrographic office manages and maintains marine spatial data for Indian waters, Indian Ocean and some friendly countries. The marine cartographic data that INHO holds, comes with a legacy of centuries of work and surveys. This spatial dataset has been the backbone of marine trade, defence and tourism in India and has also been a benign element in India's outreach to its neighbours and developing countries to help them in crisis, open their ports for trade and enhancement of tourism in island nations.

11. To illustrate the blue economy potential, IN 2004 the Tsunami struck Indian Ocean and its coastal states. Sri Lanka was badly affected, and Tsunami caused significant damage to the Sri Lankan economy, especially in the way of closure of its major ports for trade and tourism. By using Marine spatial data to open the ports of Galle and Colombo to Trade and tourism, we helped further build its resilience to future natural calamities and economic shocks. Well it's a different thing that Sri Lanka ended up handing over Hambantota to the Chinese and it would not be prudent to dither from the topic and and rather stress here on the importance of marine spatial data.

12. The works conducted by INHO in Mauritius, Maldives and African states have enabled larger ships to use their waters for safe navigation, Tourism and aid coastal resilience for climate change. The seabed habitat maps enabled the areas to be suitably managed and protected.

13. The different pathways toward the Blue economy depend on national and local priorities and goals. There are however some common steps that will be required by all coastal state to adopt this approach in managing their respective parts of the oceans.

13.1. Investment in and use of the best available Science, Data and technology is critical to underpinning governance reforms and shaping management decisions.

13.2. Each coastal state should weigh the relative importance of each sector of the Blue economy and decide based on its own priorities and circumstances.

13.3. Anticipating and adapting to the impacts of climate change is an essential component of a Blue economy approach.

13.4. Investment in ocean health programs

13.5. Effective implementation of UNCLOS, including conservation and sustainable use of the oceans their resources.

13.6. Developing coastal and marine spatial plans (CMSP) is an important step to guide decision making for the Blue economy and for resolving conflicts over Ocean space. CMSP brings a spatial dimension to the regulation of marine activities by helping to establish geographical patterns of sea uses within a given area.

Conclusion.

14. It is evident from the foregoing that to harness Blue economy for a sustainable growth of mankind, we will have to invest in Cartographic products that give a spatial dimension for better understanding and management of resources, tourism and livelihood activities.

15. I would like to move away a bit from traditional cartography that we have witnessed in our times to more Data oriented spatial representation of information. Some of us are lucky enough to have moved from traditional Copper plates to Paper charts TO App based MAPS. Time now is to move from and MAP TO APP Generation to Data based Geospatial information system.

16. The importance of oceans for sustainable development is widely recognized by the international community and was embodied in, among others, Agenda 21, the Johannesburg Plan of Implementation, various decisions taken by the Commission on Sustainable Development, the Rio+20 outcome document The Future We Want, and the 2030 Agenda for Sustainable Development. The 1982 United Nations Convention on the Law of the Sea (UNCLOS), together with its implementing agreements—the 1994 Agreement relating to the implementation of Part XI of UNCLOS and the 1995 United Nations Fish Stocks Agreement - sets out the legal framework within which all activities in the oceans and seas must be carried out and is of strategic importance as the basis for national, regional, and global action and cooperation in the marine sector. This includes the conservation and sustainable use of all areas of the oceans and their resources.

17. To effectively harness the potential of blue economy and meet above objectives of sustainable growth, there exists a huge requirement of marine spatial datasets which can or cannot be represented as standard cartographic products. Accordingly, IHO is moving from the S-57 cartographic production to S-100 format of cartographic data representation format, which is going to be interoperable with different applications that may exploit marine geospatial datasets and shall also bring in the much required modularity in data organisation.



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From Charting the Ocean Floor to Building the Future of Flight

Lt Cdr Abrajeedhan R S (Retd)

1. When people learn I served as a Hydrographer in the Indian Navy and now lead engineering teams in aerospace manufacturing at Boeing, the connection is rarely obvious. One career was rooted in the ocean; the other operates in the sky. Yet hydrography did far more than shaping my naval career. It shaped, how I think about engineering, safety and national capability.

2. Hydrography, to me, is charting the blue future; building the knowledge base that enables safe navigation, sustainable maritime growth, defense readiness and emerging ocean-driven economies. That same future-focused engineering mindset now guides how I approach aviation and aerospace - different physical environments, one purpose-driven, system-oriented way of working.

What is hydrography and why it matters:

3. Hydrography is the science of measuring and describing oceans, coasts and inland waters for navigation, maritime operations and national security. It is also a strategic enabler of the blue economy: ports, offshore energy, coastal infrastructure, undersea systems and environmental protection all rely on accurate hydrographic knowledge. Aviation and aerospace engineering operate in a different domain, but they share responsibilities that are surprisingly similar:

3.1 Decisions influence national and global systems
3.2 Errors propagate rapidly across operations
3.3 Engineering credibility depends on reliable data and repeatable processes

4. Whether charting the seabed or building aircraft structures, the objective is the same to enable the future without compromising safety today.

5. Below I draw five lessons from hydrography that translate directly into aerospace and to any discipline concerned with building safe, scalable and trusted systems.

Safety is the foundation of the blue future:

6. As Hydrographers, our charts and tidal information directly affected navigational safety. A misinterpreted seabed feature, unvalidated tide data or an incomplete chart update could imperil warships, submarines and commercial traffic - especially in constrained or strategically sensitive waters.

7. In aerospace manufacturing, the same principle appears as configuration control, quality systems, and process planning and certification discipline. Safety is not a single task; it is a system that depends on:

7.1. Standardized procedures
7.2. Independent verification
7.3. Disciplined documentation - a culture that treats anomalies as signals, not inconveniences

8. If the blue future is to be sustainable and trusted, it must rest on engineering systems that people can rely on without hesitation.

Data integrity enables ocean futures - and aerospace futures:

9. Hydrography is fundamentally data-driven: sensor calibration, positioning accuracy, uncertainty models and post-processing workflows determine whether a product is trustworthy. Transitioning into aerospace, the parallel was immediate: engineering change records, digital product definitions, tooling data, non-conformance analytics and process specifications form the backbone of production integrity.

10. The consistent truth across both domains: mission outcomes depend on data integrity. Autonomous

vessels, offshore infrastructure, smart ports and undersea systems - all will only be as reliable as the data used to design and operate them.

Charting the blue future means operating confidently in uncertainty:

11. Hydrographic work is executed in an environment of constant change: weather, sea state, access restrictions, sensor behavior and shifting priorities force dynamic decisions. Plans are carefully prepared; execution requires continuous reassessment. Aerospace faces different uncertainties: supply disruptions, design evolution, production variability and late-stage discoveries. Hydrography teaches that uncertainty is not a failure of engineering, but an intrinsic property of complex systems.

12. The professional skill that matters is the ability to:

12.1. Rapidly reassess risk
12.2. Make evidence-based trade-offs
12.3. Align teams around mission intent even when conditions evolve

That discipline is essential for aircraft programs and for any nation expanding its blue economy responsibly.

Systems thinking connects ocean and aerospace domains:

13. Hydrography is never a standalone activity. Survey vessels, sensors, positioning systems, processing software, quality assurance and chart production pipelines must work as one integrated system; failure in any part weakens the whole. In aerospace manufacturing the enterprise system is largerly design, manufacturing, quality, supply chain, tooling and digital platforms. But the same habit is required, ask where your output becomes someone else's critical input, and what downstream risk you create.

14. I developed that kind of 'Systems Perspective' at sea. It's exactly the mindset needed to build scalable, resilient and future-ready engineering organizations.

People ultimately chart the blue future:

15. Both hydrography and aviation are technologically advanced, but success does not come from tools alone. Culture matters. From my experiences I know the highest-impact behaviours are:

15.1. Clear technical communication
15.2. A shared understanding of operational risk
15.3. The confidence to challenge assumptions and speak up

16. The future of the blue economy - and of aerospace manufacturing - will be as much about how engineers interact and protect operational integrity as about platforms and systems.

17. Hydrography did not end when I left the sea. Today I lead teams in aerospace manufacturing, but hydrography continues to influence how I build trust in data, manage risk and plan long-term capability. My career is not two separate chapters but a cumulative journey:

17.1. Hydrography taught me how to build trust in data
17.2. The Navy taught me how to build trust in teams
17.3. Aerospace taught me how to scale both

18. From surveying the unseen world beneath the ocean to enabling the production systems that build aircraft for the sky, the purpose remains the same: to chart a future that others can depend on.

"Hydrography was not just a profession - it was the discipline that taught me how to chart the blue future"



Lt Cdr Abrajeedhan R S (Retd) was a Short Service Officer commissioned into the Hydrography branch on 26 Dec 2011 in the 14th Naval Orientation Course. He has served onboard Darshak, Jamuna, Investigator and Sutlej before his final appointment as Admin and Works Officer at NIH, Goa. Retired in 2021 after 10 years of service, he moved to USA to pursue his MBA from University of Michigan and on graduation started his corporate career as a Manufacturing Manager at The Boeing Company in Everett, WA. Currently he is on an assignment to Bangalore as Production Engineering Manager.

Lieutenant Suvendu Kumar Mitter, Vr.C , Indian Navy (The War Hero of 1971 War)

Commander M L Sharma (Retd)

LEST WE FORGET……..

1. When we recall the Indian Navy's role in the 1971 Indo-Pak war, the spectacular attack on Karachi harbour, known as Operation Trident and Operation Python often takes center stage. December 4, every year is celebrated, as Navy Day, to commemorate these achievements. These audacious strikes on Pakistani naval assets, dealt a severe blow to its supply lines. But beyond these high-profile engagements, the Navy was executing a far more secretive and equally consequential campaign, code named as Operation X. This was a covert mission in East Pakistan (now Bangladesh), started much before the actual war. These involved sabotage, resistance building, and underwater warfare. At the heart of this effort was a daring collaboration between Indian naval officers and the newly formed Mukti Bahini, the Bangladeshi resistance force.

2. This lesser-known dimension of the war showcased the Navy's versatility and its willingness to go beyond traditional roles by raising, training, and deploying a guerrilla naval force deep behind enemy lines. A unique and probably first of its kind, ever under taken by the Indian Navy.

