Underwater Domain Awareness (UDA) in India: Legal Frameworks and Strategic Imperatives

Piyush Pandey[1]

Legal Scholar specialising in Constitutional Laws from Chandigarh University, Mohali.

Abstract

Underwater Domain Awareness (UDA) has developed into an important element of India's whole government maritime strategy in the current century. This is particularly salient as India is situated in the Indian Ocean Region (IOR) and is facing more considerable security challenges (such as growing submarine activity by adversarial states, maritime terrorism, illegal natural resource exploitation) as well. As such, UDA now becomes a defence necessity, but also a multifaceted tool that overlaps successfully with environmental stewardship, economic growth and scientific advancement, particularly in the face of expanding and irreversible climate change impacts in the IOR.

The working development of UDA systems in India commensurately fits with efforts to secure national maritime boundaries, increase maritime security via naval domain awareness, and direct India towards the long-term economic potential of the blue economy. The Indian Navy's enthusiastic push towards indigenous solutions, including technologies like autonomous underwater vehicles (AUVs) and coastal sonar nets, indicates a market potential for real time monitoring of the underwater domain. Further, India's cooperation agreements with allies such as the United States and Japan indicates the critical geopolitical relevance of UDA systems to securing sea lines of communication and countering Chinese activity in the Indo- Pacific.

Nonetheless, a number of obstacles remain to the effective realization of UDA in India. These include technological limitations in tropical waters, reliance on foreign sonar systems, conflicts of interest between defence and civilian maritime organisations, and insufficient legal and policy structures. A robust UDA regime with the use of sonic/pinged detection of large areas of the sea, coupled with proactive and passive monitoring of the underwater environment clearly requires a collaborative civil-military approach, dedicated research and development in acoustic and marine sciences, and legislation that establishes a balance between national security imperatives and the health of the marine ecosystem.

This paper examines the strategic significance of UDA in India, considers the current challenges to its implementation, and offers policy recommendations to enhance India’s underwater situational awareness as part of a future-proof maritime security architecture.

Keywords: Underwater Domain Awareness (UDA), Maritime Security, Indian Ocean Region (IOR), Autonomous Underwater Vehicles (AUVs), Sonar Technology.

1. Introduction

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India, as a maritime nation, has more than 7,500 kilometers of coastline and its strategic location in the Indian Ocean Region (IOR) as it is the only Indian Ocean nation surrounded by the Arabian Sea to the west, the Bay of Bengal to the east, and the Indian Ocean to the south. India has geopolitical and economic interests that extend to the maritime domain; nevertheless, the underwater domain, while significant, has tended to receive less exploration and attention in the policy and security sectors[2]. Over the past few years, however, the conception of Underwater Domain Awareness (UDA) as an integral part of maritime strategy is gaining momentum.

UDA is the ability to monitor, understand and respond to underwater activities and activities associated with the underwater environment. While primarily and customarily defined and used for military purposes, UDA has civil, commercial, scientific and environmental components. As other challenges because of maritime threats, such as, stealth submarines, undersea mining, illegal fishing, underwater technology espionage, and smuggling routes, battle space awareness extending underwater is paramount to the security and sovereignty of a nation.

Simultaneously, oceans also represent a significant driver of India's Blue Economy—with vast potential in ecosystem services provided by fisheries, offshore energy, seabed mining, marine biotechnology and shipping. Now, UDA can help harness these natural resources in a sustainable manner while avoiding the exploitation of marine ecosystems and the ecological devastation associated with human activity. In addition, given the increase in climate-induced disasters such as cyclones and tsunami's, underwater sensing and interconnected systems to initiate warning systems now represent a vital step in disaster risk reduction and coastal resilience.

India has made some progress with things like establishing indigenous initiatives in Autonomous Underwater Vehicles (AUVs), sonar technologies, and other scientific collaborations. However, the challenges persist and range from technology gaps, reliance on systems that have been imported from abroad but do not function in Indian's tropical waters, overlapping jurisdictional issues and no single national framework of law that effectively deals with these concerns.[3]

Against this backdrop, this paper intends to examine the development of Underwater Domain Awareness and the implications this has for maritime governance in India. It looks at UDA's applications to national defence, economic development, environmental protection and regional diplomacy. The paper also considers the issues that inhibit the development of UDA and makes recommendations to tap into India's underwater domain capabilities through legal reform, indigenous innovation and collaborative policy frameworks.

