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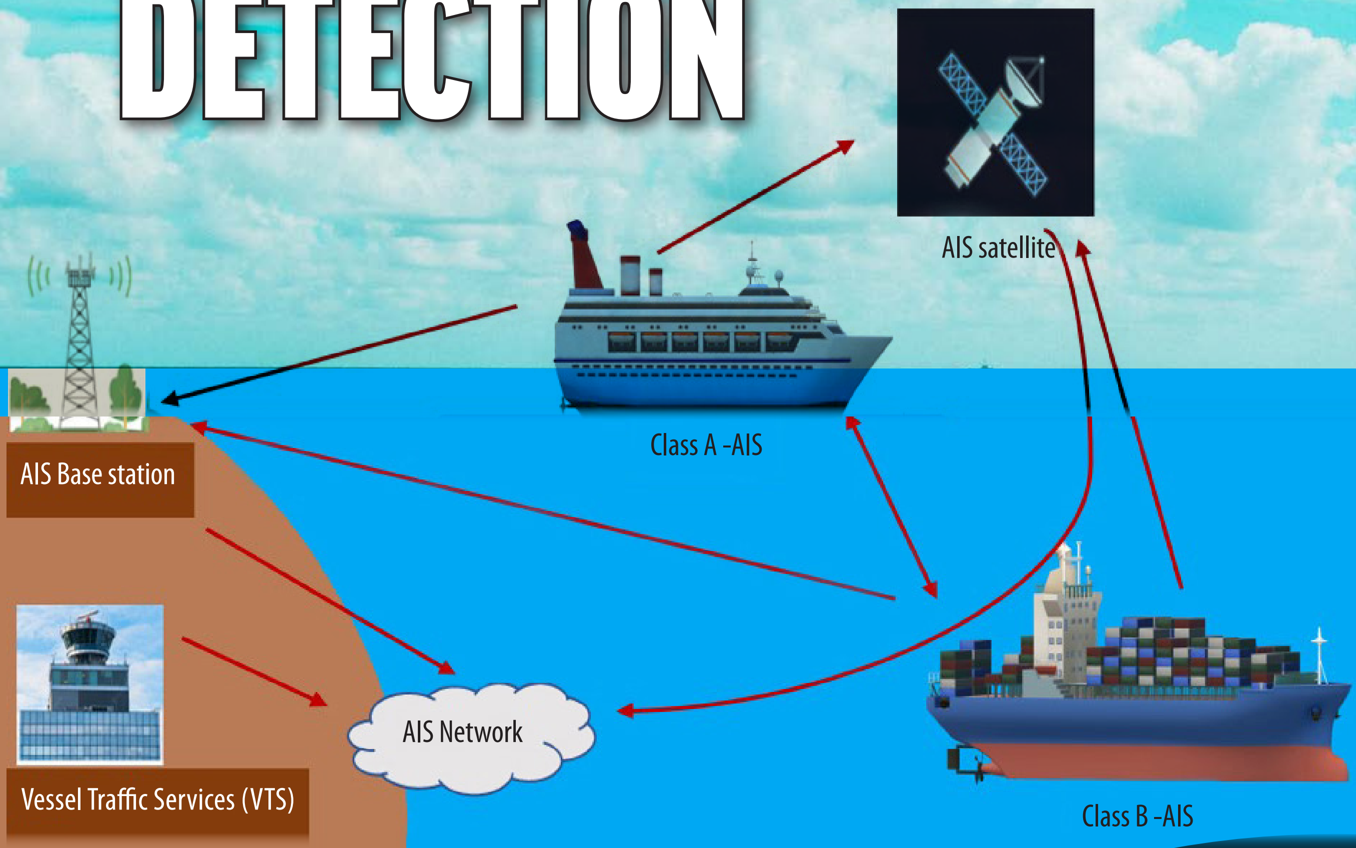
MARITIME SECURITY:
A LOOK AT ANOMALY DETECTION



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EDITORIAL

We are not there yet, but the end is in sight.
- Tedros Adhanom Ghebreyesus

The Director General of the World Health Organization's words at a recent press conference brings hope but with a caution. The globe recorded the lowest death rate (since March 2020) around second week of the September. The 7-day averages have been dropping since February and the peaks appear to be settling to shallow bumps. Research studies indicate that the link between deaths and cases has been fading though not broken in countries with highly vaccinated populace. WHO cautions that this is the time to be cautious and recommends 'integrated public health interventions including vaccine equity' to stop the variants from causing a spread. WHO will be releasing six policy briefs which will help Governments to take preventive actions. Needle-free oral dosage is another option being worked upon. WHO recommends that risk groups of health workers, older population must be fully vaccinated. Wish the seafarers are noticed as an essential worker risk group and measures are extended. Anyway, is it not the seafarer who sights the end while being not there yet, as often?

In this issue...

The Mumbai terrorist scar of 2008 is undoubtedly indelible. The terror traced its way into the metropolis through the sea route, laying bare the vulnerability of our coast. While this could be one breach we gasped about, there are others. We carry a related study on this – the Maritime Anomaly Detection. In simple words, vessels and craft movement along our coastlines can be monitored and, tracked and any illegal movement identified well in advance. We can do this applying scientific methods, says Hema Karnam and a gamut of illegal activities such as illegal fishing, vessels infringements in closed zones, piracy, smuggling etc., can be eventually averted. We present this original research (work still in progress) in a 3-part series. We hope these anomaly talks get their due attention.

Next, we continue along the Chennai coast with the drones. In this Part 2 of the drone mapping project, Dr. Srinivasan *et al*., describe the water depth measurements done using the micro temperature probes (MTP). The interesting part is the description and operation of the machine (drone), and the drone system control. The CFD studies for profiling are also explained in a simple fashion. The instrumentation, payload and control protocols may relate to the ocean studies but then they give more than a fair idea of drone operations. This knowledge will help understand drone employment in ships' tanks etc.

Moving from air above the coast, we dive deep into the ocean waters. In this Part C of bio-inspiration discussions, Dr. Veda throws light on sub-sea swarm robotics (SSR) systems. Drawing strength from the fish shoaling (predator avoidance) and bird murmurations (for energy saving), the analysis and explanations for V, J, echelon patterns are intriguing. The concluding sections underline the importance of autonomous navigation, intra-swarm intelligence, energy-efficient locomotion and soft robots for SSR systems. SSR systems apart, the elasticity of engineering boundaries could be further stretched learning from bacterial colonies, fish schools, ant colonies and bird navigation.

Container rate index had breached US$10000 levels (40' box) and is sliding down slowly. Sudhakar Unudurti gives an overview of the trade, shortages, the windfall it brought to the Container Lines (their alliances) etc., in his write-up on logistics. Quoting from informal surveys etc., Sudhakar proposes a rethink in India's logistics policies and pitches for a container-focussed approach (manufacturing; hub & spoke network etc.).

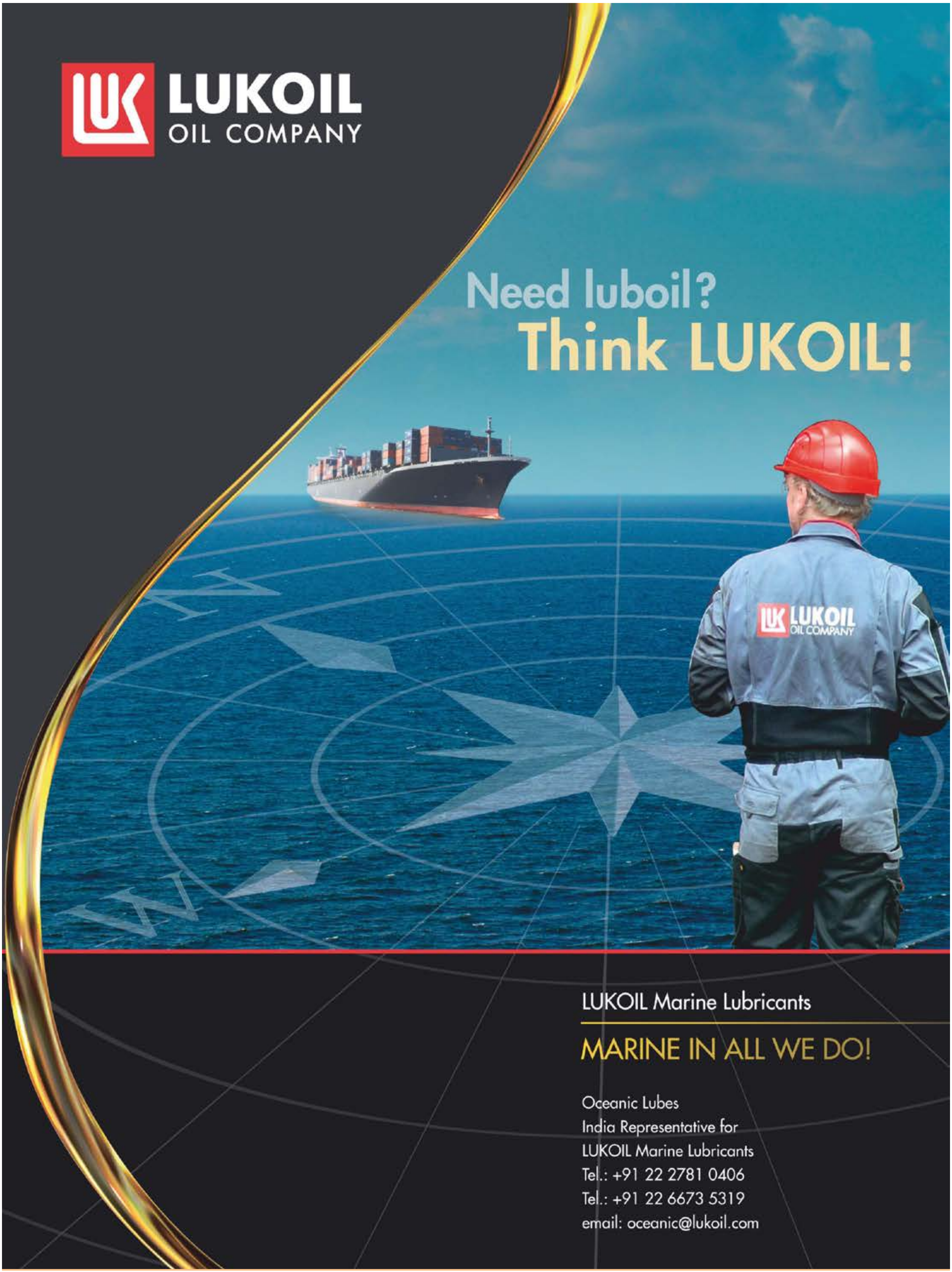
The growth of Indian logistics sector is expected to cross US$200 billion in the coming years and the National Logistics Policy (recent initiative of GoI) and the Gati Shakti initiatives might hold the answers that Unudurti seeks.

The Technical Notes section features Boiler Tube failures and Lube Matters discussing Grease. We pull out and highlight a couple of interesting discussions on Ship Automation & Fibre Optics under MER Archives.

And we have news on a new publication from the Institute. The MER Main Engine will have an auxiliary engine in the form of a Newsletter. We hope to have your support for this initiative also.

Happy reading the MER October Issue with the Newsletter (slotted to hit your email boxes this month).