3. A pivotal figure in this effort was Lieutenant S.K. Mitter, a young Indian Navy officer with expertise in Hydrography. He was one of the earliest to join the Naval Commando Operation (Operation-X), from INS Darshak, where he was then posted. .His deep understanding of river water currents, tides, and submerged terrain allowed him to train Mukti Bahini commandos in navigating East Pakistan's complex estuarial waters. The young Lieutenant's competence to command a secret mission gun boat in the enemy territory and lead his team in the emergencies encountered makes Lt Mitter's role exemplary, in the whole operation.



Lieutenant Suvendu Kumar Mitter,Vr.C, Indian Navy (The war hero of 1971 war)

4. Operation-X was not a single event mission, where courage and bravery once shown was enough. It was a mission that went on for months before the actual war started. The amount of risks involved were so high that every time a task was completed in enemy territory, it was as good, as if, a mission in itself was completed.

Lt Mitter's Key Contributions.

5. Lt Suvesh Kumar Mitter served as the Commanding Officer of the gunboat Padma during the 1971 Indo-Pak War. He was part of "Force Alpha" a naval group comprising Indian Navy personnel, the Border Security Force (BSF), and Mukti Bahini, the Bangladeshi liberation forces.

6. Padma and its sister vessel Palash were originally designed as harbor crafts requisitioned from the Calcutta (Kolkata) Port Trust and converted for wartime use. Lt Mitter oversaw their conversion and preparation for naval operations.

7. From August to December 1971, these newly trained naval commandos carried out over 40 sabotage missions, targeting major ports such as Chittagong, Khulna, Mongla, and Narayanganj Their success was staggering. Nearly 100,000

tons of Pakistani shipping were sunk or disabled. These strikes choked supply lines, disrupted troop movements, and forced Pakistan to divert resources away from collapse of Pakistan's eastern defense.

Playing "hide seek "with Death.

8. During an intense naval engagement near the port of Khulna, the gun boats Padma and Palash were mistakenly targeted and tragically destroyed by the Indian Air Force. Lt Mitter was seriously injured and several crew members lost their lives. Despite this, the actions of his unit significantly hampered Pakistani naval capabilities in the east. He was the last to abandon his boat.

9. Even after abandoning the gun boat, death was following him. He was trying to swim away from river bank, where Pakistani Razakar were firing at him. One bullet hit near the arm and bleeding profusely, and it is then he decided to close in to river bank.

10. Once ashore, Lt Mitter and his surviving crew, who were all in plain clothes just escaped being shot on production of naval identity and were taken prisoners.

Legacy.

11. Lt Mitter breathed his last on 4 January 2022 at Kolkata. He is remembered as a war hero who contributed substantially to the naval component of the Bangladesh Liberation War. His actions directly aided the Indian military's overall victory and the eventual liberation of Bangladesh. His courage and leadership were widely recognized, earning him the Vir Chakra, one of India's highest gallantry awards and surely the highest among the Hydrographers of the Navy, till to date.

Contemporary Hydrographers remembering him…

12. Lt Mitter was Commanding Officer of Gun Boat "Padma". There was another boat, named "Palash".I was a young officer posted at Haldia camp, during the war. These boats used to come to Haldia base for logistics. The boats had left Haldia base only the previous day, when these came under air fire on 10 December 1971. We had arranged loading of mines (under water explosives, for used by divers) on these boats. Since no easy means existed in 1971 to identify a floating target as friendly or enemy, therefore, the decks of these boats were provided with a big (about 10 X 10 ft) and bright yellow colour cloth for easy identification by IAF planes. However, probably that arrangement didn't work. I remember seeing Lt Natu, an Engineer officer and SLt Bandhopadhyay on board Padma. Later, I came know that, all of them were taken as POWs by Pakistan army, when they had to abandon their boat.

Cdr A J Modak (Retd), Pune.

13. I recall, Lt Mitter's visit to our Daryaganj house in Delhi, after the war. He had stayed with us for a few days. My sister cried out when she saw his "half gone" arm during the war .A big chunk of flesh had gone. Lt MItter was very brave and unfazed of the injury, .which he had sustained. He used to say that he got Pathan's blood running in his body, which was transfused during the medical treatment during his captivity as POW. He was released from the Navy, after completion of his Short Service Commission.

Cdr P K Jain (Retd), NCR / Delhi.

14. My first meeting with Lt S. K. Mitter, a Vir Chakra-awardee hero of the 1971 war, was in August 1972 at the Naval Hydrographic School, Cochin. Lt Mitter, freshly returned from the war, was posted as our course (training) officer. From the very first day, it was clear he was a man of extraordinary courage, yet a gentleman in every sense.

15. Our interactions, often during tea breaks or in the mess, left a lasting impression. He shared stories from his naval career, sometimes humorous, sometimes deeply moving, but always carrying lessons in resilience, integrity, and professionalism. One episode that stands out vividly is from 1972, when Lt Mitter, despite recovering from a serious arm injury, undertook a long scooter ride from Cochin to Coonoor(near Ooty-Tamilnadu) and back. The 270 Km journey was nearly nonstop, lasting nine hours each way. Watching him ride with such stamina and determination, despite not being fully fit, was both humbling and awe-inspiring.

16. After being released from the Navy (being SSCO), Lt Mitter continued his service as Chief Security Officer at the Victoria Memorial, Kolkata. In 1979, I had the privilege of visiting him there with Cdr P. K. Jain (then Lt Jain).

17. His life is a reminder that courage, honor, and dedication persist in every role one undertakes. -

Cdr PK Tyagi (Retd) –Mumbai.

18. During my 18 years of service as Hydrographer, regrettably, I did not know anything about Lt Mitter. It was not till I joined the Dredger of Dredging Corporation of India, operating at Haldia/Kolkata ports. There, I used to meet, Lt Cdr Bandhopadhyay, NM (was also part of operations, onboard gun boat Padma) who had joined Port Trust as pilot and used to be onboard dredgers for about 15-20 days duration (as resident Pilot). During these interactions , occasionally, he used to mention about the gun boat , Lt Mitter , incident of being taken as POWs, how a "wine chit" of INS Hugli (Now Netaji Subhas) saved their lives and so on. However, I still could comprehend the whole thing in the proper perspective of 1971 war. Once the book on operation –X was released in 2019, the heroic acts of Lt Mitter came out in public domain. Thereafter, I started contacting the contemporary Hydrographers to collect the relevant inputs. This write up is the result of these inputs and other information in public domain.

19. I wish our war heroes like Lt Mitter and other brave hearts who sacrificed their lives during survey operations are not easily forgotten and find a suitable place in the "Hydrographic Heritage Gallery" at NHO, sometime in near future.



Commander M L Sharma (Retd) is an alumnus of 13 course NAVAC and commissioned on 01 Jan 1978. Joined Hydrography in 1980 from general service. Did appointments on old Jamuna/ Darshak/ Sandhayak (EXO and CO)/ Makar (EXO). Shore appointment: NHO Dehradun, DOH (Delhi) and the first O i/C of NCD (V). He took PMR on 31 Jan 1998. Sailed (till 2018) on board merchant ships, OSVs/ PAX ships and DCI dredgers as Captain. He writes in vernacular newspapers on matters of Naval and maritime affairs, including Hydrography and dredging.

Hydrography: Charting The Blue Future from Navigational Discipline to National Strategic Asset

Commander Pramod Kumar Tyagi, NM, IN (Retd)

Introduction.

1. Hydrography has always been more than the measurement of water depths. It is the systematic acquisition of knowledge about the sea — its floor, its boundaries, its behaviour, and its interaction with the coast. For centuries this knowledge served one primary purpose: the safe navigation of ships. That purpose remains valid and vital. But the world has moved on, and hydrography must move with it.

2. India today faces a maritime environment of growing complexity. Its ocean space — the Exclusive Economic Zone, the extended continental shelf, and the broader Indian Ocean Region in which it exercises strategic influence - is subject to pressures, competitions, and opportunities that were barely imaginable when the Indian Naval Hydrographic Department was laying the foundations of the national survey database in the 1960s and 70s. The question before the hydrographic community is not whether the discipline must evolve to meet these realities. It clearly must. The question is whether the institutional will and the national strategic vision exist to drive that evolution with the urgency the moment demands.

The Regional Geopolitical Reality.

3. India's maritime neighbourhood has rarely been more consequential or more contested. Any honest professional assessment must begin here, because geopolitics ultimately determines both the threats that hydrography must serve to counter and the opportunities it must help India exploit.

4. To the north-west, the Arabian Sea connects India to the Persian Gulf — through which flows a very large share of India's energy imports — and to the Red Sea and beyond, through which passes a substantial portion of India's seaborne trade. These are not merely commercial corridors. They are strategic lifelines whose security cannot be taken for granted. The presence of extra-regional naval forces in these waters has grown considerably. Iran's posture in the Gulf of Oman and the Strait of Hormuz, Houthi interdiction activity in the Red Sea and Gulf of Aden, and broader instability across the Arabian Peninsula have all demonstrated that India's western maritime approaches are vulnerable in ways that demand serious strategic attention.

5. To the north-east, the Bay of Bengal and its rim states are subject to intensifying external engagement. China's Maritime Silk Road investments have translated into port infrastructure, commercial presence, and varying degrees of strategic access across India's near abroad — Gwadar in Pakistan, Hambantota in Sri Lanka, Kyaukpyu in Myanmar, Chittagong in Bangladesh. The pattern, viewed as a whole, represents a systematic effort to establish presence and influence across the Indian Ocean littoral that bears directly on India's strategic space. This is not alarmism. It is observable fact.

6. The dimension of this competition that most directly concerns hydrographers is the one least often discussed in open forums: the systematic acquisition of underwater knowledge by external powers. Chinese research and survey vessels have conducted extensive oceanographic and hydrographic operations across the Indian Ocean Region for well over a decade. The data they collect — seabed topography, sediment characteristics, sound velocity profiles, tidal patterns, current structures — has both scientific and strategic value. Precise knowledge of underwater terrain is directly relevant to submarine operations, to the placement of undersea sensor arrays, and to the planning of naval movements through straits and deep-water passages. A nation that systematically surveys another's waters accumulates a form of strategic advantage that is quiet, durable, and very difficult to reverse. India must respond on its own terms —

beginning with the one thing entirely within its sovereign authority: the thorough, systematic, and rigorously maintained hydrographic survey of its own maritime domain.

Extending India's Continental Shelf: A Right That Must Be Exercised.

7. A specific dimension of maritime resource sovereignty deserves more urgent attention than it has so far received in national policy discourse.