2. Strategic Significance of UDA

India's maritime security environment is shifting due both to emerging threats and emerging opportunities in the Indo-Pacific. In this regard, underwater domain awareness (UDA) is strategically critical for its role in strengthening India's defense posture, protecting maritime resources, facilitating scientific & economic projects, and allowing for regional influence. The strategic expression of UDA can be understood through several dimensions:

[2] https://cenjows.in/indias-strategic-role-in-the-western-indian-ocean-convergence-of-interest-with-the-littoral-nations/

[3] https://idrw.org/indias-high-endurance-auv-program-advances-with-developmental-trials-amid-regional-tensions/

Maritime National Security

Hostile submarine incursions, especially China's swelling undersea presence in the Indian Ocean Region (IOR), are testing India's underwater vulnerabilities. Under the character of anti-piracy, conventional and nuclear powered Chinese submarines have operated frequently in the IOR, necessitating underwater domain awareness (UDA) in order to detect, track, and respond to underwater operations in our back yard. Various indigenous UDA systems, such as passive sonar arrays, seabed sensors, and autonomous underwater vehicles, can dramatically improve India's ability to enhance surveillance and deterrence capabilities.[4]

In addition, the Andaman and Nicobar Command and the strategic naval base at Karwar require seamless situational awareness underwater to ensure mission readiness. In the future, naval dominance will depend not just on ships and aircraft, but also a leap ahead in undersea intelligence and counter-stealth awareness. UDA thus provides India with a deterrent posture and response capabilities whether it is against state or non-state threats.

Securing the Blue Economy

India's blue economy - which is estimated to add $200 billion annually in the next few many will depend on a variety of sea-based activities including offshore oil and gas exploration, marine fisheries, seabed mining, and undersea cabling. UDA ensures that India's blue economy is protected from sabotage, piracy, or illegal exploitation of its seabed. Take, for instance, the protection of undersea oil pipelines or data cables from destruction or cyber-espionage protection of such subsea infrastructure requires real-time undersea situational awareness.

Additionally, UDA against illegal, unreported, and unregulated (IUU) fishing will help govern the economy and integrity of marine ecology. India, like many coastal states, suffers from pervasive spatial and remorseless poaching by foreign trawlers in their EEZs; foreign trawlers often operate just below the radar. A fully functioning UDA system can help the Indian Coast Guard and Navy counter these threats more quickly.

Technological Sovereignty and Indigenization

Most of the sonar and ocean surveillance systems in use worldwide are tailored for temperate or cold waters, and therefore have limited performance in tropical waters such as the waters around India. Therefore, the need for indigenous technological development is crucial. India's own efforts including that of the DRDO with its UDA project, and partnerships with academic institutions such as IIT Delhi and NIOT will be instrumental in creating next-generation seas solutions for acoustic propagation in the Indian theatre. Examples of indigenous AUVs like MAYA and AMOGH are on this path.

Likewise, developing UDA technologies allows India to move away from foreign defense systems, and focus on self-reliance under the Atmanirbhar Bharat program, and gain strategic autonomy in maritime domains.

Geopolitical Influence in the Indo-Pacific

India's identity as a net security provider in the Indo-Pacific depends on its ability to assure maritime domain awareness of ship and potentially subsurface situational awareness. As part of multilateral engagement like the Quad (India, U.S., Japan, Australia), India can also offer its UDA infrastructure and partnerships to

[4] https://www.orfonline.org/research/chinese-warships-in-the-indian-ocean-are-they-a-real-threat

smaller Indian Ocean island nations with limited resources and capability to monitor their waters, enhancing India's soft power and legitimacy as a regional actor.

There are additional parameters to unilateral underwater surveillance exercises, including collective undersea surveillance initiatives and interoperability for UDA data-sharing platforms, as well as shared or multi-national strategic oceanography and oceanographic research with allies and partners.[5]

In conclusion, UDA was an option several years ago but certainly is not an option now; UDA is the basis of maritime superiority in the 21st century. The basis for national security, economic security, and technological independence, as well as a path to shaping geopolitics in the Indo-Pacific is the Underwater Domain Awareness.

