Marine Spatial Planning – A New Perspective Based on the Underwater Domain Awareness (UDA) Framework

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Introduction

The Indian Ocean Region (IOR) has become a significant theater for geopolitical and geo-strategic interactions in the 21st century. Nations, both within and outside the region, are deploying strategic assets in this region.It is the Indo part of the Indo-Pacific strategic space, which is largely defined as the tropical littoral waters of the Indian Ocean and the Pacific Ocean. The tropical waters present unique challenges and opportunities- politically, economically, and physically, thus any attempt at governance must account for the unique tropical characteristics[1].

Marine Spatial Planning (MSP) is perhaps the most effective tool for managing the challenges and opportunities in marine and freshwater systems. It involves precise mapping of the resources, their quality & availability, concerns of security & sustainability as well as many more. This information can really help in their effective and efficient exploitation. MSP can also serve as a valuable tool for exploration and deploying policy and technology interventions in vast marine and freshwater systems.. All kinds of policy & technology interventions can be deployed using MSP in vast marine and freshwater systems[2].

The Maritime Domain Awareness (MDA), became a popular concept in all the strategic interactions in the 21st century. Following 9/11 event in the US and the 26/11 event in India were the two main triggers for the rapid infrastructure and capacity building initiatives globally to ensure MDA. However, being an event driven concept, it remained limited to the security community and restricted the participation of the other stakeholders, namely blue economy, disaster management and science & technology. The democracies can never allocate infinite resources to one stakeholder at the cost of others[3].

It may be important to remind the readers that the maritime domain is more than 90% below the the water's surface and theand the current MDA has limited sub-surface penetration. The scientific community knows more about space than the underwater world, making Underwater Domain Awareness (UDA) an unknown and overlooked area of knowledge. Given the significance of the maritime domain, the

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[1]Paul C Etter, "Underwater Acoustic Modelling and Simulation", Fourth Edition, CRC Press, 2013, Taylor and Francis Group.

[2]https://ioc.unesco.org/our-work/marine-spatial-planning.

[3]Cdr Steven C. Boraz, U.S. Navy, "Maritime Domain Awareness Myths and Realities", Naval War College Review, Summer 2009, Vol. 62, No. 3.

global community cannot afford to disregard UDA any longer. The ongoing MDA has remained on surface and non-inclusive on several fronts[4].
The UDA framework proposed by the Maritime Research Center (MRC), Pune is a unique concept to address multiple challenges and opportunities in the tropical waters of the Indo-Pacific and beyond. Pooling of resources and synergizing of efforts is being encouraged by the UDA framework which will certainly overcome the resource limitation of the developing nations and also mitigate the fragmentation among the stakeholders. The UDA framework has the technology driven digital transformation at its core, which can enhance MSP and enable better management of the Indo-Pacific construct.

Indian Ocean Region (IOR)

The IOR has multiple aspects that require customized and nuanced approach to manage the challenges and opportunities. The socio-political and socio-economic situation makes it the most vulnerable in terms of security and sustainability. Fragmented politics and instability allows the extra-regional powers to meddle into the domestic politics, making governance a major concern. Resource constraints always limit the ability to build futuristic capabilities resulting in a constant struggle to catch up. The rich socio-cultural heritage has been completely ignored at the behest of the west and thus the traditional knowledge is being replaced by the modern know how imported from the west. Aspirational young people are disillusioned with the slow and erratic governance mechanism, and non-state actors are exploiting this by misleading them into unlawful and terrorist activities[5].

The tropical waters present sub-optimal sonar performance, when deployed in these waters compared to the temperate and polar region. Thus, the sonars imported from the west suffer over 60% degradation in their performance, when deployed here. The UDA in these waters, require a significant amount of local indigenous effort and making it challenging to rely on imported equipment and know-how. The siltation in the tropical waters, again show unimaginable intensity and erratic flow. Thus, water resource management, port management, navigability of the waterways, water quality management and more need to be addressed, keeping in mind the unique tropical conditions. The sediment management across varied applications require site specific and customized approach, and indigenous effort is inescapable[5].

India has been one of the oldest civilization globally, that dates back over 10,000 years and we have been a known maritime power in the past. Our civilization has

[4]Lt Donald B. Davis, USCG Guard Reserve, Port Clinton, Ohio"The Submersible Threat to Maritime Homeland Security" Master of Arts in Security Studies (Homeland Security and Defence), The Naval Postgraduate School,Sep 2013.