8. Under Article 76 of the United Nations Convention on the Law of the Sea, coastal states whose continental margins extend beyond the standard 200 nautical mile limit are entitled to claim an extended continental shelf reaching up to 350 nautical miles from their baselines. This extension does not alter the EEZ - which remains 200 NM for all states - but it confers exclusive sovereign rights over the seabed and subsoil resources of the additional area: hydrocarbons, polymetallic nodules, gas hydrates, and whatever other resources the extended shelf may hold.

9. Pakistan pursued this provision with deliberate purpose. Following a four-year scientific programme jointly conducted by the Pakistan Navy and the National Institute of Oceanography, Pakistan submitted its extended continental shelf claim to the UN Commission on the Limits of the Continental Shelf in April 2009. In March 2015, that claim was reviewed and accepted, extending Pakistan's continental shelf entitlement from 200 to 350 nautical miles and adding over 50,000 square kilometres of seabed resource area to its jurisdiction. It was a significant strategic and economic achievement — one driven entirely by systematic hydrographic and geophysical survey work conducted over several years.

10. What is true under international law for Pakistan is equally true for India. India has an extensive coastline, a broad continental margin in both the Arabian Sea and the Bay of Bengal, and island territories in the Andaman and Nicobar archipelago and Lakshadweep that generate their own maritime entitlements. The geological case for an extended continental shelf claim on both India's western and eastern seaboards is well founded in principle. India is a signatory to UNCLOS and is fully entitled to make such a submission.

11. Any extended continental shelf claim must be supported by comprehensive, high-quality hydrographic, bathymetric, geophysical, and geological survey data of the claimed area. The Commission on the Limits of the Continental Shelf applies rigorous scientific criteria, and claims must be demonstrated through evidence, not merely asserted. Pakistan's success was built on four years of dedicated survey work. India's submission, to be credible and comprehensive, requires no less. This is fundamentally a hydrographic enterprise, and INHD has a central role to play in driving it forward. Every year of delay is a year in which the opportunity cost of inaction grows.

Hydrographic Data As A National Resource: The Security Dimension.

12. Beyond the question of what areas India surveys, there is the equally important question of what happens to the data that is collected - by whom, under what conditions, and with what security.

13. Currently, hydrographic and marine survey activity in Indian waters is conducted by a wide range of agencies: the Indian Naval Hydrographic Department, the National Hydrographic Office, port trusts, state maritime boards, offshore energy operators, submarine cable companies, research institutions, universities, and private survey contractors working for an equally wide range of clients. Each collects data using both public and private funds. Much of that data serves its immediate purpose and then resides in organisational silos, inaccessible to other users, never integrated into a national picture, and never systematically maintained or updated.

14. This fragmentation is a national inefficiency. In the current strategic environment, it is something more serious. Bathymetric surveys, sub-bottom profiles, seabed characterisation data, tidal records, current measurements, and acoustic propagation studies are, by any reasonable assessment, dual-use data. In the hands of an adversary, this information serves intelligence and operational military purposes of direct relevance to India's security - the seabed profile of an approach to a major naval base, the bathymetry of a strait through which India's submarines operate, the sub-bottom characteristics of a coastal area where critical undersea infrastructure is planned.

15. Experience shows that despite the existence of rules and restrictions governing the handling of sensitive survey data, that data does not always remain secure. Survey activities are conducted by multiple agencies operating under different regulatory frameworks, with different levels of security awareness, and with limited coordination between them. Data relating to the same strategically sensitive area may be collected by a port authority under one set of rules, by a private contractor under another, and by a research institution under a third - with no single authority responsible for ensuring that the aggregate picture is appropriately protected.

16. The questions that India's hydrographic authorities must ask are direct and uncomfortable. Is there a comprehensive national database for all marine survey data collected in Indian waters? What rules govern how that data is handled, stored, and distributed? Are those rules consistently applied and enforced? When private companies or research institutions complete surveys in Indian waters, where does the data go and who controls it once the project is complete? Are survey contractor personnel - including any foreign nationals - subject to appropriate screening and oversight?

17. These questions do not require answers in the public domain. But uncertainty about whether a robust national framework for addressing them even exists is itself a vulnerability. In the current geopolitical environment in India's region, that is not an acceptable situation.

The Case For Inhd Coordination.

18. The Indian Naval Hydrographic Department is the natural and appropriate institution to coordinate the national management of all hydrographic data. This is a strategic argument, not a bureaucratic one.

19. INHD has the technical authority, the professional standards, and the security framework to serve as the national repository and coordinating body for all marine survey data collected in Indian waters. What is needed is the regulatory mandate to require all agencies - public and private - to submit survey data to the national system, the institutional capacity to receive, quality-control, and maintain that data, and the legal framework to enforce data handling standards consistently across all operators.

20. A tiered framework for data classification and dissemination would serve multiple purposes simultaneously. Openly available data - general bathymetric information, tidal predictions, chart datum references - would be accessible without restriction through a modern digital portal. Commercially available data - detailed survey data, raw soundings, seabed characterisation — would be made available to legitimate users on payment of a reasonable fee under standard terms. Restricted data of direct strategic sensitivity would be accessible only to authorised agencies under appropriate security conditions. Whatever data is made available must be genuinely authoritative, with benchmarks, datum references, tidal constants, and positional controls maintained to current standards, enabling all surveys in Indian waters to be properly tied to the national framework.

The Training Dimension: Building Regional Capability.

21. Hydrographic capability is built on trained professionals, not on equipment alone. In the early 1980s, India had the foresight to invest in regional hydrographic training through a UNDP-supported programme that established what was then conceived as a Regional Hydrographic Training Facility for the Asia-Pacific region - the institution that has since evolved into the National Institute of Hydrography. The UNDP delegation constituted in 1980-83 to select training resources for the nascent school brought into sharp focus both the scale of the regional training deficit at the time and the strategic value of positioning India as a natural centre of hydrographic excellence for the wider region.

22. That investment has paid dividends over four decades. The NIH has trained hydrographic professionals from across the region, building goodwill, professional relationships, and Indian influence in a domain where expertise is itself a form of soft power. The question is whether India is now prepared to build systematically on this foundation - expanding NIH's capacity and international reach, aligning its curriculum with the full spectrum of modern hydrographic applications, and positioning India as the preferred destination for hydrographic training across the Indian Ocean Region.

23. Nations that train with India, that adopt Indian methods and standards, and that maintain long-term

professional relationships with Indian hydrographers are more likely to share data, cooperate on surveys, and align their approaches to managing the shared maritime domain. In the current environment, where external powers are actively using technical assistance as an instrument of strategic influence across the Indian Ocean littoral, India cannot afford to cede this ground.

Professional Standards: A Crisis That Cannot Be Ignored.

24. The discussion of training and institutional capability would be incomplete — and intellectually dishonest - without an acknowledgement of a deeply concerning trend that is developing within India's commercial hydrographic survey sector.

25. Competent hydrographic surveying is a skilled professional discipline. It requires formal technical education, supervised field training over an extended period, familiarity with the physics of acoustic measurement, an understanding of tidal and datum reduction, the ability to assess and control data quality in the field, and the professional judgement to recognise when results are unreliable and must be rejected. The development of these competencies takes years, not weeks. International standards for hydrographic surveyor qualification - as defined by the International Hydrographic Organization and the International Federation of Surveyors through their Category A and Category B programmes - reflect this reality.

26. What is happening in parts of India's commercial survey sector does not reflect this reality at all. It is now possible, and apparently common, for individuals with a few weeks of informal instruction to present themselves as qualified hydrographic surveyors, armed with certificates issued by organisations whose training standards are, at best, unclear. Survey companies are being established on the basis of such certificates, equipped with low-cost echo sounders of uncertain specification and calibration, and are successfully competing for and winning survey contracts — frequently on the basis of the lowest quoted price rather than any assessment of technical capability. Quality control, where it exists at all, is nominal. The survey results produced by such operations are in many cases unreliable at best and dangerously misleading at worst.

27. The consequences of this situation are not abstract. Hydrographic survey data is used to make decisions about navigation safety, port and channel dredging, offshore structure placement, pipeline and cable routing, and coastal infrastructure design. A port approach dredged to the wrong depth because the pre-dredge survey was inaccurate. A cable route selected through a hazardous seabed area that a competent survey would have identified. A structure founded on sediment conditions materially different from those reported. These are predictable consequences of accepting survey work that has not been conducted to adequate professional standards.

28. The root of the problem lies in the absence of any enforceable minimum standard for hydrographic survey practice in India's commercial sector. There is no licensing regime for hydrographic surveyors. There is no mandatory accreditation requirement for survey companies. There is no regulatory framework under which survey data submitted to government agencies must meet defined quality standards before being accepted and acted upon. In this environment, the L1 procurement model - in which contracts are awarded to the lowest bidder without adequate technical evaluation - creates a race to the bottom in which cut-price operators with minimal capability systematically undercut competent professionals.

29. This is not sustainable, and it is not in the national interest. A formal qualification and licensing framework for hydrographic surveyors, aligned with IHO and FIG standards and administered through NIH or an equivalent recognised body, is an essential foundation. Mandatory minimum technical standards for hydrographic survey data submitted to government agencies must be established and enforced. Procurement criteria must include meaningful technical qualification requirements, not merely price. The hydrographic community - INHD, NIH, professional associations, and individual practitioners — has both the authority and the obligation to drive this agenda.

The Blue Economy Connection.

30. India's Blue Economy ambitions are well articulated in national policy. What sometimes goes unstated is the degree to which those ambitions depend directly on hydrographic foundations.

31. Offshore renewable energy requires detailed seabed surveys before any installation decision can be made. Deep-sea resource exploration in India's extended continental shelf requires systematic bathymetric and geological mapping that is itself a hydrographic enterprise. Fisheries enhancement requires habitat mapping combining bathymetry, seabed characterisation, and oceanographic data. Coastal resilience planning and sea-level rise monitoring depend on tidal, current, and shoreline data that only a functioning national hydrographic programme can provide reliably.

32. India's submarine cable connectivity deserves particular mention. The country's digital economy rests on cable links traversing the Indian Ocean seabed, planned, laid, maintained, and repaired on the basis of hydrographic survey data. As India develops as a regional hub for digital connectivity, the hydrographic competence to support and protect this infrastructure is a strategic enabler — and the data generated by cable route surveys is itself sensitive information that must be managed within the national data framework.

The Hazard of Incomplete Knowledge.