3. Legal and Policy Frameworks Governing UDA

With India's burgeoning maritime interests, the legal and policy framework to enable Underwater Domain Awareness (UDA), is embryonic and fragmented. UDA - a strategic capability related to the detection, identification and analysis of underwater threats and phenomena - is inherently cross-disciplinary, straddling militarized strategy, environmental science, international law and technology governance. The Indian legal and policy framework has yet to evolve a meaningful integrated space to converge these areas. Presently, although some of the legal infrastructure deals with maritime and defence concerns, it lacks the uniformity and specific constructs needed to manage UDA coherently or in a future-oriented way.

Lack of a Centralised and Comprehensive UDA Legislation

The lack of a dedicated legal regime for UDA is one of the most significant challenges. India has a fragmented set of laws which only indirectly regulate underwater activities.These include:

- **The Territorial Waters, Continental Shelf, Exclusive Economic Zone and Other Maritime Zones Act, 1976**
- **The Indian Navy Act, 1957**
- **The Indian Coast Guard Act, 1978**
- **The Environmental Protection Act, 1986**
- **The Marine Aids to Navigation Act, 2021**
- **The Merchant Shipping Act, 1958**

[5] https://thediplomat.com/2024/04/india-as-a-net-security-provider-in-the-indo-pacific-ambitious-but-attainable/

Although these laws regulate different areas of maritime zone regulation, naval powers, environmental issues, and shipping, they do not explicitly address underwater acoustics, subsea surveillance, or cross-domain data fusion. As there is no key UDA law, operational gaps and ambiguity result between departments.

Multiplicity of Stakeholders and Lack of Coordination

UDA in India is the responsibility of government organizations: the Indian Navy and Coast Guard, the Ministry of Defence, the Ministry of Earth Sciences, the Defence Research and Development Organisation, the National Institute of Ocean Technology, the Indian Space Research Organisation (ocean satellites), and the Ministry of Environment, Forest and Climate Change. These often work alone, with no real-time data sharing, no standard for communications interchange, and no actual legal accountability.

For instance, the Navy may collect sonar data for strategic use, while the MoES may utilize similar tools for climate studies. When no legal responsibility exists for harmonized capability, or any legal requirement for joint use of data, this operational isolation results in an unwarranted duplication of effort and wasted strategic opportunity.

Insufficient Protection for Critical Underwater Infrastructure

Indian subsea infrastructure — international submarine cables; oil and natural gas pipelines; offshore energy platforms, including rigs; surveillance arrays; and autonomous underwater systems — is increasing rapidly. Unfortunately, there is no single statute or policy that would give adequate protection, legal status, liability, or insurance for such assets.

Legislation like the Cable Television Networks (Regulation) Act or the Telegraph Act does not place adequate emphasis on the underwater facets of these structures, particularly in the case of sabotage, surveillance infringement, and infrastructure damage from climate components. While underwater infrastructure is an attractive target because of possibilities for state-sponsored works, and increases in hybrid and cyber threats, and, among its valuable assets, India's "subsea," if you will, assets do not have the legal regime to articulate and enforce laws against these attacks.

Weak Environmental Regulations for Underwater Activities

The Environmental Protection Act, 1986 and relevant laws such as Coastal Regulation Zone (CRZ) notifications are broadly prepared for coastal and terrestrial regulations. There are no specific environmental impact or acoustic limits governing sonar use, subsea and underwater projects, and seabed mining in India. India's legal context does not currently consider underwater noise pollution from military sonar, shipping, subsea drilling and other human activations, which notably impact marine biodiversity. Furthermore, India lacks clear licensing, monitoring, and grievance mechanisms for private actors in marine technology and data collection.[6]

Gaps in Alignment with International Maritime Law

[6] https://research.csiro.au/iora-blue-carbon-hub/wp-content/uploads/sites/321/2022/02/seagrass_out-of-the-blue-compressed.pdf

India is a party to the United Nations Convention on the Law of the Sea (UNCLOS), but its domestic incorporation is partial and often dated. For example:

- India's 1976 Act does not fully integrate UNCLOS Part XI provisions on seabed mining.
- Maritime zone claims under Article 76 of UNCLOS regarding continental shelf extension are still under process.
- India has limited engagement with international forums like the International Seabed Authority (ISA) or regional agreements on acoustic research and environmental monitoring.

This lack of proactive legal diplomacy undermines India's ability to influence international norms on underwater activities and secure its long-term maritime interests.