[5]Arnab Dasand D.S.P. Varma, Ocean Governance in the Indian Ocean Region – An Alternate Perspective, Maritime Affairs, 2015, pp. 1–19.

historically managed water-related challenges with great success, and we have been a respected source of shipbuilding and seafaring knowledge for the global community. We have had very matured waterway systems across our rivers and the navigability has been traditionally managed with high levels of local knowledge, passed down across generations. However, economic growth and prosperity made us vulnerable to invasion and subjugation by European powers, resulting in our downfall. The industrial revolution happened during that period and we really missed the bus. Fragmentation was the cause of our downfall and we continue to remain fragmented geopolitically in the region[6].

The tropical waters of India present rich biodiversity and unimaginable mineral resources undersea while the freshwaters are abundant in the underwater resources, both living and non-living. The effective & sustainable, exploration & exploitation of these resources, will require a nuanced approach, driven with utmost political and economic sincerity. There has been significant announcements and display of political intent, however the nuanced approach on the ground is still to be demonstrated. The Security And Growth for All in the Region (SAGAR) vision and the associated mega projects, like Sagarmala, Bharatmala, Inland Water Transport, Gati Shakti, Deep Sea Mission and more are some such measures. MSP will remain the core and deserves attention[5].

Marine Spatial Planning

Marine Spatial Planning (MSP) is a data driven process of generating a spatio-temporal real-time appreciation of our marine areas to optimize the human interactions and achieve ecological, economic and social objectives that have been specified through a governance process.

It is not an end goal, but a practical and scientific way to create a more rational use of marine space and the interactions among the components of the ecosystem, to balance requirements of people, economy and nature. The marine areas are not the only critical elements, however the freshwater systems are equally critical and demand equal attention. The tropical waters today are at the cusp of an unimaginable churn, if not managed well, can be getting into an unstoppable downward spiral.

The real-time MSP in the tropical waters requires significant acoustic capacity & capability building due to the sub-optimal sonar performance. Surface and the sub-surface mapping requires a deep understanding of acoustic propagation characteristics to generate the spatio-temporal inputs. Innovative prediction tools backed by digital signal processing algorithms are required to manage this digital transformation. Given the vast Indian Ocean Region we need to manage, both for

[6]David Michel and Russell Sticklor, Indian Ocean Rising: Maritime Security and Policy Challenges, Stimson, Jul 2012. Available at http://www.stimson.org/images/uploads/research-pdfs/Book_IOR_2.pdf.

marine and freshwater systems, digital transformation is the only viable option for MSP.[7].

Managing the diversity of requirements is a significant challenge. This diversity includes people and their practices, stakeholders and their interactions with the ecosystem, species diversity and their interactions, as well as ecosystem diversity itself, which must all be considered to ensure sustainability and efficiency. Attempting to manage each diversity individually will inevitably fail at the design stage. Instead, we need to identify certain cross cutting parameters that can represent multiple conditions to monitor the health of the ecosystem. Signal processing algorithms can then connect the diverse applications and components of the ecosystem to assess the impact. To achieve this, the Environmental Impact Assessment (EIA) must be inclusive and be backed by a detailed MSP construct[8].

The current MSP initiatives overlook the extensive and deep underwater domain. The underwater domain awareness by construct, require acoustic capacity and capability for effective MSP implementation. The acoustic propagation underwater largely depends on temperature, density and pressure which impacts the Sound Velocity Profile (SVP). Variations in the acoustic signal can be picked up to classify any deterioration or improvement of the underwater conditions. To draw reliable conclusions, the signal fluctuations due to actual source condition and medium distortions must be distinguished. Therefore, in the tropical waters, medium distortions, which are a primary source of signal corruption, must be addressed before any data analytics attempts. To manage the challenges and opportunities of tropical waters, a focused initiative on acoustic capacity and capability building, supported by site-specific local field experimental research and development, is urgently needed[9].

Case Study

To illustrate these challenges and opportunities, we discuss a few case studies. Generating real-time spatio-temporal maps presents various issues, in terms of availability of inputs and providing actionable inputs to users with diverse requirements. The diversity of applications and the user requirements makes it extremely complicated to formalize the final form of the deliverables. To illustrate these challenges and opportunities, we discuss few case studies to provide a representative case[10].

The fig. 1 below, is the real-time low frequency ambient noise map generated using the Automatic Identification System (AIS) database. The entire region is divided into

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[7]Arnab Das (2019) Underwater radiated noise: A new perspective in the Indian Ocean region, Maritime Affairs: Journal of the National Maritime Foundation of India, 15:1, 65-77, DOI**:** 10.1080/09733159.2019.1625225.