Dr Rajoo Balaji
Honorary Editor
editormer@imare.in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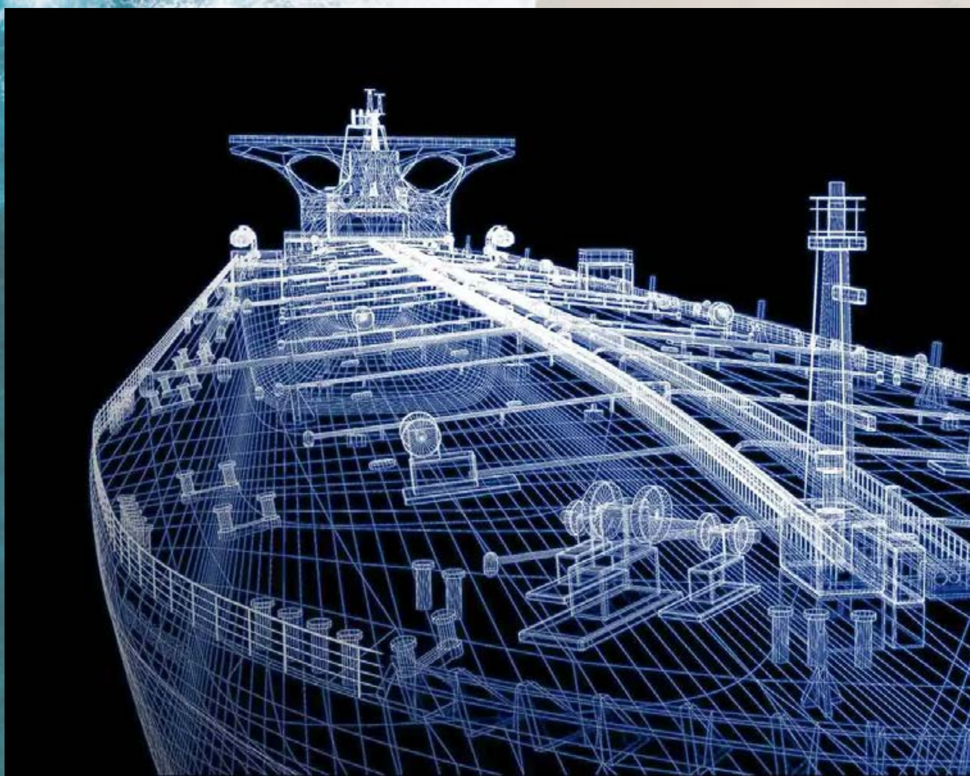

Cover Art work by **Hema Karnam**

MARITIME ANOMALY DETECTION: CLASSIFICATION OF RECENT RESEARCH APPROACHES (PART 1):

MARITIME ANOMALY DETECTION FOR MARITIME SITUATIONAL AWARENESS

Hema Karnam Surendrababu

Abstract

Maritime anomaly detection tools when used efficiently can aid in maritime safety and surveillance activities. The current practice of a majority of anomaly detection tools is in detecting anomalies which are more homogenous in nature and thus lacking in diversity. Therefore, the focus of this paper is to highlight a few of the more complex anomalies that have been less studied in the maritime domain and additionally map the anomalies detected in various approaches to potential applications for safety and surveillance in the maritime domain [4].

1. Introduction

Global economy is highly dependent on freight transportation via sea as majority of the world's commerce uses these routes for trade and energy transportation. The types of vessels that traverse the world's oceans are not limited to the commercial transport vessels but also include a wide a range of ships such as the fishing boats, ferries, passenger ships and other recreational crafts. Maritime domain can be defined as, "all areas and things of, on, under, relating to, adjacent to or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances" [1]. Given this expansive definition of the maritime domain, and the vast number of vessels sailing the oceans, it is extremely critical to ensure the safety and security of the diverse marine traffic and also the marine ecosystems.

> **Maritime domain can be defined as, "all areas and things of, on, under, relating to, adjacent to or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances"**

A key strategic element for the Coast guard to ensure the safety and security of vessels in the maritime domain, is to identify possible threats such as terrorist attacks, illegal activities such as illegal fishing, vessels infringing on a closed zone, and other criminal activities such as piracy, smuggling etc. early on so as to provide decision makers with information superiority and aid the decision-making process in order to gain valuable advantage over the adversaries. This objective can be achieved through Maritime Domain Awareness (MDA). Maritime domain awareness can be defined as "an effective understanding of activity within the maritime domain that could impact the safety, security, economy or environment" [1]. The objective of achieving maritime domain awareness requires the ability to monitor everything at all times so as to obtain a maritime situational picture that is obtained by fusing data from multiple sensors and achieving the required information superiority.

However, the vast number of ships sailing the oceans coupled with the availability of a large number of increasingly cheaper sensors and storage capacities result in data overload. Surveillance operators not only sort through the huge amount of sea traffic in order to detect anomalous behaviours that can compromise the safety, security of the maritime domain but also search and predict emerging risk situations such as collision, illegal activities such as smuggling, piracy, illegal fishing etc.

Therefore, due to the highly complex and heterogeneous nature of the data, and other constraints such as time, uncertainty, and fatigue, sifting and monitoring of this data manually by an operator is a highly demanding task which requires constant level of concentration, and places a cognitive overload on the operator. Hence, there is a need to automate this process of sifting through large quantities of data to assess the maritime situation and highlight situations that are worthy of interest and may require further investigation.

One of the critical components that aids in achieving the objective of maritime situational awareness in the context of maritime surveillance is Anomaly detection. An anomaly can be defined as "as a pattern that does not conform to the expected normal behaviour" [2], and anomaly detection as an approach that "defines a region representing normal behaviour and declares any observation in the data which does not belong to this normal region as an anomaly" [2]. In the maritime domain, vessel movement is restricted by physical constraints and mandatory sea routes and vessels in general follow set patterns of behaviour based on their type or the business they are engaged in. Therefore, if a vessel deviates from a set pattern, it can be considered as anomalous vessel behaviour and could potentially indicate that a vessel is engaged in illicit activities. Most of the vessel traffic is predictable within a local or confined region.

Therefore, if a vessel deviates from a set pattern, it can be considered as anomalous vessel behaviour and could potentially indicate that a vessel is engaged in illicit activities

Anomaly detection approaches exploit these facts to build models of normal vessel traffic patterns, and then categorise observations that deviate from these models as outliers or anomalies. An important step in the process of Anomaly detection will therefore be able to recognise these predictable patterns - which can include a statistical distribution of the normal observations, a sequence of events or a cluster of elements, the elements for instance could be ship trajectories.

Anomalous behaviours in the maritime domain can be broadly classified into vessel route deviations or kinematic anomalies (anomalies in vessel motion), unexpected port arrivals, close approach of vessels at high sea, vessels infringing on closed zones (e.g.: fishing vessels entering an illegal fishing zone or marine protected areas), unexpected AIS activity (e.g.: intentional on-off switching of the AIS transponder) [3][4][5].

All of the said anomalous behaviours can be potential indicators of illegal activities at sea and detecting these behaviours can therefore support maritime situational awareness and thus help the coast guard to evaluate the threat potential posed by the worldwide movement of ships.

More recently, the data transmitted from the Automatic Identification System (AIS) has become more popular for Maritime Anomaly detection because of the various types of vessel data that is available from the commercial AIS data providers.

2. Automatic Identification System (AIS)

The AIS transponder was made as a mandatory installation at the Safety Of Life At Sea (SOLAS) convention -2002 for all ships weighing 300 tonnes or more. AIS transmits and receives information on two Very High Frequency (VHF) radio channels operating at frequencies 161.975 MHz and 162.025 MHz. These over the air transmissions are standardised according to the International Telecommunication Union – Radio Communication (ITU-R) sector. Access to the VHF data link is accomplished through a Time Division Multiple Access (TDMA) scheme [6].

AIS data is also collected by online AIS providers and transmitted over the internet using AIS gateways deployed geographically. Additionally, AIS data can be uploaded by the ship crew to the online providers using Mobile Apps, and special forwarding software [6]. The coverage area of the AIS terrestrial data that is collected is limited to 40 nautical miles from the coast. However, commercial satellite data providers also collect the AIS satellite data from all over the globe.

AIS reports three different types of information which can be categorised into static data, dynamic data, and voyage related information [4]. The static data describes the ship's characteristics and includes information such as MMSI, IMO number, call sign, ship name, type. The dynamic data describes the ship's movements and includes information such as position (latitude, longitude), Speed Over Ground (SOG), Course Over Ground (COG), navigation status. The voyage related information includes current voyage destination, the estimated time of arrival (ETA), draught etc. [4].

The AIS data is reported at with a varying transmission rate ranging from a couple of seconds for dynamic data to a few minutes for the static data. Part of the dynamic data is automatically fed in from the ship's GPS unit, whereas the static data is manually set up and maintained by the vessel operators. Currently two types of AIS transponders exist, class A for larger vessels and class B for smaller fishing boats or pleasure crafts [7].**Refer Figure.1.**

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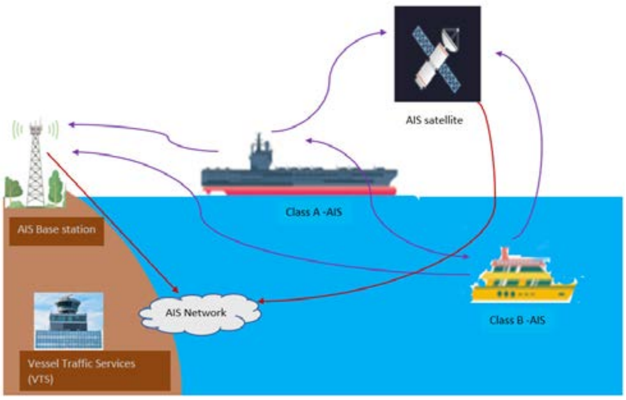

Figure 1. Automatic Identification System

2.a. Role of AIS in Maritime Anomaly Detection

The number of seafaring vessels is nearly in the range of millions, which include commercial shipping vessels, fishing boats, merchant navy, etc. Given this vast shipping densities and heterogeneous vessel types, maintaining adequate situational awareness through manual surveillance by operators is practically not feasible. In the last few years there have been several disruptive maritime incidents of which some are discussed next. Lack of adequate surveillance and monitoring of sea routes can result in less situational awareness in the maritime domain and can lead to catastrophic consequences such as terrorism putting many lives at risk, as evident from the 26/11 terrorist attacks that took place in India during 2011.

During the period from Sep 2012 and Oct 2012, Iranian Oil tankers reportedly transmitted AIS data using switched identities, by changing their country flags to Zanzibar to escape the sanctions imposed by the USA and Europe over Iran's nuclear programs [6]. In a spoofing incident reported in Elba Island during 2019, deliberate spoofing of the ships using Automatic Identification System (AIS) data affected navigation of ships temporarily [8]. In one of the most recently reported incidents in July 2020, one of the world's largest fishing fleet nations misreported its location to conceal illegal fishing activities in the Exclusive Economic Zone (EEZ) in and around the Galapagos islands [8].

Existing literature describes some of the maritime anomalies that include ship route deviations, unexpected AIS activity, unexpected port arrival, close approach, and zone entry [5]. Each of these anomalies can be characterised and detected using a wide range of AIS data which in turn can help monitor criminal activities such as piracy, smuggling, drug trade or illegal fishing etc. [4]. Ship route deviation is a most extensively studied anomaly. Ship route deviation can aid in detecting deviations from a ship's route, where a ship that generally takes the most direct path to its destination deviates from its original path.

Lack of adequate surveillance and monitoring of sea routes can result in less situational awareness in the maritime domain and can lead to catastrophic consequences such as terrorism putting many lives at risk, as evident from the 26/11 terrorist attacks that took place in India during 2011.

The AIS trajectories which comprise of the kinematic (Position, velocity) information of the vessel at various times can help detect the ship route deviation anomaly. Historical AIS data can be used to extract the sea routes that are routinely travelled by the vessels, from which normality models can be constructed. The observed AIS trajectories can then be compared with these models, and the observations that deviate from these models can help in detecting the anomalies. Unexpected AIS activity can be viewed as intentional on-off switching of AIS transponders to obfuscate any malicious actions such as pirate attacks.