Absence of Legal Provisions for Acoustic Surveillance and AI Technologies

Today's UDA is highly dependent on technology, such as passive sonar arrays, autonomous underwater vehicles (AUV), satellite-linked buoys, and artificial intelligence-based pattern recognition. Across these technologies are complex legal issues related to:

- Data ownership in multi-agency setups
- Jurisdiction over shared sonar networks
- Cybersecurity protocols for underwater digital systems
- Liability for malfunction or misinterpretation of autonomous sensors

There is currently no legislative process in the Indian legal system which governs the ethical, privacy or security aspects of these types of technology, and both the Information Technology Act 2000 and any amendments thereto fail to address subsea data governance issues.

Policy Vacuum on Capacity Building and Indigenous Innovation

While India's Maritime India Vision 2030 and Blue Economy Policy Draft (2021) indicate a focus on ocean-based growth, they do not mention UDA explicitly. Furthermore, there is no legal requirement for making strategic investments in indigenous UDA-based R&D, or skills development, or for making legally binding arrangements for public-private partnerships in this niche sector.

India's reliance on foreign sonar systems and deep-sea technology has not been legally regulated, leaving the country susceptible to supply chain issues and backdoor spying.

4. Technological Advancements in UDA

Underwater Domain Awareness (UDA) is a vital aspect of national security, ocean resource management, and a driver for strategic deterrence in the 21st century. Considering India's increasing maritime footprint and threats in the Indo-Pacific region - in particular adversarial naval activities - UDA has changed from a naval requirement to a national imperative. As such, technological development is key to creating strong UDA capabilities; there is no better way to enhance surveillance and intelligence systems than through technology. Technologies ranging from passive sonar networks to autonomous systems and artificial intelligence (AI)-driven data analysis are changing India's ability to conduct underwater surveillance and provide oceanic intelligence.

Sonar Technology and Acoustic Monitoring

Sonar (Sound Navigation and Ranging) remains the backbone of underwater detection. India has traditionally depended on imported sonar systems, but recent efforts toward indigenization have yielded progress.

- The DRDO's NPOL (Naval Physical and Oceanographic Laboratory)[7] has developed indigenous sonar systems like USHUS for submarines and PANCHENDRIYA[8], which offer capabilities like detection, tracking, and underwater communication.

- Long-range passive sonar systems like fixed seabed hydrophone networks play a critical role in low-frequency acoustic detection of underwater threats, particularly submarines. India is, however, still in early stages of developing long-range passive networks with such like the US and China like SOSUS.
- Towed array sonar and variable depth sonar (VDS) are being integrated into frontline naval platforms, but mass deployment is still limited due to high cost and integration challenges.

Future advancements could focus on distributed acoustic sensing using fibre-optic cables to convert existing infrastructure into sensing platforms for stealth surveillance.

Autonomous Underwater Vehicles (AUVs) and Unmanned Systems

The next generation of underwater monitoring is being led by autonomous and remotely operated vehicles**.** These systems offer persistent presence, data collection, and modular payload deployment without risking human life.

- India has started developing AUVs such as Maya, Matsya, and Samudra, with payloads for oceanographic data, surveillance, and mine detection.

- ISRO, DRDO, and NIOT (National Institute of Ocean Technology) are collaborating on deep-sea AUV projects that can operate at depths up to 6,000 meters.

[7] https://www.drdo.gov.in/drdo/labs-and-establishments/naval-physical-oceanographic-laboratory-npol

[8] https://drdo.gov.in/drdo/index.php/panchendriya

- The Indian Navy has issued procurement plans for Unmanned Underwater Vehicles (UUVs) with applications in ISR (intelligence, surveillance, and reconnaissance), seabed mapping, and anti-submarine warfare.

The key technological challenges include battery life, communication latency, autonomous navigation algorithms, and payload miniaturization. Integration of AI and machine learning in path-planning and anomaly detection is an emerging area of innovation.

Satellite-Ocean Data Linkages and Remote Sensing

While UDA is mostly sub-surface, satellite-based oceanographic monitoring enhances the capability to predict underwater behavior through surface indicators like thermal anomalies, salinity gradients, and chlorophyll concentrations.

- ISRO's Oceansat-2 and 3, and upcoming NISAR mission (with NASA) provide high-resolution data useful for interpreting undersea environments.

- Satellite-AUV data fusion is being explored to predict thermocline layers that affect sonar propagation — a critical factor in naval warfare.