33. Incompletely surveyed waters are dangerous waters. The Gulf of Kutch and Gulf of Khambhat, with their extreme tidal ranges and complex seabed morphology, pose hazards demanding current survey data for safe navigation and infrastructure development. The Andaman Sea, with its active volcanic geology and seismicity, requires systematic bathymetric monitoring to detect seabed changes affecting navigation and undersea infrastructure integrity.

34. In waters where unexploded ordnance from past conflicts lies on or beneath the seabed — a reality in parts of the Indian Ocean Region, the Persian Gulf, and the Red Sea — the consequences of incomplete survey knowledge can be lethal. Systematic UXO survey conducted to hydrographic standards, with full georeferencing and rigorous quality control, is the only responsible basis for infrastructure development or intensive fishing activity in such areas. Experience in Iraqi waters demonstrated both the methodology required and the consequences of applying it rigorously: comprehensive coverage, zero accidents, and a permanent georeferenced record serving future operators in those waters.

Priorities For Action.

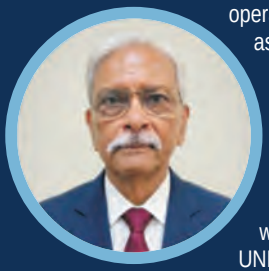
35. The priorities that emerge from this assessment are clear in their identification, though sustained in their execution. India must complete the systematic survey of its maritime domain and pursue its extended continental shelf claim under UNCLOS Article 76 on both seaboards with the urgency the strategic and economic stakes demand. INHD must be established as the coordinating authority for all hydrographic data collected in Indian waters, with regulatory authority to require submission, enforce standards, and protect data of strategic sensitivity. A tiered data dissemination framework must replace the current fragmentation with a coherent national system.

36. A professional qualification and licensing framework for commercial hydrographic surveyors must be established, aligned with international standards, and applied with consistency. Procurement frameworks for survey contracts must be reformed to make technical competence a genuine and evaluated requirement, not an afterthought. India's investment in regional hydrographic training through NIH must be expanded with deliberate strategic purpose, reinforcing India's position as the natural centre of hydrographic authority across the Indian Ocean Region. None of this is beyond India's institutional capacity. Much of it builds on foundations INHD has already laid over six decades of professional work. What is required now is the recognition, at the level of national policy, that hydrography is not a supporting function of the maritime enterprise. It is one of its foundations and like any foundation, its integrity determines the soundness of everything built upon it.

Conclusion.

37. The Indian Ocean is not a benign environment. It is a space of growing strategic competition, immense economic potential, and real and present hazard, natural, man-made, and geopolitical. India's ability to navigate this environment depends on how comprehensively and securely it manages knowledge of its own waters. Hydrographic data is that knowledge. Collecting it systematically through qualified professionals

working to recognised standards, holding it securely as a managed national asset, disseminating it intelligently under a coherent framework, pressing sovereign claims over the seabed resources that international law permits, and protecting it from exploitation by adversaries, these are not bureaucratic aspirations. In the current regional environment, they are national security imperatives. The blue future belongs to nations that invest in this knowledge with seriousness and protect it with discipline. India has every reason, and every capability, to be among them.



Commander Pramod Kumar Tyagi, NM, IN (Retd) holds a Masters in Physics and a Masters in Defence Studies. He is a Fellow of the Institution of Surveyors (India), a Senior Member of the Computer Society of India, and a Member of the Indian National Cartographic Association. During his naval career (1970–1993), he served afloat for approximately fifteen years across survey and operational vessels, including command of INS Meen and INS Nirupak as Charge Hydrographer. Ashore, he served as Training Commander at the Hydrographic School, Goa, and held staff appointments in the Office of the Chief Hydrographer to the Government of India at the Naval Hydrographic Office, Dehradun. He qualified as a hydrographic surveyor in 1972–73 and participated in the multinational OCEANNAVEX 74 exercise and the landmark MONEX 79 oceanographic programme, both conducted across the North Indian Ocean region encompassing the Arabian Sea and Bay of Bengal. He is a proud veteran of the 1971 Indo-Pakistan War. He is the recipient of the Chief of Naval Staff Commendation for his contribution to automation in hydrography, and was awarded the Nausena Medal for undertaking several challenging hydrographic surveys of uncharted waters in the Andaman and Nicobar Islands. He managed the UNDP project and served as a member of the UNDP delegation for the establishment of the Regional Hydrographic Training Facility for Asia and the Pacific region, the forerunner of today's National Institute of Hydrography. Since 1993 he has worked as a professional hydrographic and offshore surveyor across the Indian Ocean Region, the Persian Gulf, and the Red Sea. He is currently the Chairman and Managing Director of Ocean Science & Surveying Pvt. Ltd., Navi Mumbai.

Section - 4

Anecdotes

Charting The Unseen

Lt Cdr Anand CM

On the deck of INS Darshak, at the break of dawn,
A quiet soul stands where the night is gone.
Not a warrior with weapons, nor flags unfurled high,
But a mapper of oceans, of earth and sky.

With charts and echoes and satellite light,
He reads the deep sea through shadow and sight.
Where the world sees water - endless and dark,
He sees the lines where the seabeds mark.

The sonar sings secrets from valleys below,
Mountains of silence the currents don't show.
Each signal returned is a story untold,
Of ancient trenches and rivers of gold.

Salt on his skin and wind in his breath,
He measures life in depth, not death.
While storms may roar and waves may rise,
He holds the compass, calm and wise.

Far from the shores where loved ones stay,
He charts tomorrow, mile by mile, day by day.
Not for glory, not for fame,
But for safe passage and a nation's name.

Ports will rise where his data flows,
Ships will sail where his guidance goes.
Fishermen pray on lines he drew,
Pilots trust paths he made true.

Unknown to the world, unseen by the crowd,
His service is silent, his courage unbowed.
For not all heroes carry guns or flames
Some carry maps and depth with fame.

So here's to the man on INS Darshak's side,
Where science and service together reside.
A guardian of waters, both humble and brave,
A hydrographer, mapping the paths where the deep oceans wave.





Lt Cdr Anand CM (08723-Z) is an alumnus of National Defence Academy and 90th ICC. He has tenanted afloat appointments on IN ships Sarvekshak, Nirdeshak as AHS. Presently, he is appointed as SHS onboard INS Darshak

Through Tide and Time

Karanbir Singh, EM (R) I

Five years have passed upon the sea,
In silent strength and dignity.
Under open skies so wide and blue,
I learned what courage means and true.

At early dawn on steady deck,
With careful chart and compass check,
We sail with focus, calm and sure,
Through waters deep and currents pure.

The ocean tests both mind and will,
Through quiet night and moments still.
It teaches patience, discipline,
And strength that rises from within.

No fame I seek, no praise I claim,
Just honest work in duty's name.
With every watch and every day,
I serve with pride in my own way.

If storms may rise or winds may roar,
My faith in service grows the more.
For in my heart, steadfast and free,
I stand committed to sea.



Karanbir Singh, EM (R) I is a sailor with five years of service in the Navy and he has been onboard INS Darshak from last four years and has been part of all survey activities.

Hydrography – The Science of the Sea

Yogesh Kumar LS (HY), PO 'Q' (HY)

Across the oceans deep and wide,
Hydrography walks with tide.
Studying waters, near and far,
Guided by each shining star.

Depths are measured, soundings made,
Careful notes in charts are laid.
Echo sounders send a beam,
Touching bottom, soft or steep.

Seabed features come to light,
Hidden hills and valleys bright.
Contours drawn in steady lines,
Showing depths in clear designs.

Tides that rise and tides that fall,
Moon and sun controlling all.
Spring and neap in cyclic play,
Changing levels night and day.

Currents moving, swift or slow,
Across the paths where vessels go.
Surface drift or deep-sea flow,
Guiding routes that sailors know.

Latitude and longitude,
Fix the ship in attitude.
GPS gives position true,
Marking points both old and new.

Shoals and reefs that danger bring,
Are marked with care in everything.

Rocks beneath the water hide,
Threat to ships that wrongly glide.
Buoys that float and lights that shine,
Mark the channel, safe and fine.
Beacons stand both day and night,
Guiding ships with steady light.

Survey vessels sail with aim,
Collecting data, point by frame.
Multibeam scans the ocean floor,
Revealing shapes not seen before.

Data processed, checked with care,
Errors fixed with skill so rare.
Charts are printed, digital too,
Helping mariners pass through.

Ports and harbors safe are made,
With hydrographic plans well laid.
Dredging depths and channel lines,
Support the trade of all mankind.

From rivers small to oceans grand,
Hydrography serves every land.
Protecting life and guiding way,
For ships that sail both night and day.

So science meets the restless sea,
In careful work and accuracy.
Hydrography, strong and true,
Keeps the world's waters safe for you.



Yogesh Kumar LS (HY), PO 'Q' (HY) – 83: 650 trainee of NIH, Goa

Importance of Hydrography

Hemant Kumar LS (HY), PO 'Q' (HY)

अथाह सागर की चुप्पी में,
जब दृष्टि भी थम जाती है,
तब Echo Sounder की ध्वनि,
हर गहराई को बताती है।

SBES की सीधी किरणों से,
तल का पहला ज्ञान मिला,
फिर MBES के स्वाथ ने आकर,
पूरा समुद्री मानचित्र खिला।

Beam Steering की शक्ति से,
हर कोण को नापा जाता है,
Constructive–Destructive तरंगों में,
डेटा सटीक बनाया जाता है।

Motion Sensors – Heave, Pitch, Roll,
हर हलचल को सुधारते हैं,
Gyro और GPS Positioning से,
सटीक निर्देशांक उभारते हैं।

Sound Velocity Profile (SVP) लेकर,
तरंगों की चाल समझते हैं,
Refraction Error को हटाकर,
सही गहराई पर पहुंचते हैं।

Side Scan Sonar की आँखों से,
तल की तस्वीर उभरती है,
हर wreck और obstruction की,
सच्चाई सामने आती है।

TVG और Signal Processing से,
कमजोर echoes को उभारा जाता,
Slant Range Correction करके,
डेटा को सटीक बनाया जाता।

Patch Test Calibration के संग,
हर त्रुटि को दूर किया जाता है,
हाइड्रोग्राफी के हर मिशन में,
Precision ही आधार बन जाता है।

ना केवल विज्ञान, ये सुरक्षा है,
हर जहाज की सुरक्षित राह,
हर survey line में छुपा हुआ,
देश सेवा का एक प्रवाह।

सागर की भाषा पढ़ने वाले,
ये मौन प्रहरी कहलाते हैं,
तकनीक और समर्पण के संग,
भविष्य के नक्शे बनाते हैं।



Hemant Kumar LS (HY), PO 'Q' (HY) – 83: 650 trainee of NIH, Goa

For Those Who Sail After Us

Manish LS (HY), PO 'Q' (HY)

We sail where the tricolour flies,
Under open seas and endless skies.
No road ahead, no guiding line,
Yet we map the depths for ships to find.