Approaches that use the AIS dynamic data such as Speed Over Ground (SOG) can be used to detect velocity changes during the intentional on-off switching of the AIS transponders, which can in turn be used to detect when a ship is trying to change course and at the same time hide this fact by switching off the AIS transponders. Unexpected port arrival can be detected using the AIS voyage information such as the destination port and waypoints, which could for instance be used to detect illegal fishing, where illegal fishing catch is offloaded at a not normally destined port [3][4].

Close approach between vessels at high seas can possibly indicate anomalies such as illegal exchange of contraband or drug trade. The AIS kinematic data coupled with contextual information can aid in identifying close approach anomalies [3][4].

Zone entry anomalies can occur when vessels which are not allowed to enter into restricted zones such as marine protected areas or exclusive economic zones, military installations are identified to have entered these zones. AIS data such as the position which has the latitude, longitude information can be used to identify the zone entry anomaly. Therefore, detection of the zone entry anomaly, which is a potential indicator of illegal fishing, can aid in marine environmental monitoring that will help prevent or reduce the degradation of the marine environment [3][4].

Additionally, dark shipping or illegal activities at sea can be concealed by vessels by not transmitting critical maritime data such as position based on AIS. The increasingly congested sea lanes, and shipping densities also increase the probability of maritime accidents, in particular collisions. From a safety perspective, Maritime anomaly detection can use AIS trajectories and other AIS features such as Close Point of Approach (CPA) for collision risk detection and prediction [9]. By reducing the risk of collision between ships, anomaly detection tools can help in effective marine traffic management and planning.

Maritime incidents such as oil spills from large tanker ships can have huge environmental impacts. Therefore, there is a need to monitor and prevent such accidents, which can be potentially identified using maritime anomaly detection. The more complex anomalous behaviours such as vessel spoofing, and loitering can also be detected using AIS data. Vessel spoofing can be detected when a vessel transmits fake static or dynamic AIS data, and loitering can be detected when a vessel travels at unusually low speeds without displacing itself to a significant distance at designated areas [3][4].

Hence maritime anomaly detection tools when used efficiently can help identify and monitor various criminal activities such as terrorism, piracy, illicit drug and/or weapons trade, smuggling etc., support safety related activities such as avoidance of collision, grounding, territorial violations etc., [10] and environmental monitoring activities such as illegal fishing, pollution etc.

It is extremely vital that using past observations and history of the maritime data, to develop early detection and warning systems that predict these anomalous situations before they can potentially occur and lead to catastrophic consequences. This can in turn help reduce the critical response times for actions to be taken by the coast guard.

2.b. Limitations of AIS

It is to be noted that AIS transmits data using an open, unencrypted, non-proprietary RF Protocol, which implies that technically the AIS data can be spoofed, where an adversary impersonates another ship's identity or location or transmits fake AIS data. The security evaluation of the AIS has shown that it also highly susceptible to other forms of cyber-attacks such as hijacking of AIS data by transmitting a higher-powered signal on the VHF channel, creating false collision alerts etc. [6]. Currently there is no source vetting and checking to ensure if the reported AIS data is actually coming from a genuine vessel or from a purported location.

These well-documented vulnerabilities can easily be exploited by an adversary armed with a simple software-defined radio (SDR) and a VHF antenna. The consequences of these attacks are that a malicious adversary can exploit this security flaw to negatively affect maritime safety and navigation, global commerce, and escalate political tensions between rival governments.

Therefore, one of the potential mitigation measures to identify falsification of AIS data is to apply maritime anomaly detection techniques to the collected AIS data in order to detect suspicious activities like unexpected changes in vessels' route or static information such as a vessel's identity.

3. Related Work

Maritime Anomaly Detection has been an active area of research for the last two decades and continues to be so. A review of selected literature in the domain of maritime anomaly detection is presented in [10], where a taxonomy is defined for various anomalous ship behaviours and methods used for maritime anomaly detection. However, the review is more focused on specific organisations developing maritime anomaly detection systems. Additionally, the review presented in [10] does not include the more recent approaches that focus on the more complex anomaly types. In [3] a more comprehensive classification of the publications with respect to maritime anomaly detection is presented.

The research approaches in [3] are broadly summarised into four categories with focus on a) Maritime data b) Maritime anomaly detection Methods and techniques c) Systems used d) User aspects and the challenges with respect to each of these categories are discussed. The literature survey in [4] indicated that the majority of the publications focus on positional or kinematic anomalies with region centric models and highlighted the gaps with respect to lack of a universally applicable and trained models. The survey in [4] also rightly pointed out the lack of publicly available AIS dataset that can be employed for a comparable evaluation of different anomaly detection methods that have been developed so far.

The studies discussed in [3][4][10] while using various approaches to classify maritime anomaly detection research, do not specifically highlight the less focused areas of maritime anomaly detection such as loitering, spoofing etc. The current study based on a literature survey and the existing reviews, calls attention to the fact that spoofing which is becoming a global threat in the maritime domain has only been marginally studied. Loitering is another type of anomalous behaviour which has not extensively been explored. Additionally, this study also attempts to map the detected anomalies in each of the approaches with a potential application in the maritime domain [4]. The current study also calls attention to the lack of a publicly available and usable AIS dataset in the Indian context. Establishing such AIS datasets can aid in significantly improving the maritime anomaly detection process and thereby enhance maritime surveillance in the Indian Ocean Region.

[All References shall be published with the concluding Part 3 of the manuscript.]

About the Author

Hema Karnam Surendrababu is currently a PhD scholar at the National Institute of Advanced Studies (NIAS), Bengaluru (affiliated to The University of Trans-Disciplinary Health Sciences & Technology, Bengaluru, India). She works as a part of the International Strategic and Security Studies (ISSSP) Group at NIAS. Her research experience comprises of Signal/Image Processing and Cyber security. Her current research focus is on the usage of Artificial Intelligence techniques for Maritime Anomaly Detection.

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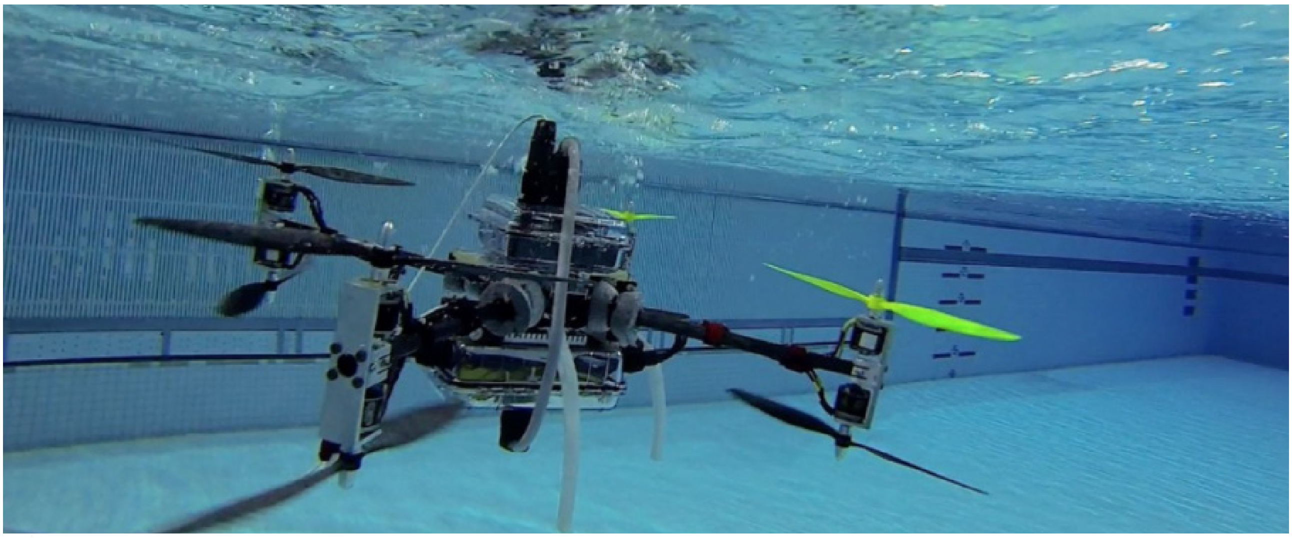
ADAPTING THE DRONE TECHNOLOGY FOR MARINE APPLICATIONS – A HIGH RESOLUTION WATER QUALITY MEASUREMENT SYSTEM USING DRONE (PART 2)



R. Srinivasan, V. Gowthaman, Tata Sudhakar, G.A. Ramadass

4.0 DRONE BASED HIGH RESOLUTION WATER QUALITY MEASUREMENT SYSTEM

The proposed drone based high resolution water quality measurement system (**Figure 4**) consists of drone as a carrier of the instrumentation payload. The instrumentation payload will be designed having interfaced with various sensors such as the fast responding micro temperature probes @ 1m, 2m, 5m, 10m, 15m, 20m, 25m,30m, 35m, 40m, 45m, 46m, CT sensor @ 0.25m, pH @ required depth, DO@ required depth, Turbidity@ required depth, Partial CO_2 sensor @ required depth, Micro plastic sensor @ required depth, regular CTD sensor @ 48m (**Figure 5**) are mounted and encapsulated in the marine grade multi core coaxial cable at the designated depth of measurements as depicted in **Figure 5**.

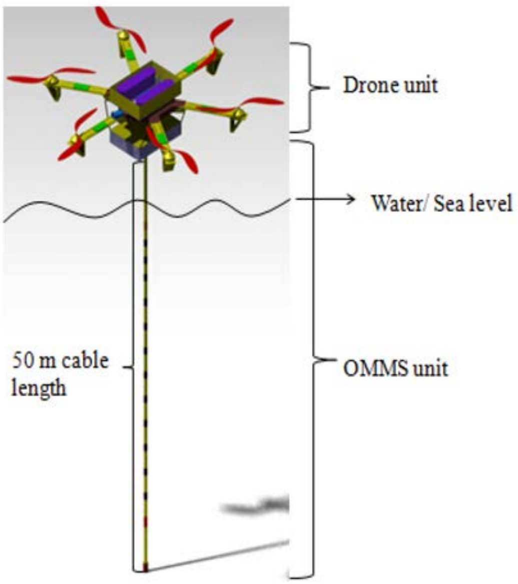


Figure 4. Schematic of Drone based WQMS

Suitable data acquisition electronics module catering the above instrumentation payload and it does the control of measurement scheme as enlisted in **Table 2** and data storage. The Global Positioning System (GPS) receiver

Table 2. Sensor Configurations and sampling details

Parameter	Details	Sampling details
Fast responding micro-thermistors	To study & understand microstructure temperature variability	24 Hz
CT Sensor at 0.25m	To measure CT values	24 Hz
pH sensor	To collect ocean pH value	24 Hz
DO sensor	To measure Oxygen percentage in sea water	24 Hz
Partial pressure CO_2 sensor	To study & understand carbon distribution in ocean waters	24 Hz
Turbidity Sensor	To measure the turbidity level	24 Hz
CTD Sensor @ 50m	To measure CTD values	24 Hz
GPS receiver	To precise time and location reference	1 Hz