- India's Ocean Information and Forecasting System (INCOIS)[9] helps with real-time ocean monitoring but lacks military integration.

India needs to develop dual-use ocean satellites and link them in real time with naval command centres for strategic advantage.

Artificial Intelligence and Big Data Analytics

The underwater environment generates massive and complex datasets, particularly from sonar, bathymetric sensors, underwater drones, and remote sensing systems. Traditional methods of analysis are no longer sufficient.

- DRDO and MoES are now incorporating AI/ML models to detect patterns in sonar noise, classify marine life vs. vessel signatures, and predict undersea object movements.

- AI-enabled platforms can help fuse acoustic, seismic, and magnetic data, improving detection of stealth submarines and UUVs.

[9] https://incois.gov.in/portal/osf/osf.jsp

- Use of neural networks, reinforcement learning, and edge computing is gradually expanding in India's defence tech sector.

The challenge remains the lack of annotated training datasets, real-world testing environments, and access to deep-sea data repositories. Additionally, India must focus on cybersecurity protocols for AI systems operating in underwater conditions.

Smart Underwater Infrastructure and Cable Monitoring

India is heavily dependent on undersea fibre-optic cables for internet and strategic communications. With UDA expansion, these same cables are now being seen as dual-use assets for sensing purposes.

- Advanced technologies allow these cables to be retrofitted with sensors that detect vibrations and acoustic anomalies — essentially turning the seafloor into a "listening grid."

- India can collaborate with telecom companies and ISPs to develop Smart Cables for both civilian and strategic surveillance applications.

Efforts must be made to **secure these cables** from sabotage, while enabling their use for UDA in a legally regulated and technically robust manner.

6. Acoustic Camouflage and Stealth Technologies

As underwater warfare becomes more competitive, developing quiet propulsion systems, noise reduction coatings, and magnetic shielding becomes critical.

- India's Project-75(I)[10] and future submarine acquisitions are now focused on integrating air-independent propulsion (AIP) and quiet hull design to evade enemy sonar.

- Research into biomimicry (e.g., fish-inspired silent propulsion) and meta-materials for sound wave absorption is ongoing at institutions like IITs and DRDO labs.

Such technologies will not only enhance India's stealth but also improve its own detection resistance — a critical balance in underwater warfare.

[10] https://www.navalnews.com/naval-news/2025/01/indian-navys-p75i-submarine-program-progresses/

5. Challenges in Enhancing Underwater Domain Awareness (UDA) in India

Underwater Domain Awareness (UDA) is a key issue in India's maritime security architecture, especially in light of foreign submarines and underwater drones increasingly operating within the Indian Ocean Region. However, India has certain issues that limit its ability to support a comprehensive and effective UDA framework.

One of the issues relates to technology. India still relies a lot on foreign technologies to provide critical underwater surveillance technology components, such as modern sonar systems and unmanned underwater vehicles (UUVs). The Defence Research and Development Organisation (DRDO) and the National Institute of Ocean Technology (NIOT) have produced some indigenous solutions, but in general, resource constraints, timelines, and deployment are often a challenge. Continuous deep-sea surveillance technology is inherently long-endurance autonomous systems that require sophisticated sensors able to detect low-frequency quiet sounds. India's present capacity to do so is still in its early stages. Furthermore, ai and ml capabilities are necessary to give large amounts of acoustic data meaning so that it can differentiate between a real threat and benign underwater noise —an area of technology which India has not successfully developed[11].

Institutional fragmentation exacerbates the technological divides. UDA involves collaborations among an overwhelming number of actors including the Indian Navy, DRDO, ISRO, Ministry of Earth Sciences, and most of the available civilian research organizations. However, the overall lack of a unified command or coordination mechanism leads to fragmented data silos where valuable underwater data exists untouched or is replicated across different bodies. Joint operations become bogged down by bureaucratic turf wars or by undefined mandate. And join efforts toward establishing an effective and encompassing MDA system that also serves underwater surveillance have been delayed. Because there is no central coordinating authority, India's underwater surveillance capacity remains scattered and ineffective.