The ocean is vast, silent, and deep,
With secrets it chooses to keep.
But step by step, line by line,
We chart its paths for all mankind.

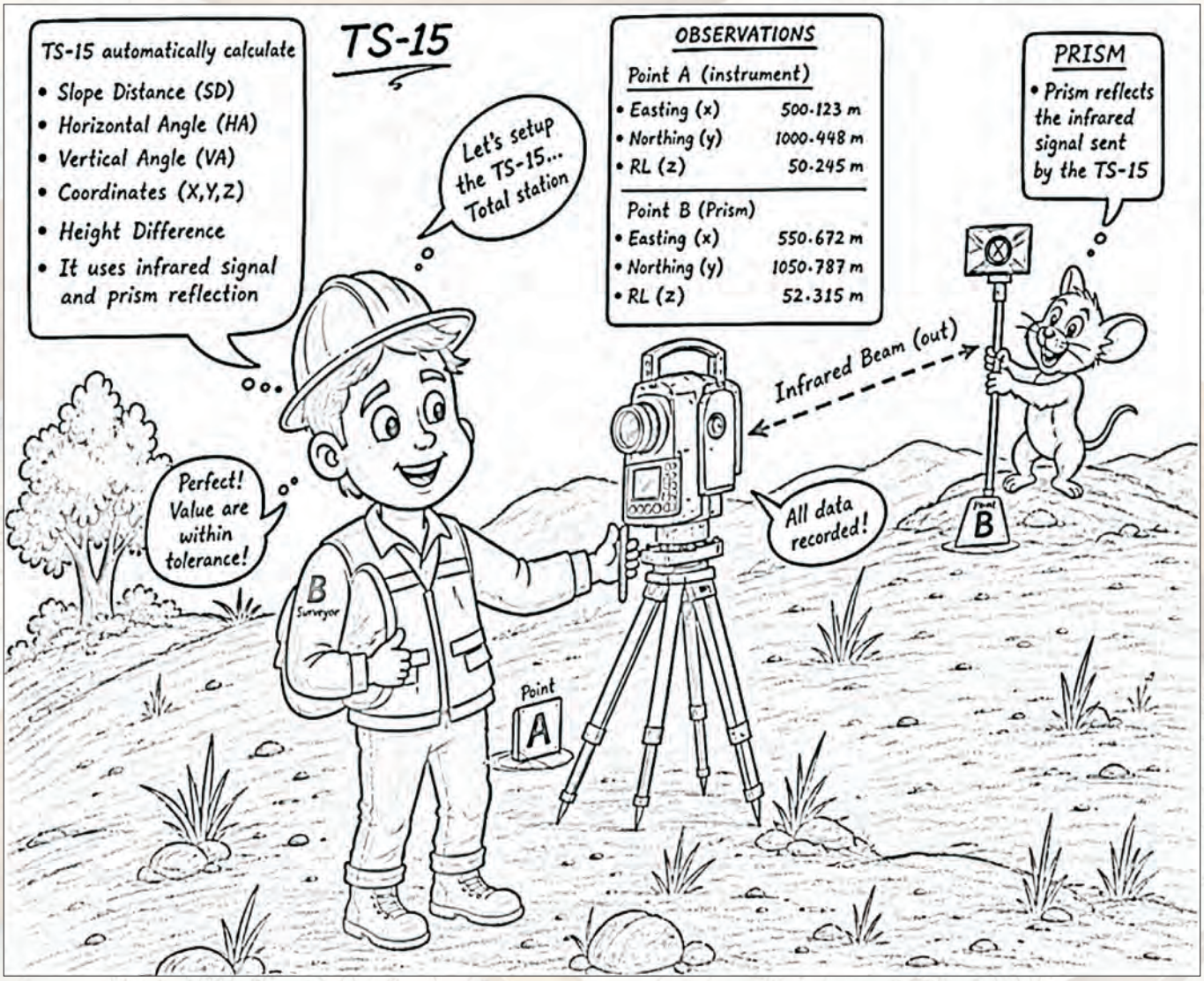
Not for glory, not for name,
But for our Nation's strength and fame.
Each depth we measure, each mark we draw,
Protects our shores with silent law.

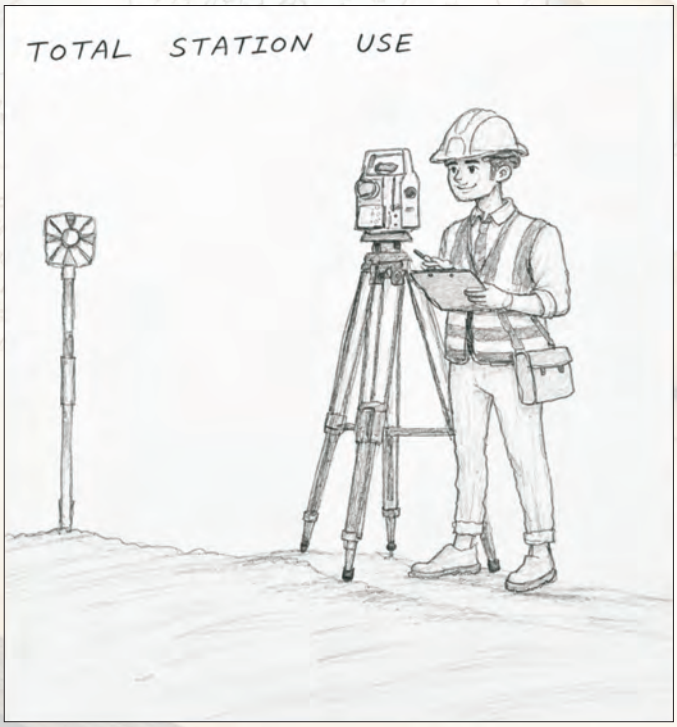
In storm and calm, by night or day,
We stand on duty, come what may.
So others may sail safe and free,
On waters we made known to be.



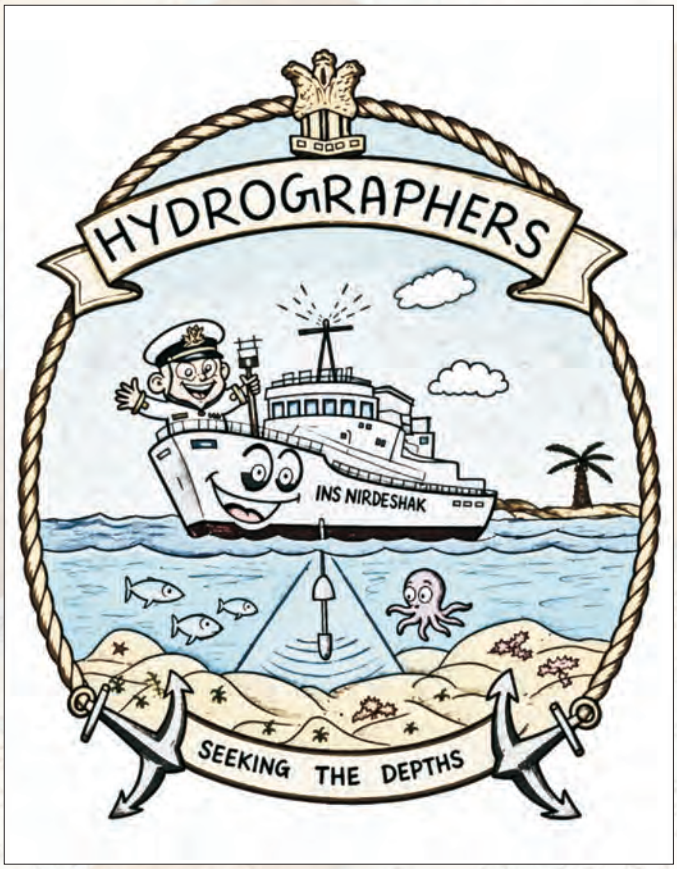
Manish LS (HY), PO 'Q' (HY) – 83: 650 trainee of NIH, Goa