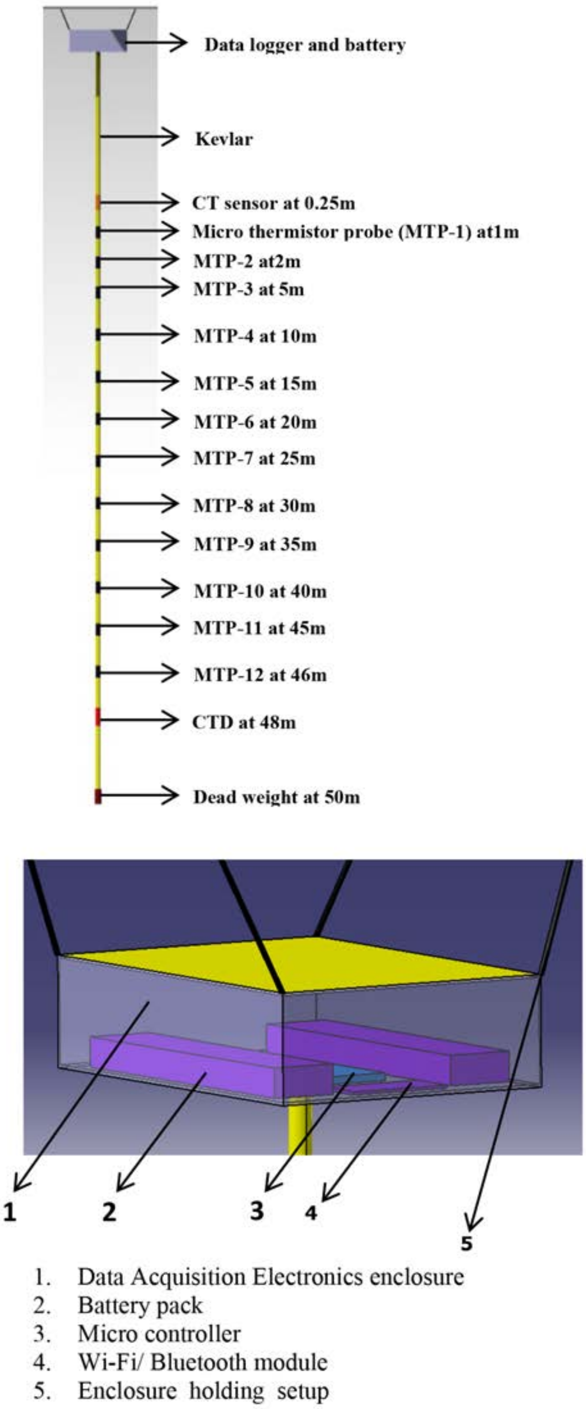


Figure 5. Block diagram of drone based shallow water quality measurement system

provides time and position reference to measurement system.

4.1 Drone & Navigation requirements

The block diagram of drone based WQMS system is shown in **Figure 6**. UAV – drone is an aerial vehicle that does not carry a human operator. It uses the aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely. Drones are fully autonomously controlled by on-board computer and the necessary way point and elevation details are feed in to the system for

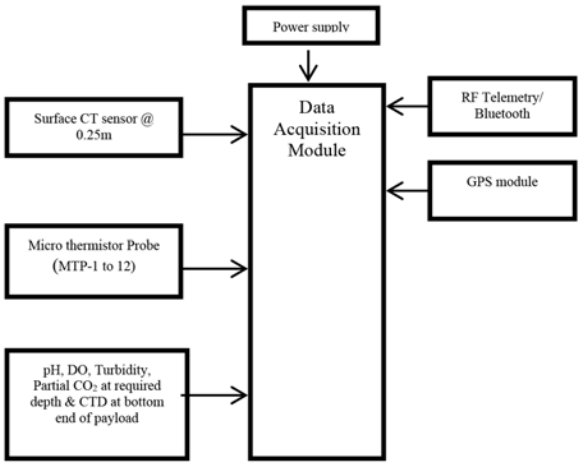


Figure 6. Block diagram of drone based WQMS

each measurement cycle. Also, it can be controlled lively using handheld control devices such as a pilot control from the ground. Drone technology has improved a lot and it is operated and controlled by a radio frequency controller and it can send audio-video visuals. Recent day's controller-based drone control system with RF transceivers operating at 2.4 GHz frequency is used for the remote operation of drone.

A professional hexacopter built with 6 nos of thrusters of make Hobbywing X6 propulsion each having torque required to lift 12 kg and the maximum theoretical takeoff weight of systems is 72 kg of weight is selected as carrier according to the instrumentation payload design requirements and weight. The main components of carrier - hexacopter are a frame, motors, propellers, electronic speed controllers, flight controller, GPS receiver, telemetry radio transmitter, and a power supply module and it is shown in the **Figure 7**.

The pictorial view of the Hexacopter drone and its subsystems are shown in **Figure 8.** The navigational control of the hexacopter is managed with a pilot system. The system is comprising of UAV Drone, Pilot system for its remote control mechanism and the string of instrumentation payload. Sensor array is attached to the drone while the pilot system controls the entire process. Drone system control always rests with the pilot or operator.

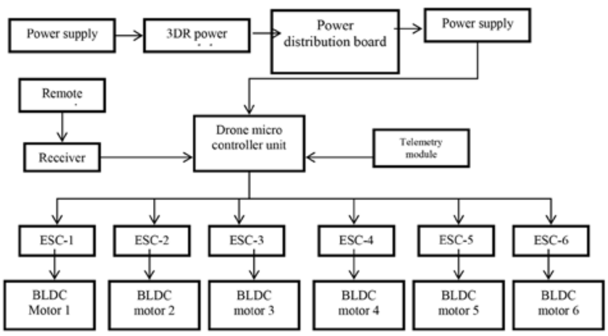


Figure 7. Block diagram of drone a carrier

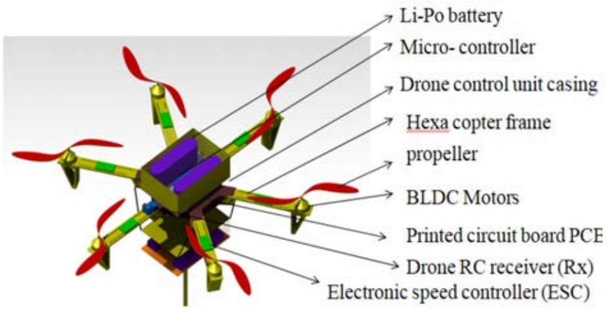


Figure 8. Pictorial View of Drone and its subsystems

The pilot uses visual tracking to determine position and orientation. The pilot inputs the GPS/GNSS waypoints which the drone will follow using the autopilot functions. Then, drone system starts flying and head towards the set coordinates. Once the drone reaches the location, it is set in to the Position-Hold mode. The drone maintains a fixed location at a set altitude using barometric altimeter or laser altimeter. It completes the measurement cycle and the data is relayed to the pilot system at the shore or ship. Once the measurement is done, Return-to-home navigation mode returns the drone automatically to its take-off location. In case of Bad weather or lost communication signals, the failsafe mode in drone will guide it back to its original coordinates. The sequence of operation involved in the measurement cycle is illustrated in **Figure 9**.

4.2. Instrumentation and sensor payloads

The WQMS data acquisition module is mounted at the bottom frame of drone contains a data acquisition module, memory module, data telemetry device. The water quality monitoring sensors such as micro thermistors probes, pH sensor, Dissolved Oxygen sensor, Turbidity sensor, partial pressure CO_2 sensor and CTD sensor are interfaced and encapsulated in 18mm thickness, 60 m length the multi core coaxial cable at designated length corresponding to the depth of measurement interest. The top end of the payload is connected with the data acquisition module and there is no sensor mounted at the top 3 m of the payload cable. Data acquisition system suitable for high resolution sampling and measurement will be interfaced with payload and the whole payload will be attached in to the carrier.

The lower 47 m of cable containing the payload is winded as 3 feet diameter pool and made in-tacked using quick dissolvable marine tapes (**Figure 10**). The instrumentation payload will be deployed in to the Sea using quick dissolvable wraps and once the payload touches the sea water it will get released and descend down vertically. The instrumentation system collects the high resolution vertical data sets of depth up to 50 m on parameters such as temperature, salinity, Dissolved Oxygen, partial pressure CO_2 and pH.

A ground control station installed in a computer which communicates with the UAV through the telemetry radio transmitter. The ground station collects information about the flight situation including battery level, altitude, location, flight mode situation, and GPS connection status during a flight mission. All electronic circuits in the system were waterproofed using a corrosion prevention spray to prevent water damage to the installed components. This method of drone based observatory ensures instant real time data collections at any given location and even time series measurement for a short period shall be possible using series of drones based on the locations criticality.

The list of WQMS sensors to be configured to measure high resolution water quality parameters are summarised in the **Table 1** (Part 1 of MER Sep '2022) along with data sampling details. The complete specifications of sensors and its operational range, accuracy, resolution and the details of its serial interface are listed in the **Table 2**. A fast responding micro-thermistor is selected to measure the oceans temperature variability with sensitive electronic capsule to provide digital output. Sensors like pH, DO sensor and partial CO_2 are of Optical or Infrared type with low power consumption modules.

4.3 Power requirement, Endurance and weight estimate

The operational period of the drone including the time of hovering and measurement cycle is a critical element

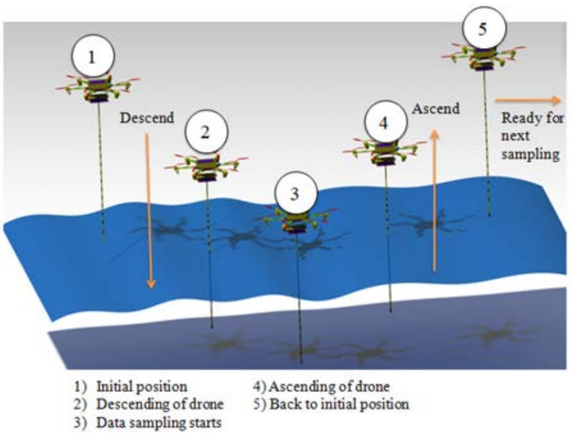


Figure 9. Sequence of operation during ocean data collections

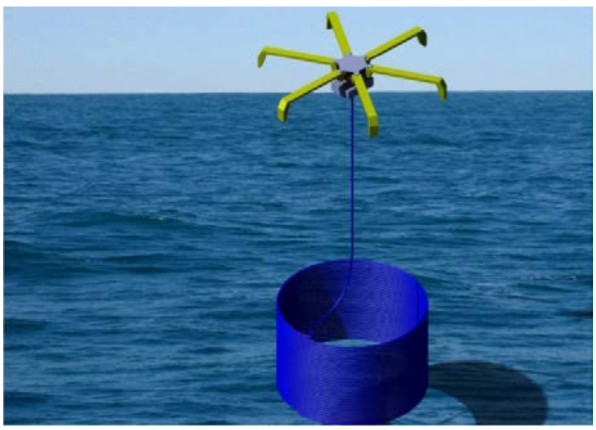


Figure 10. Drone with instrumentation payload in winded condition – ready to carry

in designing the proposed system. Generally drones of self-weight from 10 kg to 20 kg flies at nominal speed of 7 m/sec and 5 m/sec respectively. Hence, the battery pack design which meets the power requirement of drone and thruster motors to lift and carry a weight of ~30 kg in addition to its self- weight of Drones calculates to be around 110 to 330 Ampere hour (Ah) @ 12 V a nominal voltage to ensure the drone operation period of minimum 30 minutes.

We use extra-long life Molicel INR-21700 P42A series, 4200 mAh @ 3.6Vdc Lithium Ion battery is used in building the batter pack by 6Cx 2set with 10C rating. Similarly the battery pack design for instrumentation payload will aim to provide a data collection of minimum of 30 minutes in a single drive. The optimal power needs of the instrumentation payload and the power need of the carrier is performed. The nominal voltage of the battery pack 12 V or 5 V shall be arrived based on the operating voltage of individual sensor and instrumentation system. Individual battery pack is considered for both instrumentation payload and for a carrier.