The separation between civilian use and military use of underwater infrastructure presents another barrier. Most of the oceanographic research infrastructure in India, research vessels and seabed sensors, focuses on scientific or commercial considerations. The civilian use of any submarines or underwater surveillance capacities does not have military lead agents to utilize. The potential strategic value of these capabilities decreases due to civilian purposes and minimal military uptake of civilian activities. In has been noted that other maritime powers invest in developing partnerships between public and private sectors to capitalize on dual-use technologies. Private partnerships are rare in India's underwater domain due to regulatory challenges and procurement complications. Consequently, the civil-military divide in underwater operations in India means that there is limited capacity to take use what exists, or innovate or sustain capacity.

Financial limitations also aggravate India's UDA development. Underwater surveillance technology and infrastructure require large investments of capital. For example, from seabed sensor grids to autonomous underwater vehicles, India would need to make capital investments into these. Furthermore, being limited in investment, India's defense budget tends to focus on either land and air forces, which relegates investment into maritime and underwater capabilities. As a result, research institutions work under constrained budgets, undermining the application of innovative and sustainable technology, investment in well-trained experts, and the conduct of long-term development. Long-term development projects suffer especially from inconsistent funding in terms of delayed start, timeline compression, and/or dumbing down the complexity of projects for

[11] https://drdo.gov.in/drdo/underwater-defence-technologies

survival. Stunted funds diminish India's capability to be able to detect and respond to underwater threats in ways that would otherwise be more effective and efficient.

The legal and regulatory constructs in India, have not kept pace and adapted to the underwater surveillance requirements of the 21st century. The legal frameworks in places as per the Indian Maritime Zones Act implementing the 1976 legislation are not suitable for contemporary underwater surveillance issues such as seabed sensor deployments, data ownership, and military monitoring of civilian infrastructure. Another area of uncertainty relates to privacy issues that could arise from acoustic monitoring of commercial shipping lanes, along with the monitoring of foreign vessels. Until comprehensive legislation is enacted to appropriately govern these activities, the introduction of next generation UDA systems remains highly susceptible to legislative challenges, as it will introduce labour-intensive redundancies to operational efficiency[12].

Environmental features which are characteristic of the Indian Ocean also create operational complexities. A number of factors including changes in salinity, variations in temperature layers, and changes in bathymetric features affect sonar signal propagation and sensor accuracy. More typically, seasonal monsoons lead to sediment disturbances, while extreme weather events, such as cyclones, challenge the physical security of underwater sensor networks. In addition, the vast natural biodiversity of the region generates high levels of acoustic noise. This provides nothing but noise, and limits India's ability to detect potential underwater hydraulic surprises, hence developing and securing effective UDA capability ultimately relies on environmental modelling and sophisticated signal processing. To this end, India remains as a developing country.

Finally, India's ability to further develop UDA is influenced by the strategic and diplomatic environment. China's increasing presence in the Indian Ocean is further demonstrated by military bases on maritime territory and weaponized undersea capabilities, which pose security threats to India. Within a regional context, India is involved with several collaborative frameworks and exercises such as the Indian Ocean Naval Symposium (IONS), Quad and many others, but there is no formal agreement for exchanging underwater surveillance data with any partner. Due to domestic political sensitivities surrounding disputed maritime territory, India is also challenged from deploying surveillance networks in some of the highest risk areas. Establishing regional cooperation frameworks and reaching agreements for underwater domain security with trusted strategic partners, will allow India to maintain its strategic advantage.

India's ability to build its Underwater Domain Awareness is plagued by a complicated web of technological dependence, institutional fragmentation, funding restraints, archaic legal frameworks, environmental barriers and strategic constraints. The capacity to tackle a multitude of challenges requires a coordinated, well-funded, and proactive approach that ties technology together with policy reform and international relationships.

6. Case Studies

INS Sindhukirti Submarine Incident (2014)[13]

- INS Sindhukirti, an Indian Navy submarine, faced operational challenges due to outdated underwater communication and tracking technology.

[12] https://www.icwa.in/show_content.php?lang=1&level=3&ls_id=10959&lid=6965

[13] https://www.bbc.com/news/world-asia-india-23691558

- Highlighted limitations in real-time underwater tracking and coordination between naval assets.
- Exposed gaps in India's ability to monitor submarine activities within its own waters.
- Led to increased focus on upgrading underwater acoustic communication and sensor networks.