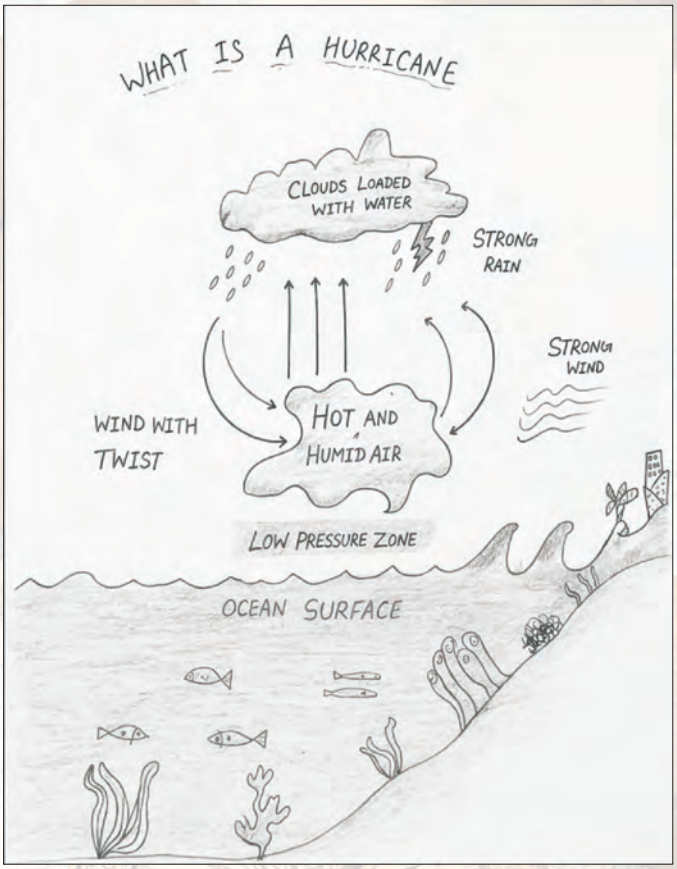
SKETCHES – AVR (HY) - 83:647

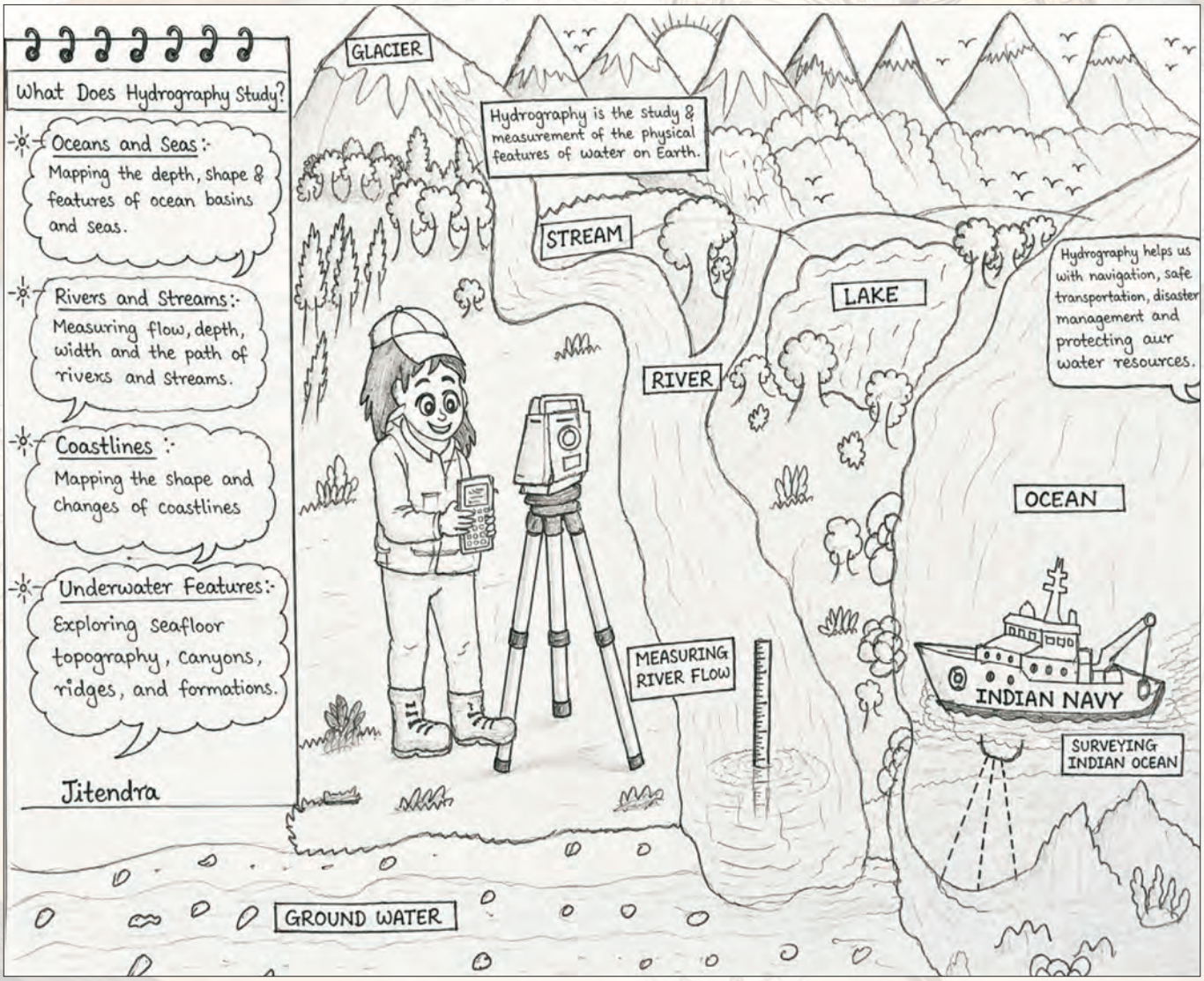


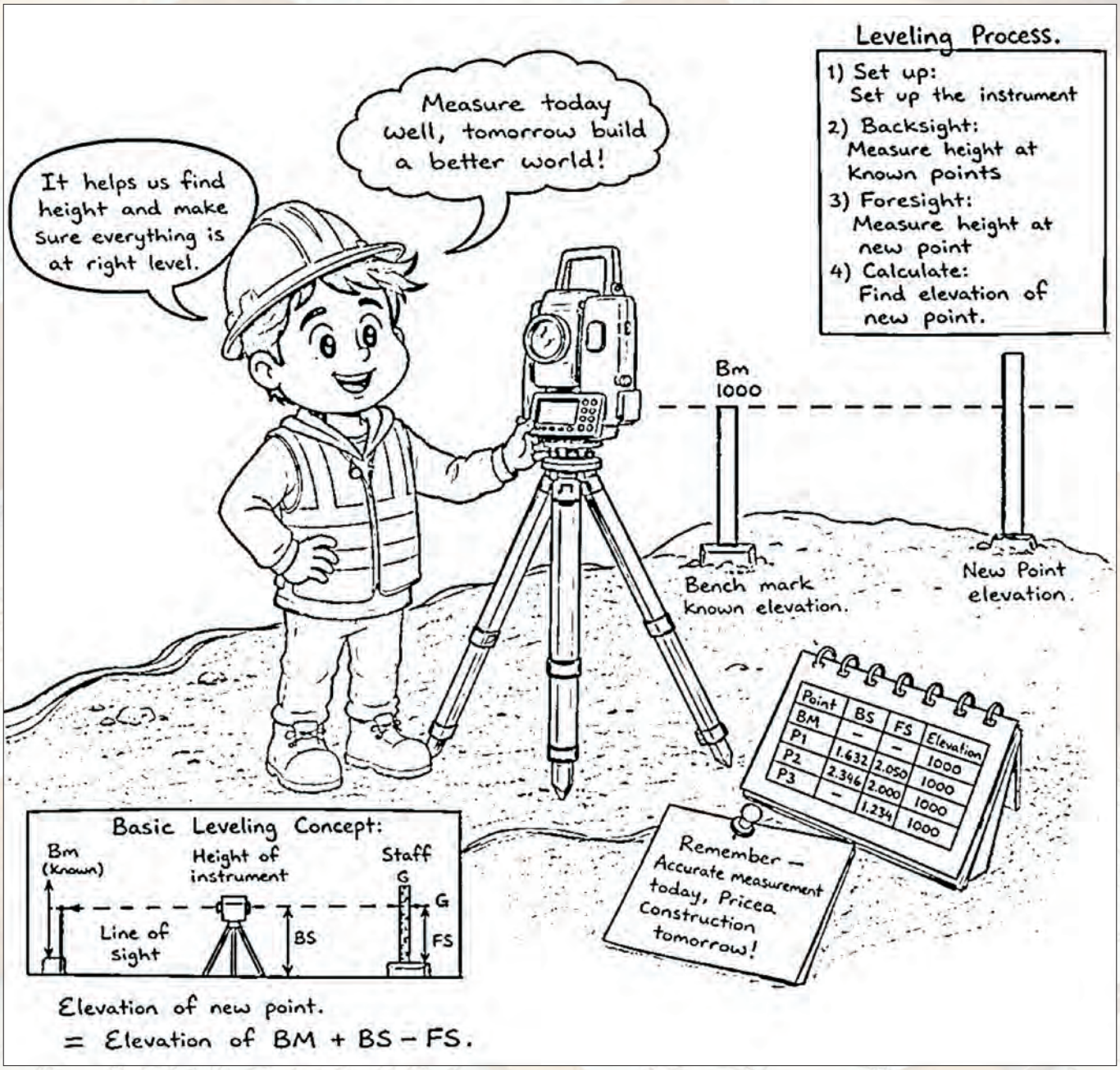


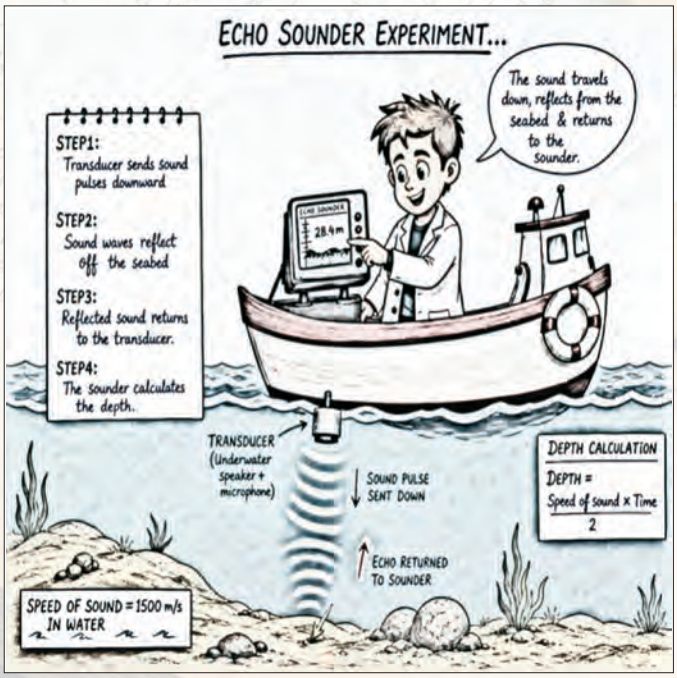


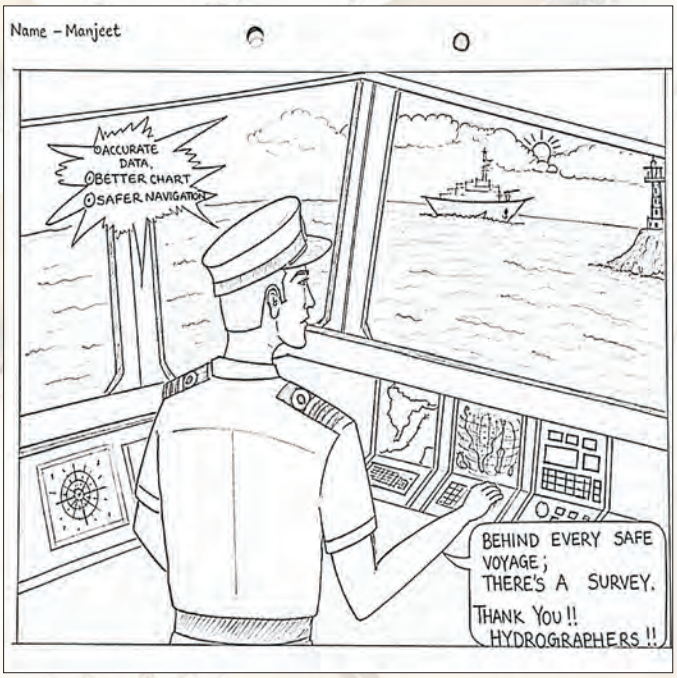

HYDROGRAPHERS
INS NIRDESHAK
SEEKING THE DEPTHS

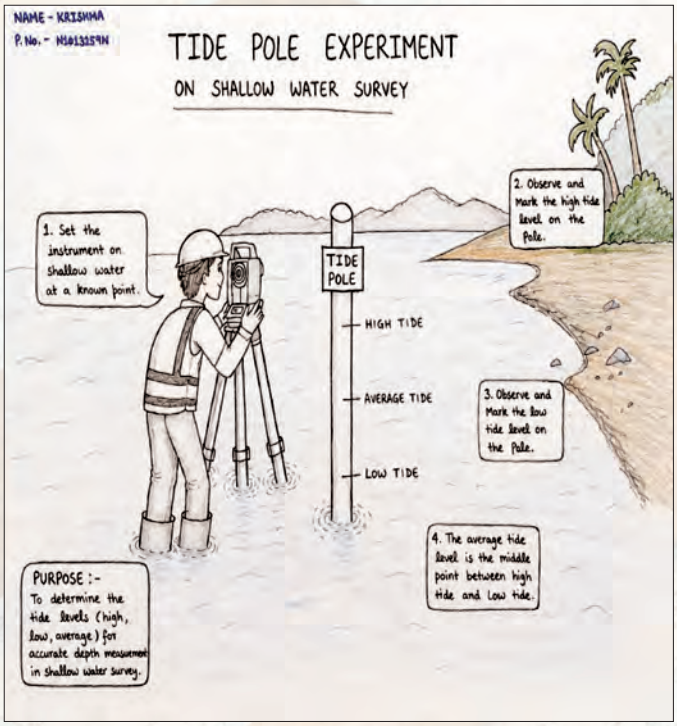

WHAT IS A HURRICANE
CLOUDS LOADED WITH WATER
STRONG RAIN
STRONG WIND
WIND WITH TWIST
HOT AND HUMID AIR
LOW PRESSURE ZONE
OCEAN SURFACE

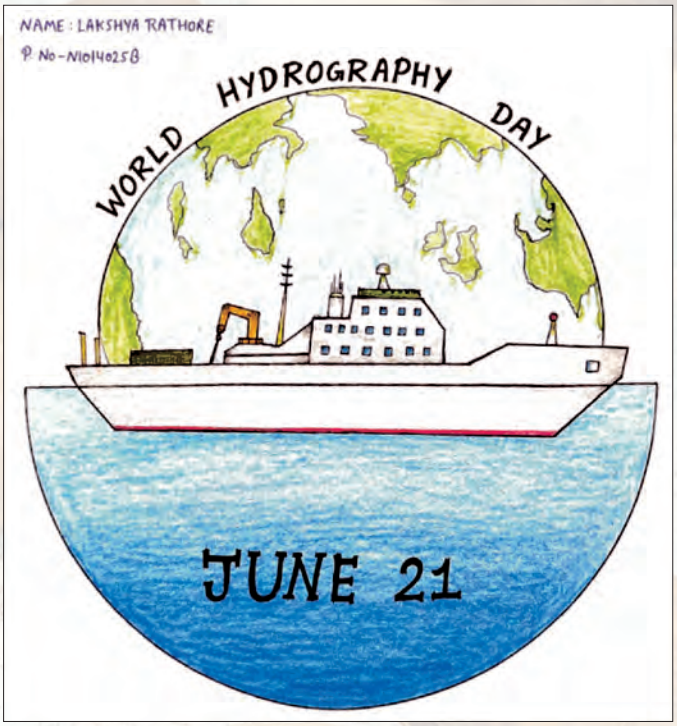

What Does Hydrography Study?
Oceans and Seas :- Mapping the depth, shape & features of ocean basins and seas.
Rivers and Streams :- Measuring flow, depth, width and the path of rivers and streams.
Coastlines :- Mapping the shape and changes of coastlines
Underwater Features :- Exploring seafloor topography, canyons, ridges, and formations.
Jitendra
GLACIER
Hydrography is the study & measurement of the physical features of water on Earth.