The discharged or drained battery pack is scheduled to be replaced or swapped using new pack on completion of each measurement cycle or based on voltage conditions. Provision to recharge the drained battery pack is planned on board the vessel to ensure a continuous run in a day and to carry out a large data collection cycles. The nominal recharge period of battery pack is 3 to 4 hours. Stock of redundant spare battery pack and charging devices is scheduled to ascertain break free data collections. The tentative weight estimate of WQMS instrumentation payload is summarised in **Table 3.**

Table 3. The tentative weight estimate of instrumentation payload

Description	Quantity	Weight in Kg
Data Acquisition Module, RF module and Enclosure	1	1.0
Power module	1	2.0
Coaxial multi core cable of 50m length (0.225 kg/m)	1	11.2
Fast responding micro-thermistor sensor modules (0.1kg/module)	15	1.5
CT Sensor @ 0.25 m	1	1.0
CTD Sensor @ 50 m	1	1.0
pH, DO, Turbidity & Partial pressure CO_2 sensor	Each 1 No	3.0
Dead weight according to the need	1	2.3
Total weight of the proposed measurement payload		23.0

4.4 Computational fluid dynamic analysis on Drone with Instrumentation Payload

Computational Fluid Dynamic (CFD) analysis is carried out for the drone with specified instrumentation payload in the fluent module in ANSYS software. A standard K-epsilon model is selected and used in this simulation. CFD Analysis is devised in to two phases. First phase analysis is applied to study about the swing load and behaviour of drone with instrumentation payload while hovering with the designated payload from a shore or boat to the remote measurement location. Second phase analysis is applied to study about the drone with instrumentation payload for different ocean current conditions while instrumentation payload is in measurement mode when it is dipped in to the top mixed layer of 50 m depth.

4.4.1 Computational fluid dynamic analysis on Drone with instrumentation string while hovering in the air

Computational fluid dynamic analysis is carried out for the drone hovering in the air with the sensor string winded. The weight of the drone considered is 20 kg and it has the lifting capacity of 40 kg. The various sensors enlisted in **Table 4** are interfaced and encapsulated in 18mm thickness, 60 m length, multi core coaxial cable at designated length corresponding to the depth of measurement. The lower 57 m of instrumentation payload is winded in to 3 feet diameter reel sort of assembly with the support of quick dissolvable tape and the top free end of cable having 3m height is connected to the drone.

The overall length of the instrumentation payload assembly while hovering is maintained 5m including drone dimensions (**Figure 10**). All the analysis boundary conditions and options are as same as the analysis type when the drone is taking the measurements in the water (surface current). Only one change has been done in this analysis part, which is that working domain has changed from water to air. So, there is a change in the density value. In this simulation, air density is 1.225kg/m^3 has considered. In this analysis, angle made by the drone occurred during the hovering period. At 0^0 angle represents the ideal condition of the drone when there is no hovering takes place. At 10^0, 20^0, & 30^0 angle represents the angle made by the drone during the hovering such as pitching (forward) motion of the drone. Inlet velocity of the fluid (air) has taken at 1.38m/s (5km/h) minimum velocity and 4.16m/s (15km/h) maximum velocity at 0^0, 10^0, 20^0 & 30^0 angle tilt made by the drone with string.

Figure 11 shows the generation of static pressure at different velocities of air flow likewise (a) represents 1.38m/s air flow at 0^0, (b) represents 1.38m/s air flow at 10^0, (c) represents 1.38m/s air flow at 20^0 & (d) represents 1.38m/s air flow at 30^0 angle made by the

Table 4. Detailed Sensor Specifications & Interfaces

S.No	Sensors	Parameter	Range	Accuracy	Resolution	Interface type
1.	Thermistors	Temperature	-5°C to +45°C	± 0.05°C	0.01°C	RS 485
2.	CT Sensor at 0.25m	Conductivity Temperature	0 to 60 mS/cm -5°C to +45°C	±0.003mS/cm ± 0.05°C	± 1µS/cm 0.01°C	RS232
3.	pH sensor	pH value of water	0 to 14 pH	2% of FS	0.1	4-20 mA
4.	DO sensor	Oxygen percentage	0 to 2000 ppb	± 0.5 ppb	-	RS485
5.	Partial pressure CO_2 sensor	Carbon distribution	0 to 10 bar	± (10% of reading +10mbar)	-	RS485
6.	Turbidity Sensor	Turbidity	0 to 400 NTU	0.08 NTU	0.01NTU	RS232
7.	CTD Sensor @ 50m	Conductivity Temperature Depth values	0 to 60 mS/cm -5°C to +45°C 0 to 100m	±0.003mS/cm ± 0.05°C ± 0.25% fs	± 1µS/cm 0.01°C ± 0.01% fs	RS232
8.	GPS receiver	Time & position	---	± 2.5 m	---	RS232

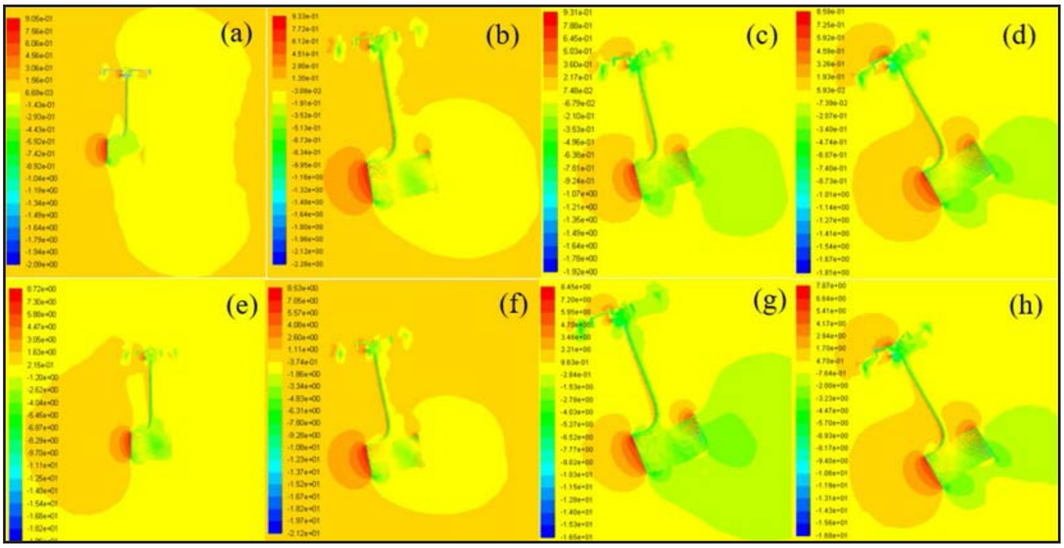


Figure 11. Static pressure generated at different angles with 1.38m/s air flow velocity at (a), (b), (c) & (d) at 0°,10°,20° & 30° angle made by drone and 4.16m/s air flow velocity at (e), (f), (g), & (h). 0°,10°,20° & 30° angle made by drone

drone similarly (e) represents 4.16m/s air flow at 0°, (f) represents 4.16m/s air flow at 10°, (g) represents 4.16m/s air flow at 20° & (h) represents 4.16m/s air flow at 30° angle made by the drone respectively. The trend of the static pressure states that, generation of static pressure on drone decreases with increasing angle but the static pressure increased with increasing velocity of air flow. The drag coefficient has noted maximum at 30° & minimum at 0°. The drag coefficient increases with increasing tilt angle made by the drone and similarly the drag force. The dynamic pressure shown in **Figure 12.**

4.4.2 Computational fluid dynamic analysis on Drone with instrumentation payload while at measurements at Ocean

A simple scheme is used under the pressure-velocity coupling implemented under the solution methods. Under the spatial discretisation method second order pressure, second order upwind momentum, first order upwind turbulent kinetic energy and first order upwind turbulent dissipation rate have been considered in the simulation. In this configuration, various sensors enlisted in **Table 2**

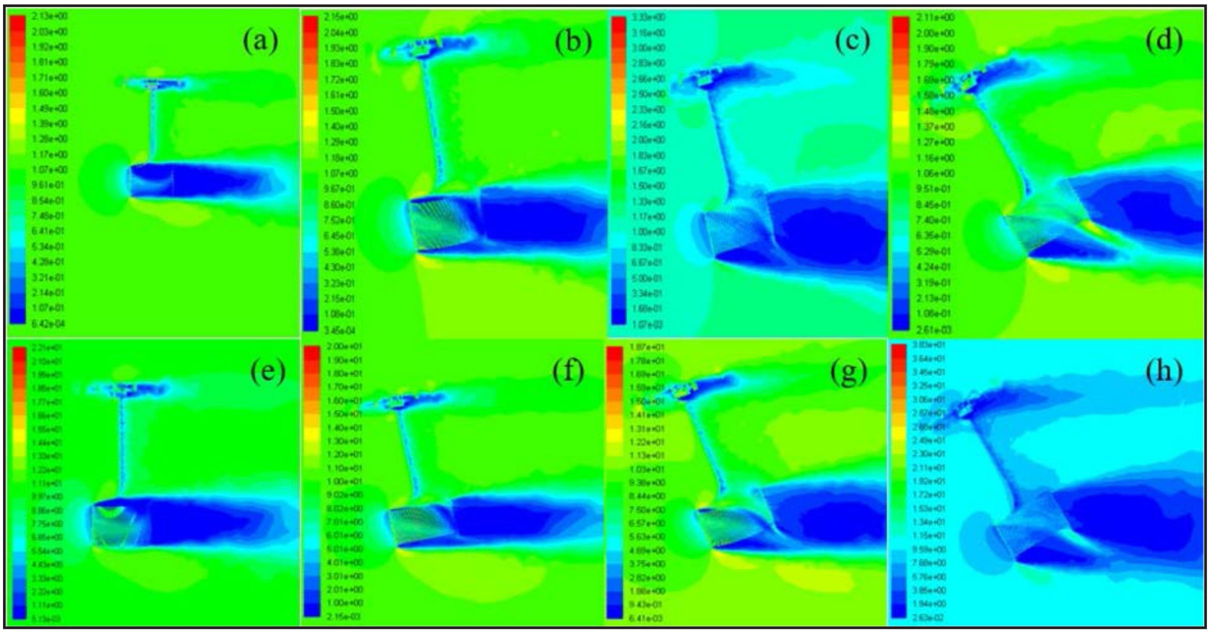


Figure 12. Dynamic pressure generated at different angles with 1.38m/s air flow velocity at (a), (b), (c) & (d) at 0^0,10^0,20^0 & 30^0 angle made by drone and 4.16m/s air flow velocity at (e), (f), (g), & (h). 0^0,10^0,20^0 & 30^0 angle made by drone

are interfaced and encapsulated in the lower 50 m length of multi core coaxial cable (18mm thickness, 60 m length having weight of 0.23kg per meter) at designated length corresponding to the depth of measurement (**Figure 5**).

There is no sensor mounted in the top 10 m of cable and the top free end is attached to the drone and further to the data acquisition module. While in measurement mode, the bottom 50 m of instrumentation payload is dipped in to mixed layer depth of up to 50 m and the top 10 m cable is connected with the drone. The vertically is ensured by adding the necessary dummy weights in the cable bottom most point. The drone maintains its position and stable vertical height of 10 m above the water surface using the feedback of Laser or Barometric type altimeter sensor.