Sino-Indian Submarine Movements in the Indian Ocean Region

- Reports of Chinese submarines operating stealthily near Indian waters, including near Lakshadweep and Andaman & Nicobar Islands.
- Demonstrates the strategic challenge posed by a foreign naval presence in India's underwater domain.
- Points to the urgent need for enhanced sonar surveillance and regional data-sharing agreements.
- Reflects India's current limitations in detecting quiet submarines over large ocean areas.

DRDO's Indigenous Autonomous Underwater Vehicle (AUV) Development[14]

- DRDO's attempt to develop and deploy indigenous AUVs capable of long-endurance underwater monitoring.
- Delays and technical hurdles in making the AUVs operational at par with global standards.
- Showcases challenges in domestic R&D and technology absorption in underwater defense tech.
- Emphasizes the gap between India's ambition and actual delivery in high-tech underwater systems.

The Andaman and Nicobar Command (ANC) - Strategic Underwater Surveillance[15]

- ANC's efforts to deploy seabed sensor arrays around key strategic chokepoints such as the Malacca Strait.
- Operational difficulties due to underwater environmental factors such as deep-sea currents and monsoon impacts on sensor maintenance.
- Institutional coordination challenges between ANC, Navy, and civilian oceanographic agencies for data sharing.

[14] https://www.drdo.gov.in/drdo/index.php/autonomous-underwater-vehicle-auv

[15] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2004689

- Illustrates both the strategic importance and practical hurdles in maintaining persistent UDA in contested waters.

Collaboration with France and Japan on Maritime Surveillance[16]

- India's joint exercises and technology-sharing initiatives with France (through the Strategic Partnership) and Japan (within the Quad framework).
- Technology transfer agreements focus on underwater sensors, sonar, and AI-powered data analytics.
- Reflects India's attempt to overcome technological dependence via international partnerships.
- Demonstrates diplomatic and strategic leverage used to enhance indigenous UDA capabilities.

Legal Ambiguities in Underwater Surveillance Operations

- Example: Disputes over installing seabed sensors near international shipping lanes in the Indian Ocean, involving commercial and environmental stakeholders.
- Lack of clear legislation on acoustic data ownership and privacy concerns.
- Demonstrates how unclear regulatory frameworks hamper deployment of advanced UDA infrastructure.
- Case led to policy discussions on updating the Indian Maritime Zones Act and other related law

7. Recommendations and Way Forward for Enhancing Underwater Domain Awareness in India

To address the numerous challenges presently impacting India's Underwater Domain Awareness (UDA) framework, an holistic and integrated system-wide approach would be important. The following recommendations represent strategic, technological, legal, institutional and diplomatic means to significantly enhance India's ability to monitor and safeguard its underwater domain.

Strengthening Indigenous Technological Development

India needs to make a large investment in domestic research and development to reduce reliance on technologies from other countries. Partnering with defense organizations such as the Defense Research and Development Organization (DRDO), higher education levels, and the private sector to allow organizations to quickly develop advanced sonar systems, autonomous underwater vehicles (AUVs), and underwater sensor networks will be extremely beneficial. AI and machine learning perspectives will be important to enhance threat accuracy, among other priorities. Commitments to long-term funding, too, while engaging the increasingly popular fast-track of the prototype-to-deployment pipeline will also be important.

Establishing a Unified Command and Coordination Mechanism

[16] https://capsindia.org/india-france-partnering-in-the-indo-pacific-positioning-japan/

Due to the many players involved in UDA--such as the Indian Navy, civilian oceanographic agencies, and agencies that perform space research--it is critical that India set up a centralized command or authority to lead underwater surveillance responsibilities. Not only would it reduce potential redundancy in the collection and analysis of data and reporting to multiple organizations, it would help with reporting to multiple organizations and ensure nations are overseeing the deployment of their resources. A national UDA center could work with the MDA arrangements that are already in place to facilitate total surveillance operations--both at the sea surface and subsea surface.

Enhancing Civil-Military Integration and Public-Private Partnerships

he Indian state should prioritize the military use of civilian maritime infrastructure for purposes of surveillance. If India creates frameworks around data sharing, working together in a collaborative way and transferring technology between the defence area of responsibility and civilian research institutes, India would be able to multiply its surveillance tractability and capacity without overlaps in activity. Moreover, by involving the private sector while taking advantage of the innovation, flexibility, and cost savings the adoption of civilians' infrastructure and the tech enhances civilian sectors in designing, developing, and operating technology can provide. However, this would take well-articulated regulatory policies and incentives to prompt private sector investment.