[8]Arnab Das, "Marine Eco-concern and its Impact on the Indian Maritime Strategy," Journal of Defence Studies, Vol 8, No. 2, Apr 2014.

[9]Chapter 1 of https://www.icwa.in/pdfs/IndoPacificOceansInitiative.pdf.

[10]Arnab Das (2016), "Impact of Maritime Security Policies on the Marine Ecosystem", Maritime Affairs: Journal of the National Maritime Foundation of India, 12:2, 89-98.

grids of one degree latitude and longitude and the shipping traffic in each grid is evaluated. The static (draught, tonnage, machinery details, machinery layout and more) and dynamic (speed, course, location and more) shipping data is extracted from the AIS database to drive the algorithms for computing the radiated noise at source. The environmental and underwater medium parameters were further extracted from online open source databases to compute the real-time underwater channel models for Indian Ocean's tropical waters. The noise at source and the underwater channel model were combined to generate the real-time low frequency ambient noise map as shown in fig. 1 below. Although, the figure below, only shows the two dimensional map and a single frequency of 300 Hz, the actual mapping was done for a 3D scenario and for all frequencies from 50 Hz to 2000 Hz at 1 Hz resolution, and can be generated for any resolution and any spectral range, as required. The ambient noise below 2 kHz is understood to be dominated by shipping noise.

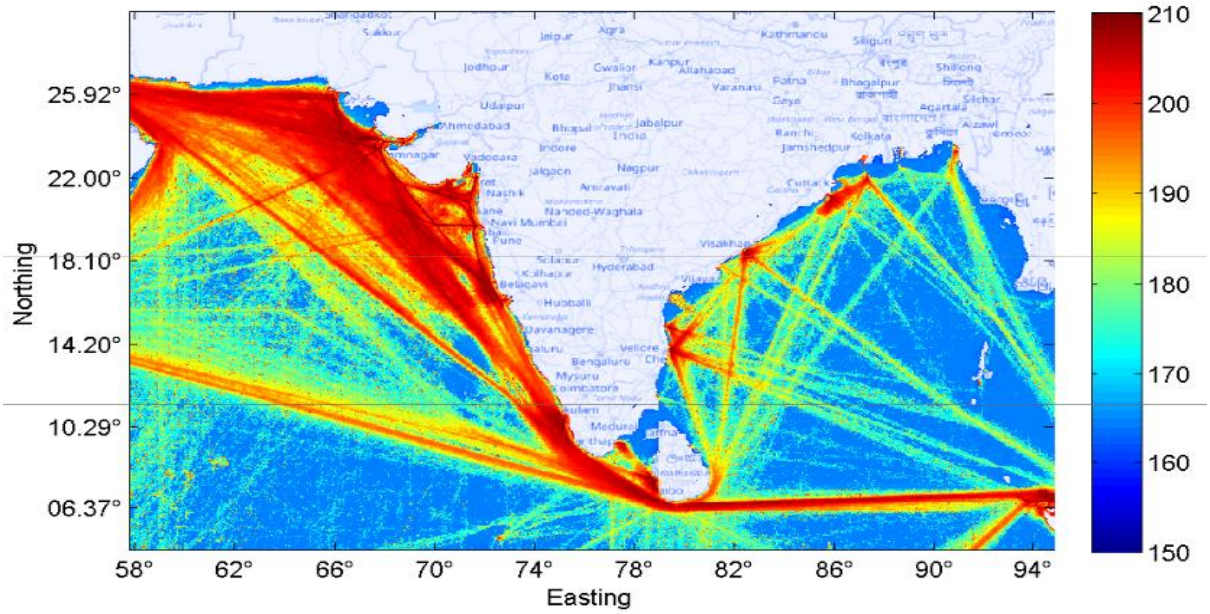

Fig. 1 Spatio-temporal Low Frequency Ambient Noise Mapping

One can see the vast variation in the distribution of low frequency ambient noise, however it follows the shipping traffic pattern to explain the distribution. It is important for us to appreciate that this real-time spatio-temporal map can be used for multiple interventions including the following:

(a) Policy and technology interventions are needed to address high levels of acoustic habitat degradation in ecologically sensitive areas for managing sustainable shipping. Mapping of these areas can guide interventions such as diversion of shipping traffic and use of quieter propulsion technology.

(b) It provides a realistic appreciation of the qualitative and quantitative acoustic habitat degradation analysis for any kind of political and economic interventions. Real data driven interventions are always inclusive and enhance the governance mechanism.