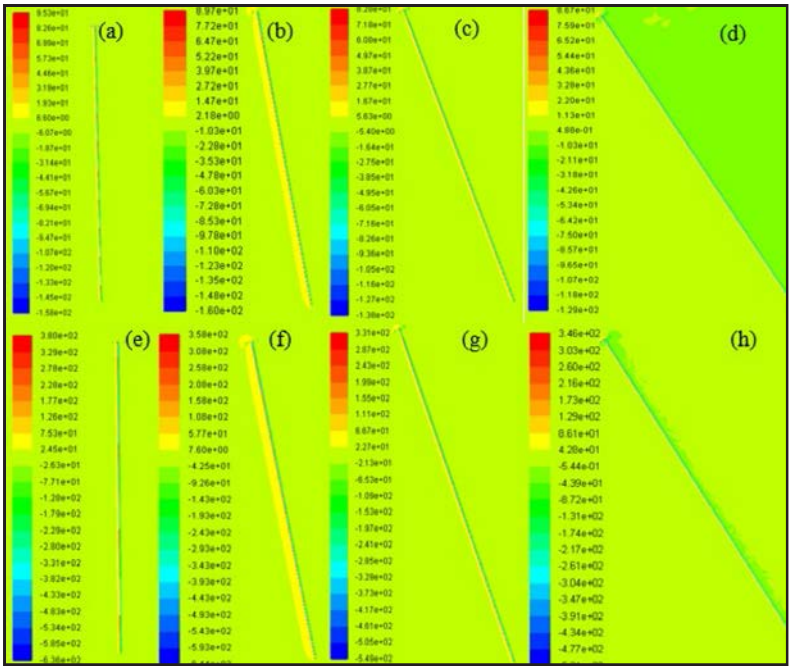


Figure 13. Static pressure generated at different angles with 0.5m/s fluid flow velocity at (a), (b), (c) & (d) at 0^0,10^0,20^0 & 30^0 drone string angle and 1 m/s fluid flow velocity at (e), (f), (g), & (h). 0^0,10^0,20^0 & 30^0 angle made by the drone string

Boundary condition:

Inlet	:	velocity inlet
Outlet	:	pressure outlet
Bottom wall	:	No-slip wall
Side wall	:	No-slip wall

Inlet velocity of the fluid has taken at 0.5m/s & 1m/s at 0^0, 10^0, 20^0 & 30^0 angle tilt of the drone with string.

Figure 13 shows the generation of static pressure at different velocities of fluid flow likewise (a) represents 0.5m/s fluid flow at 0^0, (b) represents 0.5m/s fluid flow at 10^0, (c) represents 0.5m/s fluid flow at 20^0 & (d) represents 0.5m/s fluid flow at 30^0 similarly (e) represents 1 m/s fluid flow at 0^0, (f) represents 1 m/s fluid flow at 10^0, (g) represents 1 m/s fluid flow at 20^0 & (h) represents 1 m/s fluid flow at 30^0 respectively. The trend of the static pressure states that, generation of static pressure on drone string decreases with increasing angle but the

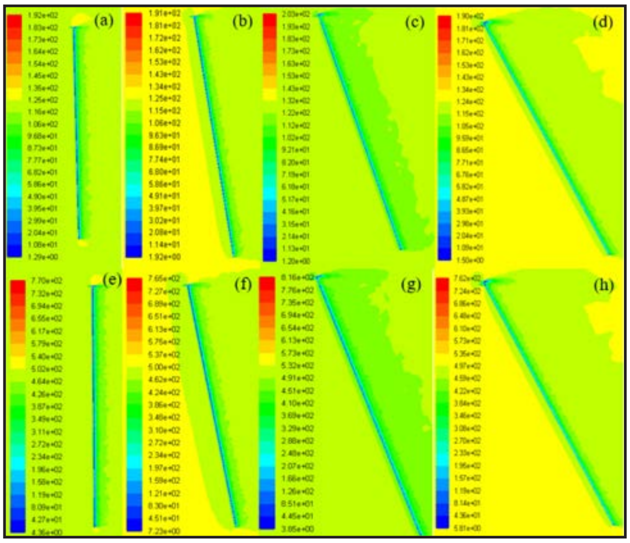


Figure 14. Dynamic pressure generated at different angles with 0.5m/s fluid flow velocity at (a), (b), (c) & (d) at 0⁰,10⁰,20⁰ & 30⁰ angle made by the drone string and 1 m/s fluid flow velocity at (e), (f), (g), & (h). 0⁰,10⁰,20⁰ & 30⁰ angle made by the drone string

static pressure increased with increasing velocity of fluid flow. The drag coefficient has noted maximum at 0⁰ and minimum at 30⁰.

The dynamic pressure shown in **Figure 14.**

Drag force calculation on drone instrumentation payload,

$$F_D = \frac{1}{2} \rho v^2 C_D A$$

Where: F_D = Drag force (N)

C_D = Drag coefficient (4.93, 4.83, 4.34 & 3.65)

V = Velocity of fluid flow (0.5m/s & 1m/s)

A = Projected area / cross sectional area (3.6 m^2)

ρ = Density of sea water (1029 kg/m^3)

The trend of drag force starts reducing at the angle of the drone string increasing due to the fluid flow (flow of current at 0.5m/s and 1m/s).

4.4.3 Ocean data collection methodology

1) Drone based data collection observatory consists of multi rotor with Hexa-copter configuration which can able to lift higher pay load up to 30 kg and hover for 30 minutes for single fly time.

2) By taking the advantage of higher pay load lifting capacity of drone, ocean parameters measuring sensor attached to a string of 15 m or 50 m long at bottom.

3) Initially data collection location should be finalised at shallow water region based on study area.

4) Once selection of location had done, drone should be installed with ocean parameters measuring sensor kit.

5) Before going to real time data collection in shallow water location, we have to check meteorological (wind speed, wind direction, humidity, air temperature, rain, land breeze and sea breeze directions) and oceanographic (depth, wave speed, wave direction and presence of long shore or RIP currents) condition at that location.

6) After initial calibration done to drone, now it's ready to take-off for data collection with in 500m to 800m diameter area data can be collected.

7) After single data collection, data can be stored in SD card or transferred through WiFi module to control side.

8) In the similar way number of ascend and descend operations can be achieved based on battery power holding capacity in the drone.

9) Every descend operation one complete data set will be collected by the drone.

10) Each data collets with GPS location for further validation of data in particular location.

11) Collected data will compare with satellite measured data sets, model data and moored buoy.

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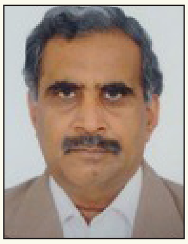

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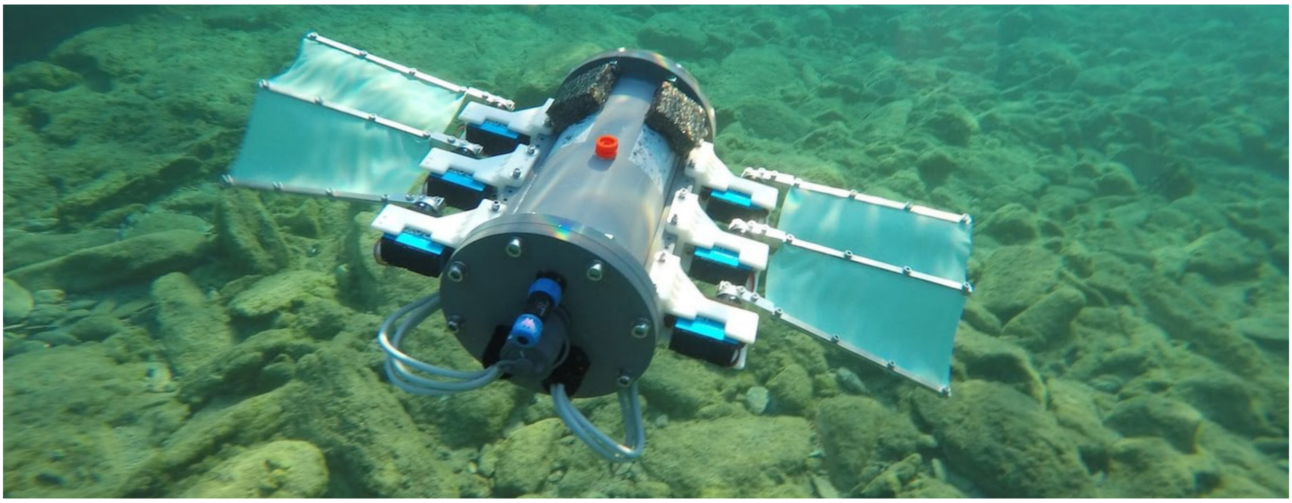
INSPIRATIONS FROM NATURE IN ENGINEERING BIO-INSPIRED AUTONOMOUS UNDERWATER VEHICLES-PART C

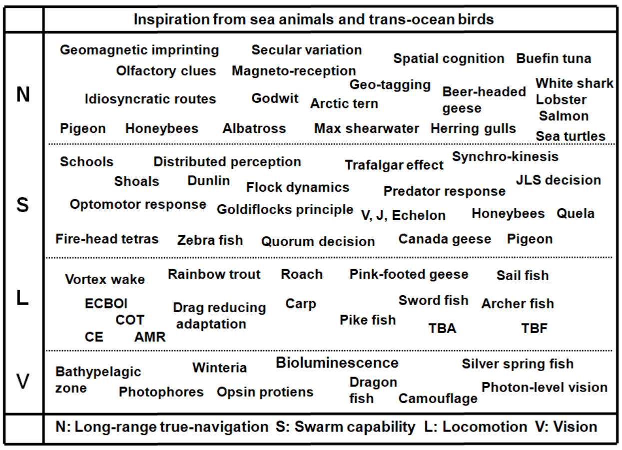


N.Vedachalam

Abstract

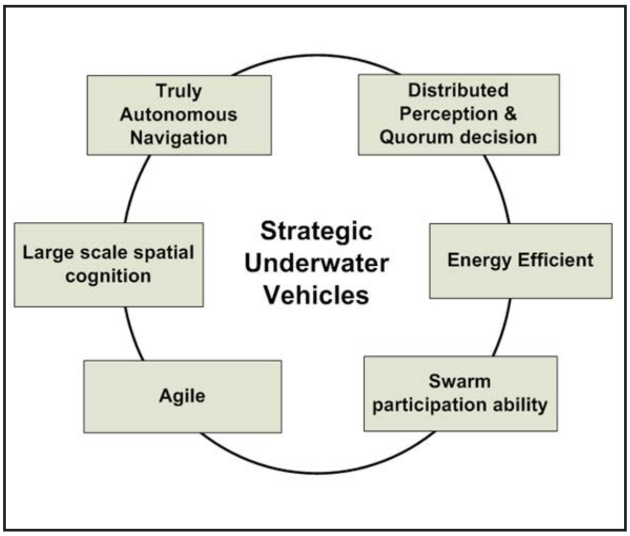
Intelligent and efficient autonomous underwater vehicles (AUV) are vital for exploring the vast marine resources, spatiotemporal monitoring of the oceans for understanding climate change patterns, monitoring marine pollution, defense and identification of assets lost in the oceans. The article is published in three parts. The first part reviewed the trends in bio-inspired engineering, maturity of underwater navigation, abilities of sea animals including turtles, lobsters, salmon, whales and trans-ocean birds in long-range true-navigation with large-scale spatial cognition abilities that helps to establish idiosyncratic routes and the developments in bio-inspired magnetic homing guidance systems for AUV. The second part discussed on the present maturity of AUV locomotion, energy-efficient locomotion of aquatic animals and the recent developments in bio-inspired continuum and soft robotics.

This (third) part brings out the need for swarm operations, fish flocking/shoaling abilities with intra-swarm intelligence supported by precise optomotor mechanisms, distributed perception, quorum decision process during predation and extreme low light vision capabilities in deep sea fishes. The observations presented could help in developing strategic bio-inspired agile AUV with improved propulsion, sensing, vision, control, navigation, machine-learning driven artificial intelligence and swarm capabilities.



Intra swarm Intelligence-Shoaling and flocking

At present, a 6m long, 1m diameter, 2t AUV cruising at 3 knots has a locomotion energy efficiency of ~7kms/kWh, endurances up to 100h at 4 knots speed, and a turning radius of < 15m. With AUV-mounted synthetic aperture sonar (SAS) covering a range of 200m on each side, cruising at 2 m/s, it is possible to have on-board



high resolution of up to a few centimetres, as well as have co-registered images, covering ~ 2km^2/h (**Figure.1**). However, the strategic requirement demands AUV with higher spatiotemporal capabilities, energy efficiency, agility and improved maneuverability.