Updating Legal and Regulatory Frameworks

India needs to take immediate action in reforming its maritime laws, in order to support 21st century UDA, clarifying issues regarding jurisdiction over underwater sensors, data privacy, environmental impact assessments, and the use of civilian infrastructure for defense purposes. Good legal frameworks provide operational certainty, enhance stakeholder collaboration, and reduce litigation risks. Furthermore, India should align its policies with international maritime law, in order to make the UDA that India undertakes in conformity with international legal norms, but the law also coincides with India's national interests.

Building Regional and International Partnerships

Maritime security in the Indian Ocean is both regional and global. India needs to leverage the capability of intelligence sharing and collective surveillance with friendly nations and continue this cooperative partnership through forums like the Indian Ocean Naval Symposium (IONS), through cooperative forums like the Quad, and through bilateral agreements with nations such as France, Japan, and Australia. Collaborative underwater monitoring will create maritime situational awareness for India outside its territorial waters and establish a deterrent against hostile underwater actions.

Addressing Environmental and Operational Challenges

To address the challenges presented by the Indian ocean's complicated underwater features and changing situations, investment in innovative environmental modelling along with adaptive sensor technology will be essential. Investigating acoustic signal propagation under environmental conditions that change based on salinity, temperature and weather will allow sonar effectiveness to improve. Developing sensor networks that are resilient against the impacts of monsoons and degree of seabed disturbance will provide constant underwater monitoring opportunities.

Developing Skilled Human Capital and Training Programs

The success of UDA relies on talented personnel who are not only able to use advanced underwater surveillance equipment, but also have the ability to analyze advanced data. It is critical to grow the specialized training capacity in India at naval academies, research institutes, and technical universities for underwater warfare, acoustic engineering, and data science. Further, retaining talent to sustain capability development in the long-run, will depend on providing competitive salaries and career development opportunities.

Securing Dedicated and Sustained Funding

Improving UDA entails significant and sustained investment. Defense budgets should provide funding lines for UDA underwater surveillance technology development, infrastructure deployment, and maintenance. Long-term planning will provide meaningful continuity for projects that can last years. New and creative funding models, including public-private partnerships and international grants, could be unlocked to enhance Government funds.

India's ability to leverage underwater domain awareness depends on a combination of technological innovation with strong institutional coordination, legal reform and strengthening international collaboration. By proactively dealing with both internal limitations and external challenges, India can reposition its underwater surveillance related options into a significant strategic asset that protects its maritime interests in a more contested and complex oceanic environment.

8. Conclusion

Underwater Domain Awareness (UDA) has become a fundamentally important aspect of India's maritime security as we progress through the 21st Century, signaling the increasing strategic importance of the Indian Ocean Region. The paper has discussed the varying challenges for India creating a UDA framework, including: technological limitations; environmental concerns; legal issues; and fragmentation of institutional actors. As India’s maritime interests expand and potential adversaries increase in the IOR, credible underwater surveillance will be crucial to continued national security, the protection of our economic assets and to furthering our regional influence.

Strategically, India will need to increase its abilities to detect, track and respond to underwater threats, including foreign powers' submarines and underwater drones. Technological solutions, through developing indigenous autonomous underwater vehicles, advancing sonar technologies and developing AI enabled data analysis, offer potential means of achieving this aim. However, the development of these technologies must be part of a more integrated institutional approach that enables greater cooperation between the Navy, civilian agencies and the private sector.

It is also imperative to pursue both legal and policy reforms to help create a clear expectation of regulation and support for the deployment and operation of underwater surveillance without compromising environmental and commercial concerns. Moreover, regional cooperation and international partnership is likely to improve actionable situational awareness for India beyond the confines of its territorial waters, and to help build a collective security architecture in the context of the Indian Ocean region.

Lastly, operational challenges such as poor underwater environmental conditions and human resource development will need to be solved to maintain an effective UDA capability. Accordingly, regular funding,

skilled personnel, and support for ongoing research will help give India's underwater surveillance infrastructure the strength to remain flexible and relevant.

To summarise, a holistic, multi-faceted response to the challenge of India's intention to emerge as an underwater power, safeguard its maritime interests in an increasingly contested ocean, with advancing technology at its disposal—and not least the potential for collaboration and cooperation—is necessary.

9. References

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