(c) Real-time digital transformation enables effective cause & effect analysis of operational interventions and long term noise quietening effort. The multiple

proposals for quietening methods can be objectively evaluated in the real world using this tool. Even long term prediction of trends and corresponding interventions can be effectively managed using such tools.

(d) The spatio-temporal ambient noise map can be used to compute Signal-to-Noise Ratio (SNR) computation for deploying underwater sensor in the region. Such real-time and long term digital data availability will allow significant inputs for system design and deployment effectiveness.

The fig. 1 and fig. 2, can be corroborated to justify the increasing stranding of big whales and the serious acoustic habitat degradation prevalent in the west coast of India. A recent report revealed over 80 big whale stranding in the Maharashtra coast alone. It was not expected that big whales would be seen along the 720 km of the Maharashtra coast over the last 100 years. However, in the last decade, due to piracy in the Somalia coast, there has been a diversion of shipping traffic towards the coast, resulting in severe acoustic habitat degradation.

Fig.2 Recent Marine Mammal Stranding along the Indian Coast.
Left: 42 ft Blue Whale Stranding off the Alibaug Coast in Jun 2015.
Centre: 50 ftBryde Whale Stranding off the Mumbai Coast in Jan 2016.
Right: 90 Short-Finned Pilot Whales Stranding off Tuticorin Beach in Sep 2016.

Policy interventions are urgently required; however in the absence of nuanced cause and effect analysis, such interventions become difficult. The vested interest groups are able to build narratives that mislead the policy makers and local communities.
The proposed effort has multiple innovative contributions for real impact on governance and technology development as follows:

(a) The multi-dimensional use of AIS data optimizes the existing system and allows for cost effective scaling up of this model globally.Democratizing such massive public infrastructure enhances its own quality and expands its use beyond narrow security purposes

(b) The addition of a local tropical underwater channel model is a significant addition which brings focus into the tropical waters and the Indo-Pacific region. The west driven global policy initiative will become more inclusive and allow more realistic participation by the local players.

(c) Digital transformation with a focus on acoustic signal processing enables greater science and technology inclusion in policy interventions and governance mechanisms. However, the cost optimization will democratise entire global policy formulation.

(d) The International Maritime Organization's (IMO) recognition of unique tropical characteristics and consideration of a regional framework with local site-specific aspects for policy formulation ensures inclusive governance mechanisms.

(e) Real-time data-driven quantitative and qualitative analysis of local site specific inputs along with acoustic capacity and capability building, will facilitate effective policy and technology interventions.

Similar spatio-temporal maps can be generated for the local coastal and riverine communities involved in traditional practices such as pisciculture, aquaculture, seaweed farming and many more.These tools can improve policy and operational interventions and help manage business models, while regulators can use them to monitor long-term sustainability impact and derive MSP outputs. Development of micro and macro MSP tools across the 3D underwater region using digital tools is necessary.

Underwater Domain Awareness (UDA) Framework

The concept of Underwater Domain Awareness (UDA) in a more specific sense will translate to our eagerness to know what is happening in the undersea realm of our maritime areas and also the freshwater systems. This keenness for underwater awareness from the security perspective, means defending our Sea Lines of Communication (SLOC), coastal waters, waterways and varied waterfront assets against the proliferation of submarines and mine capabilities intended to limit the access to the seas and littoral waters. However, just the military requirement may not be the only motivation to generate underwater domain awareness. The earth's undersea geophysical activities have a lot of relevance to the wellbeing of the human kind and monitoring of such activities could provide vital clues to minimize the impact of devastating natural calamities. The commercial activities in the underwater realm need precise inputs on the availability of resources to be able to effectively and efficiently explore and exploit them for economic gains. The regulators on the other hand need to know the pattern of exploitation to manage a sustainable plan. With so much of activities, commercial and military, there is significant impact on the environment. Any conservation initiative needs to precisely estimate the habitat degradation and species vulnerability caused by these activities and assess the ecosystem status. The scientific and the research community need to engage and continuously update our knowledge and access of the multiple aspects of the undersea domain. Fig. 2, presents a comprehensive perspective of the UDA. The

underlying requirement for all the stakeholders is to know the developments in the underwater domain, make sense out of these developments and then respond effectively and efficiently to them before they take shape of an event.