Polarisation is the measure of the degree to which fishes of the group move in the same direction that makes them easier to detect an impending danger

The demanding requirements are evident from the challenging events such as the searches undertaken to locate the US sunken Thresher and Scorpion submarines in the Northern Atlantic in 1960s; need to understand the impacts of Gulf of Mexico oil spill in 2010 where crude oil spread over an area of > 6500 km^2 ; searching the wreckage of lost aircraft French AF447 in the mid-Atlantic ridge over 8000 km^2 in water depths up to 4300m in 2011; the US$ 0.2 billion efforts expended in mapping about 1 million km^2 of the deep seabed for locating the wreckage of the Indian Ocean-lost MH370 aircraft in 2014; recently announced Polar challenge by the World Ocean Council involving the 2000 km continuous under ice mission in Arctic and Antarctica; and the challenging deep-ocean mineral mining needs that requires precise high resolution mapping of the vast polymetallic nodule, cobalt crust and sulphides fields at water depths ranging from 3000-6000m; and the ongoing Seabed 2030 project aimed to create a full global sea floor map by 2030 with a 100m resolution.

Subsea operations are limited by the onboard energy endurance of the AUV. Operating multiple AUV in a coordinated manner is essential for increased spatiotemporal capabilities required for effective/ economical seabed mapping and time-bound search operations. When multiple AUVs are involved in the spatial mapping of physical or chemical entities in a vast ocean, the AUVs shall exchange the mapped parameters with their peers so that the trajectories of the other peers (**Figure.2**) could be planned accordingly to optimise the search/ survey time.

Subsea swarm robotics systems (SRS) involves multiple AUV inspired by the spatial self-organising, navigation, collective decision-making, flocking, searching, path formation, collaborative manipulation and task execution inspired by the bacterial colonies, fish schools, ant colonies, bird navigation and human behaviour.

During late 1970s, interests in understanding fish shoaling and bird flocking behaviours to achieve predation and foraging capabilities led to understand the reaction time and the swarm communication modes required for the coordination that is necessary to perform spectacular underwater and aerial manoeuvres, respectively (**Figure.3**).

The tendency of fishes to form schools varies both between and within species, depending on their ecological niche and motivational state such as avoiding predation and improved foraging capabilities. Shoals comprise a group of fish that remain together for social reasons, while schools are shoals that are polarised and coordinated.

Polarisation is the measure of the degree to which fishes of the group move in the same direction that makes them easier to detect an impending danger. Shoaling fishes counter predator attacks by tactics of avoidance, dilution, abatement, evasion, detection and mitigation. In a school or shoal, each fish tends to occupy a water volume of about one-body length cubed, and that this volume changes with the swimming speed and nervousness. Schooling fishes choose neighbours within a 15% band around their own size [1].

In a shoal, the optomotor response allows individual fish to match velocities with neighbours using the stripes along their sides or large spots on fins or tail that comprise specialised plaques of pressure-sensitive neuromast hair cells that can detect very rapid pressure waves generated by swimming. This is used to communicate turning and velocity changes within the school or shoal.

The 'Join-Leave-Stay' (JLS) decisions that drive shoaling dynamics depends on the social competition for food and the differences among the fishes in responding to perceived predation risk. Information about approaching

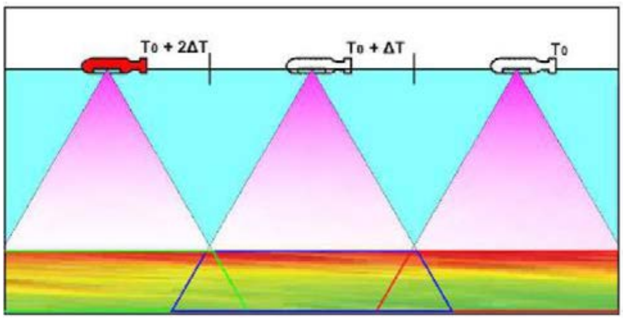


Figure.1. Rendering of AUV mapping the seafloor using SAS

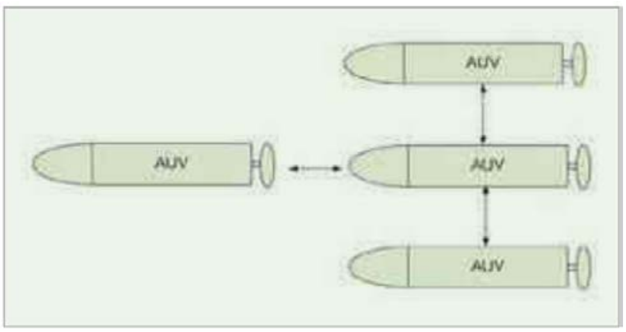


Figure.2. AUVs operated in swarm mode

danger travels rapidly across compact polarised schools 2 to 7 times faster than the approach speed of the predator, which is termed as the Trafalgar effect and synchro-kinesis [2].

> **Irrespective of the phase difference between the adjacent wing flaps, if a bird moves ahead of the V-line, it should require increased power to keep up with the flight**

Distributed perception (DP) and quorum decision processes combine to create swarm intelligence, which reduces the need to undertake complex cognition at individual fish level, and allows robust decision-making to take place even when individual perceptions are inaccurate.

The quality of the decision and the size of the group are highly correlated which forms the basis of the Fish School Search (FSS) and the Artificial Fish Swarm Algorithms (AFSA). In a shoal, the DP for the i^{th} fish is described in below equation in which Pi is the position of the i^{th} fish, and the sum is calculated over all neighbours within an assumed range of interaction of the i^{th} fish.

$$DP_i = \sum_{j=1}^{N_i DP} \frac{(p_j - p_i)}{N_i DP}$$

Experiments were carried out to understand the importance of the lateral system in fire head tetras and zebra fish in shoaling by deactivation using aminoglycoside antibiotics. A significant drop in shoaling capabilities including higher Nearest Neighbour Distance (NND), mean Inter-Individual Distance (IID), increased shoal radius by 25%, shoal order and increased number of collisions between individuals were observed [3].

For more than a century, humans have been analysing the reasons and advantages behind the V, J and echelon bird formation flying. In 1914, Wieselsberger and Storer suggested that the V-formation would favour equipartition of the aerodynamic drag among the flock.

In 1968, Cone theoretically described that the potential energy saving in the V-formation flying compared to a solitary flight could be up to 22% [4]. Lissman and Shollengberger proposed that birds fly in V-formation to capitalise on the upward rising components of the wing tip vortex currents generated by the wings of the neighbouring birds flying to the front and sides.

Figure.3. Coordinated fish shoal and bird flocks

His studies indicated that in a V-formation with 25 birds the flying range could increase of ~70%, as compared to a lone bird. Irrespective of the phase difference between the adjacent wing flaps, if a bird moves ahead of the V-line, it should require increased power to keep up with the flight. By analysing the videos of ~104 flocks of migrating Canada geese in V, J, Echelon, and compound Vee clusters, the formation angles are in the range of 24-122° for V-formations and 70±5° for J-formations. The formation angles >58° would enable every bird in the formation to see every other bird, even those following behind [5].

Groups must coordinate the timing and direction of movement to prevent splitting/fission. Reduced group fission will result in larger group sizes that help to maximise selective benefits such as protection from predators and homing accuracy, although interestingly not the costs of locomotion.

Flying at potentially compromised speeds with the group, rather than risking flying solo at a different, but energetically favourable speed, could maximise the benefits for each individual in the collective flight. Investigations are carried out on individual and group level mechanisms that influence the determinants and consequences of group speed.

Experimental investigations on speed consensus in homing pigeon flocks using high-resolution GPS indicate that compromises of up to 6% from the preferred solo speed (which was positively correlated with bird mass) were made to reach consensus in flocks. Despite group-wide advantages, contemporary flight models have suggested unequal energetic costs in favour of individuals with intermediate body mass/preferred speed, described as Goldilocks principle.

Experimental studies were carried out on GPS-tracked monocularly-occluded homing pigeons by conducting seven group training releases and one final solitary release from each of the two sites. The experiments also included a release from each site after a phase-shift of the light-dark cycle under binocular conditions in order to distinguish compass-based orientation from landmark-based pilotage.

Observations indicated that processing and memorising of visual landmarks in the context of route fidelity is mainly a property of the left eye/right hemisphere, while the right eye/left hemisphere is engaged in parsing flying objects, such as companions or potential predators.

When a large colony of honeybees leaves the parental nest to establish a new colony, an informed minority of scouts (5% of the swarm) guides a swarm quickly and directly to their new home. Based on the field studies conducted on swarms comprising of 11500 and 4000 bees, it is identified that flying scouts streak through the swarm cloud in the direction of the goal, thereby indicating the travel direction visually.

Attenuation of the light in sea water is due to the process of absorption and scattering

The experiments done on bees with sealed nasanov gland disproved the olfaction hypothesis that flying scouts release pheromones from their nasanov glands in front of the swarm for path guidance.

Various studies were done to understand the response stimuli of birds such as quela, startle, flocks of Dunlin, and schools of damselfish. From the laboratory experiments, the startle reaction times were 76ms for light stimuli and 80ms for sound stimuli [6]. One of the main forms of defence from predation in fish schools and bird flocks is the fast-start response, which is a rapid, anaerobically-driven acceleration, typically in response to a threat stimulus.

Following a predator attack, individuals in social groups can be alerted to predation risk either by directly detecting the predator's presence or through socially transmitted information from group-mates, typically in the form of rapid changes in locomotion (e.g. speed and direction). There are direct links among survival of predator attacks, reaction timing and escape kinematics, with the chance of survival increasing directly with faster reaction time, higher speed, and greater acceleration.

Experiments to study the response of a habitat of caged gregarious quelea to a predator (goshawk) indicated that the flight latency declined with increasing flock size. The probability of detection (PoD) of a predator increased with flock size, ie. from 0.3 to 0.6 for flocks of 4 and 32, respectively.

As flock size increased the type of response elicited changed from "taking wing" to "flight intention movements" to "orienting responses", the trend (**Table.1**) which can be understood functionally in terms of the reduced risk of capture in larger flocks, once the flock has been detected by a predator. Flock of infinite size would be maximally adaptive in terms of detecting danger.

Experiments were carried out in damselfish schools (24 fishes) to understand the reactivity through response

Table.1. Response of bird flocks to a predator [7]

Flock size	% of flock response in ms	
	Orienting	Intention to fly/ Fly
2	8	72
4	40	60
8	60	35
16	70	35
32	80	30

latency (agility) and kinematic performance (propulsion parameters including latency, average turning rate and distance moved) following a simulated predator attack, as well as to distinguish between first (direct response to stimulation) versus subsequent responders (response triggered by social stimulation).

The first responders in familiar groups exhibit latencies that are ~ 60% shorter than first responders in unfamiliar groups. Subsequent responders from familiar schools exhibit ~ 5 times faster latency compared to unfamiliar schools, i.e. 12ms and 68ms, respectively. These findings demonstrate that the benefits of social recognition and memory enhance individual fitness through greater survival of predator attacks.

By analysing the video captures of the aerial manoeuvres of Dunlin, the orientation changes in ~200ms and the self-generated synchrony could be a possible mechanism for the highly coordinated group behaviour [8]. Based on Dunlin flock image captures, the average neighbour-neighbour propagation time of ~15ms and a manoeuvre could be initiated by any bird in a flock that spreads through the flock as a wave.

The propagation which begins relatively slowly reaches three times the speed higher than would be possible if the individual birds were simply reacting to their immediate neighbours [9]. Based on the recent developments in computational capabilities, comprehensive numerical models capable of simulating V-formations and flock dynamics are being developed [10].

Thus the lessons from the shoal formation, shoal dynamics, response of shoals to predators, their optomotor response, distributed perception, quorum decision process and the vision capabilities could serve as key inputs for the developing bio-inspired robust AUV swarm intelligence algorithms.