STREAM
LAKE
RIVER
Hydrography helps us with navigation, safe transportation, disaster management and protecting our water resources.
OCEAN
MEASURING RIVER FLOW
INDIAN NAVY
SURVEYING INDIAN OCEAN
GROUND WATER

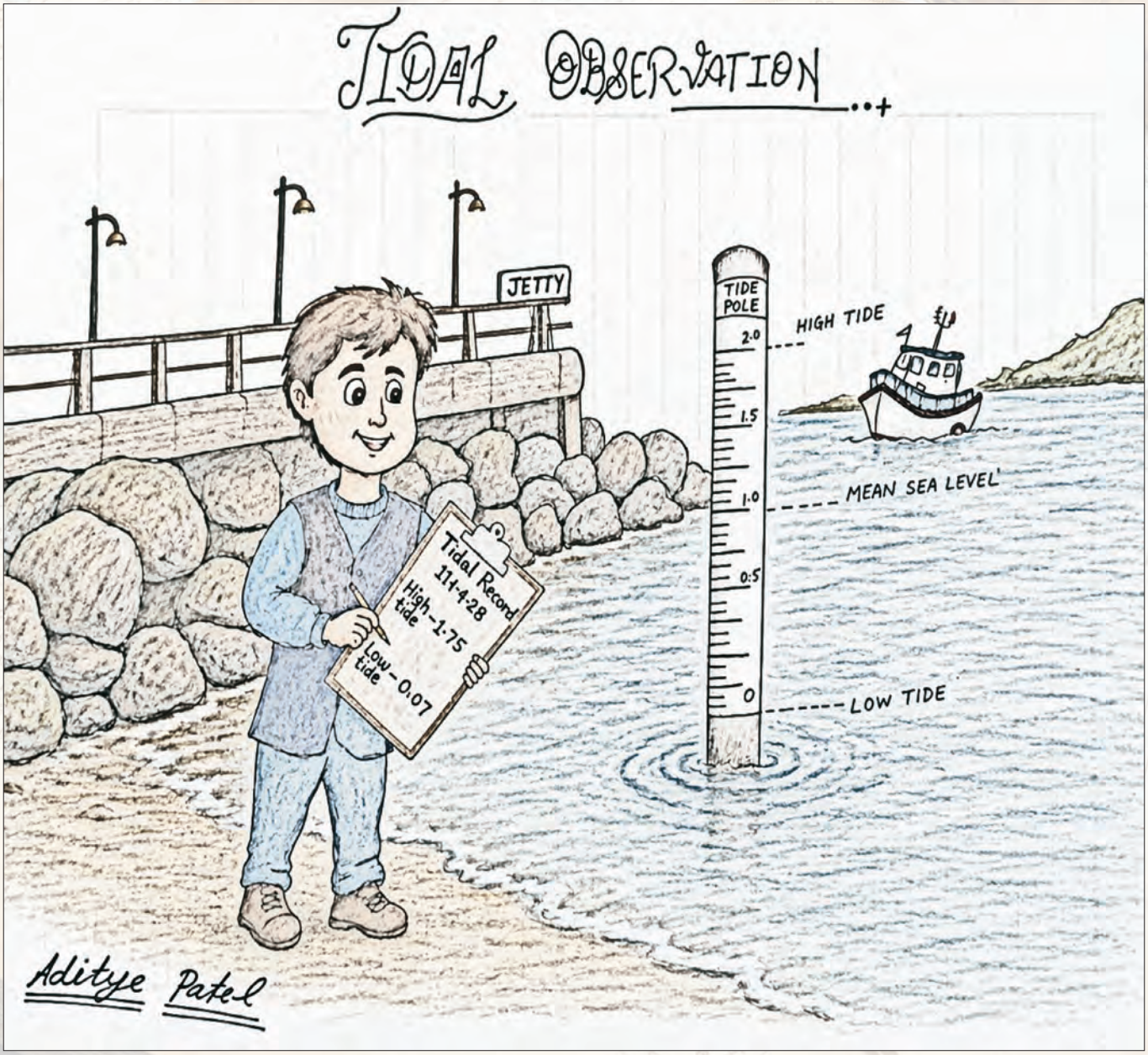

Leveling Process.
1) Set up:
Set up the instrument
2) Backsight:
Measure height at known points
3) Foresight:
Measure height at new point
4) Calculate:
Find elevation of new point.
Measure today well, tomorrow build a better world!
It helps us find height and make sure everything is at right level.
Bm
1000
Bench mark
known elevation.
New Point
elevation.
Point | BS | FS | Elevation
BM | – | – | 1000
P1 | 1.632 | 2.050 | 1000
P2 | 2.346 | 2.000 | 1000
P3 | – | 1.234 | 1000
Remember –
Accurate measurement today, Pricea Construction tomorrow!
Basic Leveling Concept:
Bm (Known)
Height of instrument
Staff
G
Line of sight
BS
FS
Elevation of new point.
= Elevation of BM + BS – FS.