The UDA on a comprehensive scale needs to be understood in its horizontal and vertical construct. Horizontal construct would be the resource availability in terms of technology, infrastructure, capability and capacity specific to the stakeholders or otherwise. The stakeholders represented by the four faces of the cube will have their specific requirements; however the core will remain the acoustic capacity and capability. The vertical construct is the hierarchy of establishing a comprehensive UDA. The first level or the ground level would be the sensing of the underwater domain for threats, resources and activities. The second level would be making sense of the data generated to plan security strategies, conservation plans and resource utilization plans. The next level would be to formulate and monitor regulatory framework at the local, national and global level.

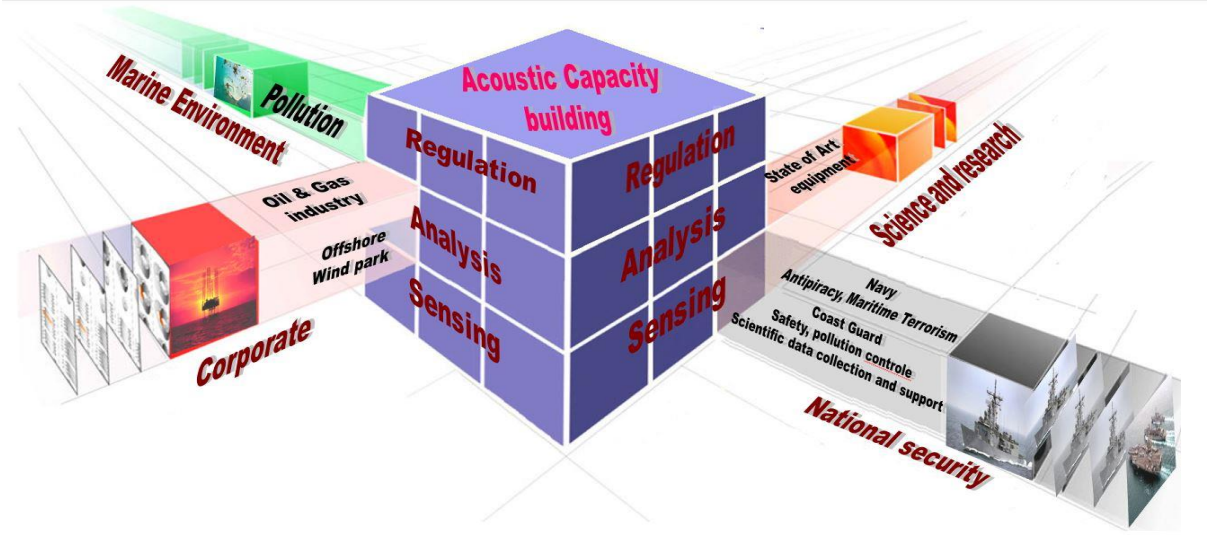

Fig. 2 Comprehensive Perspective of Undersea Domain Awareness

The figure above gives a comprehensive way forward for the stakeholders to engage and interact. Individual cubes represent specific aspects that need to be addressed. The User-Academia-Industry partnership can be seamlessly formulated based on the user requirement, academic inputs and the industry interface represented by the specific cube. It will enable a more focused approach and well defined interactive framework. Given appropriate impetus, UDA framework can address multiple challenges being faced by the global community today. Meaningful engagement of young for building a future probably is most critical aspect that deserves attention. Multi-disciplinary and multi-functional entities can interact and contribute to seamlessly synergize their efforts towards a larger goal.

The UDA Framework as proposed above has been formulated jointly by the Maritime Research Centre (MRC), Pune and M/S NirDhwani Technology Pvt Ltd (NDT). The focus is on all the three aspects- policy and technology intervention along with

acoustic capacity & capability building. More details are available in the MRC website http://foundationforuda.in/mrc/.

Acoustic Capacity & Capability Building

The acoustic capacity & capability building for MSP will include two categories of efforts. First category involves developing prediction maps using online data from multiple open-source databases, which will require substantial computational infrastructure to manage real-time predictions. The seamless connecting of the online database to the hardware running the acoustic signal processing algorithms will be critical. The prediction tools will include underwater acoustic propagation models based on the medium parameters available from open- source online databases. Application specific source prediction will include examples such as Underwater Radiated Noise (URN) or sediment bed load prediction, species specific vocalization or hearing impact assessment and more. Each specific application will have its own input-output matrix that must be carefully addressed. The source-path-receiver model has to be carefully designed and implemented.

Source is the original signal underwater that needs to be analysed. This will include application specific source signal like URN of marine platforms, species vocalization, activity specific signal at source and more. The acoustic characteristics of the source signal must be picked up with finer details.