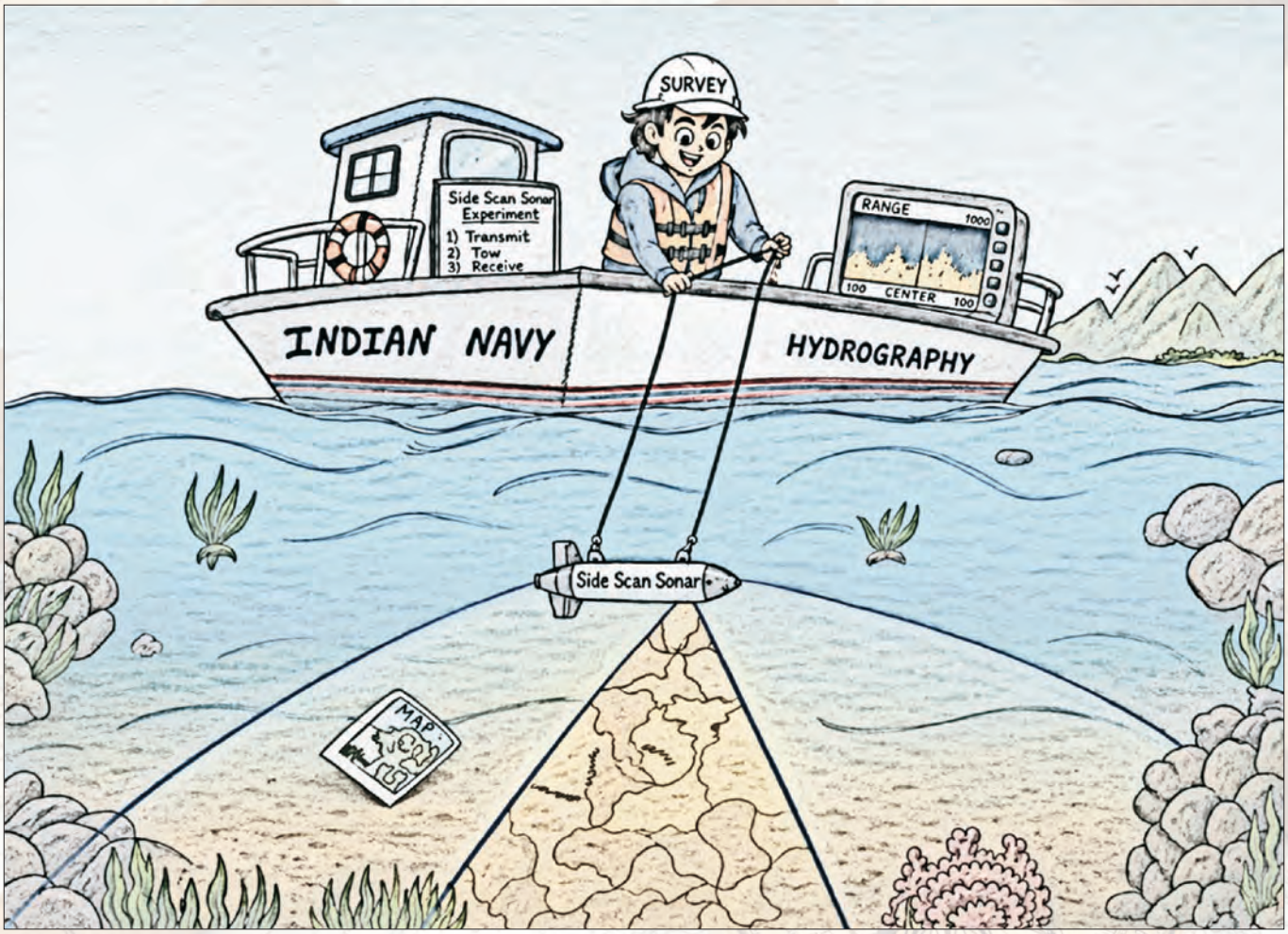

ECHO SOUNDER EXPERIMENT...
STEP1:
Transducer sends sound pulses downward
STEP2:
Sound waves reflect off the seabed
STEP3:
Reflected sound returns to the transducer.
STEP4:
The sounder calculates the depth.
The sound travels down, reflects from the seabed & returns to the sounder.
28.4m
TRANSDUCER
(Underwater speaker + microphone)
SOUND PULSE SENT DOWN
ECHO RETURNED TO SOUNDER
DEPTH CALCULATION
DEPTH =
Speed of sound x Time
2
SPEED OF SOUND = 1500 m/s IN WATER


Name – Manjeet
ACCURATE DATA,
BETTER CHART
SAFER NAVIGATION
BEHIND EVERY SAFE VOYAGE; THERE'S A SURVEY.
THANK YOU !! HYDROGRAPHERS !!


NAME - KRISHNA
P. No. - M1013359N
TIDE POLE EXPERIMENT
ON SHALLOW WATER SURVEY
1. Set the instrument on shallow water at a known point.
TIDE POLE
HIGH TIDE
AVERAGE TIDE
LOW TIDE
2. Observe and mark the high tide level on the pole.
3. Observe and mark the low tide level on the pole.
4. The average tide level is the middle point between high tide and low tide.
PURPOSE :-
To determine the tide levels (high, low, average) for accurate depth measurement in shallow water survey.


NAME : LAKSHYA RATHORE
P. No - M1014025B
WORLD HYDROGRAPHY DAY
JUNE 21


TIDAL OBSERVATION
JETTY
TIDE POLE
2.0
1.5
1.0
0.5
0
HIGH TIDE
MEAN SEA LEVEL
LOW TIDE
Tidal Record
11-1-28
High - 1.75
tide
Low - 0.07
tide
Aditye Patel


SURVEY
Side Scan Sonar Experiment
1) Transmit
2) Tow
3) Receive
RANGE
1000
100 CENTER 100
INDIAN NAVY
HYDROGRAPHY
Side Scan Sonar
MAP


DGPS ANTENNA
GNSS GPS RECEIVER
Echo Sounder System
MONITOR APPLY SURVEY
• TIDE
• SCOPE
• SUDE
• COLLECT
• DATA
• IDENTIFY
• HAZARD
SURVEY BOAT
SOUND WAVES TO MEASURE DEPTH
HYDROGRAPHY
The Science of measuring and mapping the physical features of oceans, seas and water bodies.
SHALLOW WATER
DEEP WATER
UNDERWATER FEATURES
HYDROGRAPHIC SURVEY: MEASURING DEPTH, MAPPING SEABED

Review & Designing Team



CAPTAIN KISHORE AER

Captain Kishore Aer

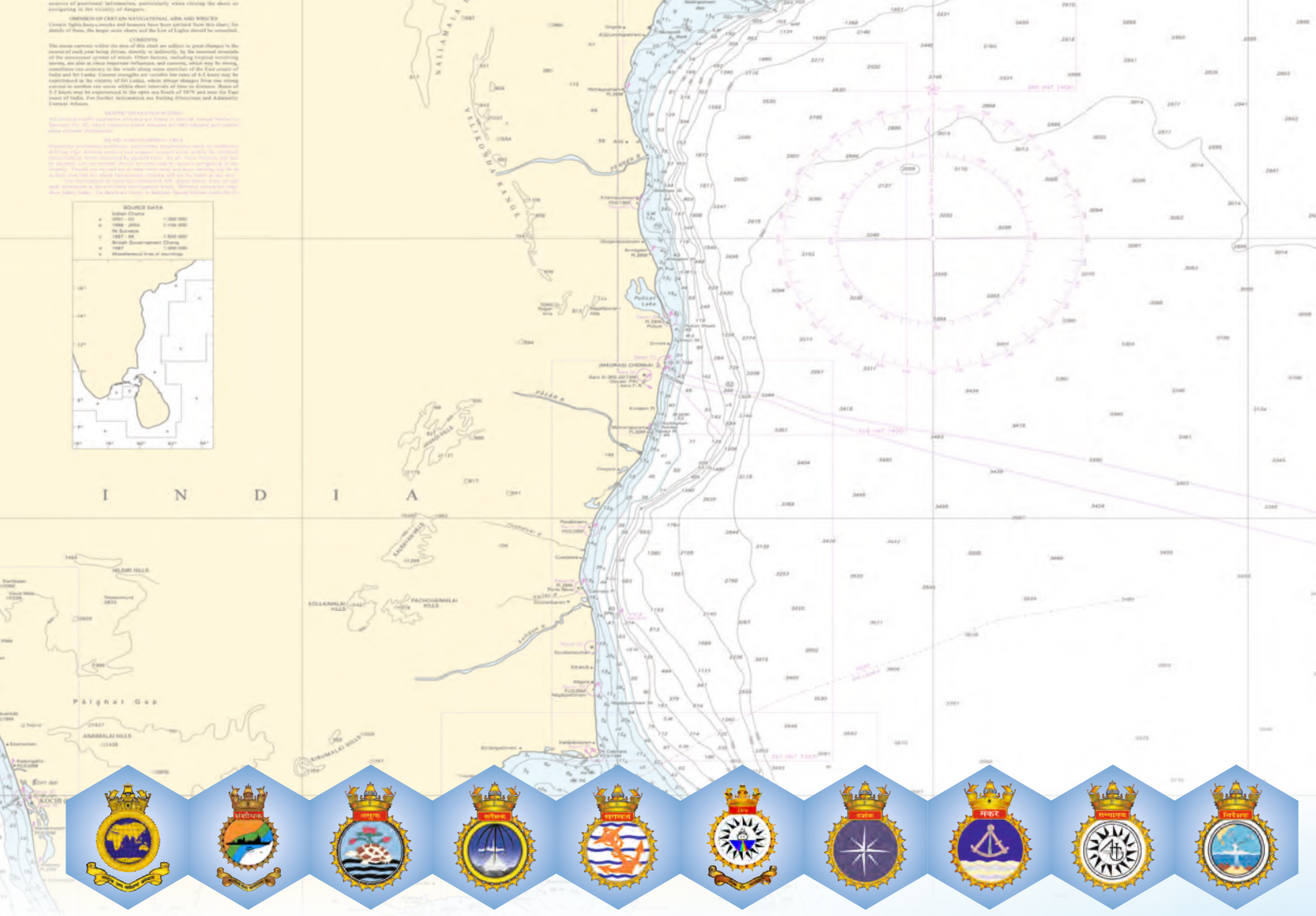
Captain Kishore Aer is an alumnus of the 72 ICC. He is a qulaified Charge Hydrographic Surveyor. He holds a MSc Hydrographic Sciences degree from Goa University and MSc Defence and Strategic Sciences from Madras University. He is an alumni of the 76th Staff Course of DDSC, Wellington. He has Commanded INS Makar and INS Sarvekshak. He is presently posted at NHO as Capt(H) - Personnel and Training.

Sh. M. P. Gupta, ACCHO

Sh. M. P. Gupta is Assistant Chief Civil Hydrographic Officer (ACCHO) and has served as Senior Nautical Cartographer at the National Hydrographic Office, Dehradun, for 27 years. He holds an MTech from Banaras Hindu University, Varanasi, specializing in seismic, magnetic, and electrical geophysical surveys and well-logging techniques. He has conducted detailed geophysical surveys for the Government of Rajasthan, including the IGNP projects.In 2003, he completed the Cat-B Nautical Cartography course at the IHO-IMO affiliated institution in Trieste, Italy. His expertise includes nautical chart planning, Chart and ENC production, digital QA/QC, and defining gridded ENCs for the Indian Ocean and NIOHC regions. He has integrated HPD technology into operational production and developed internationally compliant hydrographic products. Sh. Gupta is a member of the IHO Tides, Water Level and Currents Working Group under HSSC.



SH. M. P. GUPTA, ACCHO





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