Path is the medium distortion that is likely to happen during the source signal propagation in the underwater medium. The high resolution underwater channel model with a precise mapping of the medium conditions is critical. Combining the source signal and the path modification is the key to the accurate prediction of the received signal.

Receiver is the victim or the aggressor. The receiver characteristic is equally important to assess the impact of the degradation on the victim. Thus, the entire effective management of the application will be tightly linked to the source-path-receiver model.

A deeper understanding of the source-path-receiver model can also be used to deliberately create a disconnect, and minimize the impact of source on receiver or vice-versa. Path modification could be used to optimize the mitigation strategy across applications. Tropical waters present severe underwater medium distortions and the same can be used for lowering the threshold for URN management or for any concessions to be given to the developing world.

The second category of field validation is more complex and infra-structure intensive. It can be segregated into three stages, namely to see, to understand and to share.

To See - includes the sensors and the platform that will carry the sensor to the site. The acoustic sensors of the required specification will have to be mounted onto the surface and the sub-surface platforms with the requisite manoeuvrability, payload,

endurance, agility and more. These platforms will have to be optimized as per the application requirement. The sensor capabilities and the sensor effectiveness will have to be factored before formalizing the deployment plan for these platforms.

To Understand- translates to the data analysis at multiple levels. The first is the pre-processing to manage the fluctuations and distortions in the data due to measurement system, medium uncertainties, signal processing errors and more. Once the received data is cleaned up for possible errors, application specific data analytics could be planned. This will require deep appreciation of the domain and the application. Even post processing will be useful to provide feedback for future data recording, measurement and analysis inputs.

To Share- is the provisioning of actionable inputs in real-time to the users at multiple levels. The policy makers need to be provided inputs with high analytical aspects, whereas the practitioners on the ground would require inputs in quick and simple format for immediate action. Other associate stakeholders will have to be provided with specific inputs in desired formats. There could be static displays and mobile applications to provide the seamless interface for users to receive actionable inputs.

The acoustic capacity & capability building, specifically for the tropical waters will require focussed approach and sustained efforts.

Conclusion and Way Ahead

The Geographic Information System (GIS) based systems have become very popular these days to manage the Marine Special Planning (MSP) by utilizing mapping tools for surface information. However, the underwater component requires acoustic surveying to manage any kind of sub-surface inputs; especially the tropical waters require highly specialized understanding of local site specific characteristics. Moreover, the ambient noise and underwater channel conditions in tropical waters requires advanced modelling and simulations. Moreover, due to stakeholder diversity and application-specific requirements, MSP governance becomes a complicated exercise.

To achieve comprehensive MSP in the tropical waters of the Indian Ocean Region (IOR), a nuanced approach is necessary. The UDA framework as discussed above can certainly enhance the effective realization of the MSP and corresponding governance mechanism for the entire maritime space. It is well aligned with the global focus on the Indo-Pacific and the regional IOR centric SAGAR vision. The global forums like QUAD and the regional groupings like BIMSTEC, IORA, IOC, IONS and others could build focus on the UDA framework for enhanced MSP. Specific aspects of the larger UDA framework can be identified and progressed with clear agenda and resource allocation. However, given that this is a new concept, it will face a lot of inertia and the following three step formulation will be necessary:

Outreach Aggressive sensitization efforts through webinars, seminars, workshops and other interaction will be required to reach to the stakeholders, policy makers, practitioners and communities. Detailed sensitization will be critical to apprise them of the nuances and relevance of UDA framework.

Engage The sensitization will have to be followed up with identification of specific interest areas and intense engagement with the stakeholders and communities. The engagement will happen at multiple levels, including awarding UDA fellowships to young students seeking career opportunities. The corporates involved in specific areas of blue economy, will have to be presented with the digital transformation aspect of their relevance. The policy makers will have to be provided tools for policy & technology interventions that will help them in their governance activities. The communities involved in exploitation and exploration of the water bodies will have to be provided science & technology tools to enhance their traditional practices. These tools will have to be in sync with the regulatory provisions.

Sustain The final goal will be to build larger policy frameworks at local, national, regional and global levels, aligned with the global trend and collective thinking. To achieve this, long-term and seamless infrastructure for data collection, processing, and nuanced policy interventions must be formulated and executed comprehensively. Global and regional forums must include the UDA framework in their agenda and deliberate. Their secretariats must run sustained projects to provide regular updates to the leadership to formalize the structured policy framework that is inclusive and politically viable.