Vision

Long-range optical vision in low-light or no-light environments is one of the important requirements

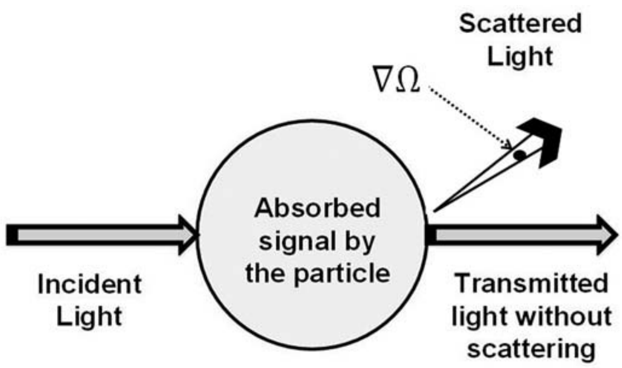


Figure.4. Underwater absorption and scattering process

for deep-ocean AUV. Attenuation of the light in sea water is due to the process of absorption and scattering. The absorption of light is due to the presence of dissolved salts, fumic and fulvic acids, as the photons interact thermally and lose their energy.

> *By construction, fish eye lenses present little spherical aberration and a gradient of refractive index with the highest value in the centre guarantees that the focus of the light is sharp*

In the visible spectrum, sea water absorption coefficient is minimum for 470nm wavelength, which lies in the blue-green region. Scattering deflects the light from the desired path and reduces the number of photons captured by the camera. Scattering is caused by the particles of size comparable to the wavelength (λ) of the incident light. Rayleigh scattering occurs if the particulate size is smaller than the wavelength, whereas Mie scattering occurs when the particle sizes are larger than the wavelength.

With reference to **Figure.4** and the indicated relationship, the spectral volume scattering function (VSF) is the fraction of the incident power scattered out of the beam through an angle ϕ into a solid angle ΔΩ centered on β. The wavelength-dependent scattering coefficient b(λ) is obtained by integrating the VSF over all directions as a function of β.

$$b(\lambda) = 2\pi \int_0^{\pi} \beta(\Psi, \lambda) \sin(\Psi)\, d\Psi$$

The inherent property of the underwater optical channel, which is a function of the seawater composition and the particulate content, including chlorophyll, determines the optical attenuation coefficient c, the sum of wavelength-specific absorption and scattering coefficient, expressed in m^{-1} and is represented as

$$c(\lambda) = a(\lambda) + b(\lambda)$$

The inherent property (attenuation) of the ocean water varies with geographical location and water depth (**Table 2**).

Table. 2

Type	Attenuation m^{-1}	Wavelength
Clear Ocean	0.151	450-500 nm; BG region
Coastal Ocean	0.298	520-570nm; YG region
Turbid Ocean	2.170	

Blue light irradiance was measured up to a 90m water depth at location (latitude 13°07.80′ N, longitude 72°02.61′ E) in the Arabian Sea on the 28th of March 2017; 10h using the NIOT-developed remotely operated vehicle (PROV500). The irradiance recorded at 5m and 90m water depths were 198 and 1.6 mW/m^2, respectively.

From the measured underwater irradiances at 470 nm, the attenuation coefficients of the blue light up to a 90m water depth are calculated and plotted in **Figure.5.** The attenuation coefficient is found to be a maximum of 0.23 m^{-1} at 10m and about 0.07 m^{-1} at 90m water depths. The attenuation trend matched with the S8 profile of Hardrin's depth chlorophyll maximum based classification.

Using the same attenuation coefficient, the irradiance at the 220m water depth is calculated and found to be less than 10^{-12} W/m^2 (i.e. in picowatts) [11].

The faunal zones of the deep-sea include the epipelagic (euphotic) zone up to 200m water depth, twilight mesopelagic (disphotic) zone up to 1000m, the numbingly dark bathypelagic (up to 4000m), abyssopelagic (up to 6000m) and hadopelagic (> 6000m) zones which are aphotic (**Figure.6**).

Due to the spectral filtering by water, at depth, light primarily consists of a narrow band of radiation between 470 and 480 nm, although ultraviolet penetrates to allow some crustaceans living at depths of up to 600m. Compared to fishes in shallower waters, fishes living in bathypelagic zone and beyond have photonic-level vision,

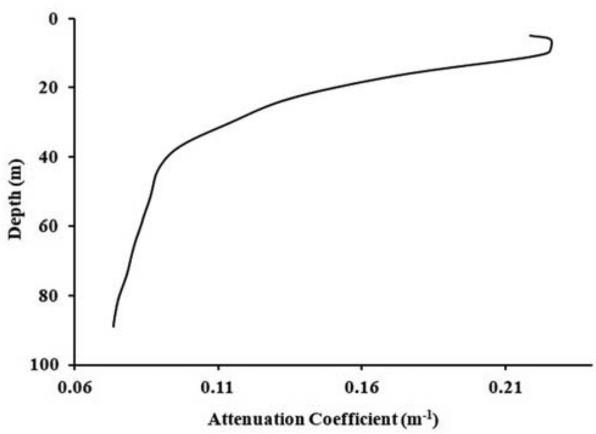


Figure.5. Attenuation coefficient profile up to 90m

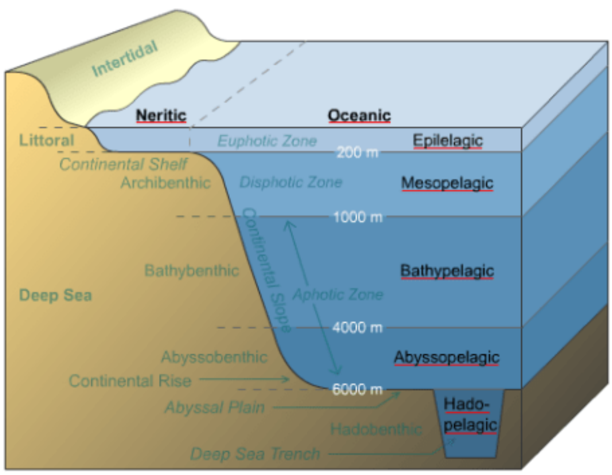


Figure.6. Faunal zones of the deep-sea

flimsy skeletons, weak and watery muscles, reduced internal organs and very slow swimming speeds.

It is before ninety years, John Murray and Johan Hjort first puzzled over the evolution of the visual systems for the fishes living in these different zones of the ocean [12].

By construction, fish eye lenses present little spherical aberration and a gradient of refractive index with the highest value in the centre guarantees that the focus of the light is sharp. Higher lens transparency improves the sensitivity and the lens pigments influence the colour of the light reaching the retina. Wider pupils with wide apertures allow more photons, increasing the visual sensitivity.

> **Autonomous navigation, intra-swarm intelligence, energy-efficient locomotion and soft robots are the key requirements for realising next generation subsea swarm robotic systems**

Thus wider pupils, larger photoreceptors and shorter focal lengths, all increase the optical sensitivity. The eyes of fishes are larger relative to body size, the deeper they live in the mesopelagic zone. The retinae of the deep sea fishes tend to be exclusively constructed of tightly-packed rods and the photoreceptors adapted for sensing dim light intensities.

Their photoreceptive outer segments are typically four times longer than in humans, and are rich in photo-pigments tuned to the blue down-welling sunlight. The aphakic gaps greatly increase sensitivity, but at the expense of spatial resolution. Tubular eyes mostly found in fishes inhabiting the lower mesopelagic zone sacrifice the field-of-view (FoV) as they gain sensitivity. The rarely seen tubular-eyed fish, Winteria, has the ability to rotate its tubular eyes to switch from a frontal view to a position where they look directly upward [13].

When approaching the bathypelagic zone, fish eyes tend to become smaller again, although pupil size relative to eye size tends to become greater, which is important for detecting bioluminescent point sources. About 90% of creatures in the deep sea are capable of bioluminescence (producing biological light).

A bioluminescent signal is defined by its intensity, spectral peak(s), temporal and spatial characteristics. The bioluminescence generated can be used by a fish to communicate with its congeners, attract prey or avoid and startle predators. They possess extraordinarily more number of genes for rod opsins and retinal proteins that detect bioluminescence light.

Those extra genes have diversified to produce proteins capable of capturing every possible photon at multiple wavelengths, which could mean that despite the darkness, the deep ocean fish can see in colour. The retina of the silver spiny fin has an unusual arrangement of low light sensing rod cells, which house diverse photoreceptor proteins.

Some of the rod layers are stacked to best capture the few photons available below a depth of 1000 meters. Many of the opsin proteins found in the silver spiny fin's rod cells are sensitive to distinct wavelengths, which enables the fish to see the full range of bioluminescence, the faint light given off by other creatures [18].

The visibility of the bioluminescent point sources in bathypelagic fishes is represented in **Figure.7**. The farthest distance *r* (m) that a fish with a pupil diameter *A* (mm) can see a bioluminescent flash containing *E* photons could be calculated numerically from the equation embedded in **Figure.7**. The curves represent different bioluminescent flash intensities ranging from dimmest (10^7 photons) to the brightest (10^{13} photons) measured in the ocean.

Brighter flashes or larger pupils extend the range of visibility, although beyond 150m flashes are not likely to be visible. For typical pupils (~7.3mm diameter) and

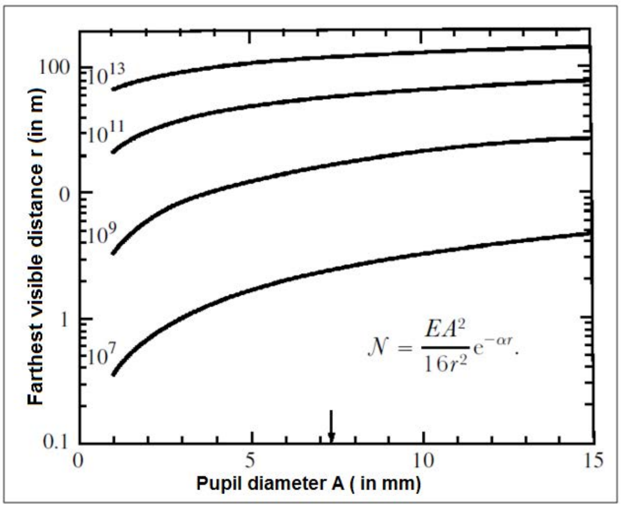


Figure.7. Visibility of bioluminescence in bathypelagic fishes [13]

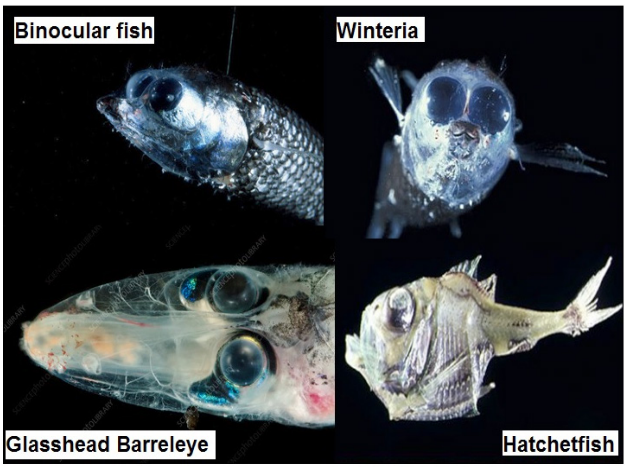


Figure.8. View of deep sea fishes

flash intensities (~10^{10} photons), the visible range is about 30-40m [14]. Thus eyes of bathypelagic fishes are highly adapted for detecting and localising bioluminescent flashes over ecologically meaningful distances of a few tens of meters. These eyes, together with other well-developed senses, including the olfactory and lateral line systems, allow bathypelagic fishes to intercept mates and prey in a dark.

Many species of dragonfish produce bioluminescent blue light like other deep sea fish. They can also emit far-red light using photophores in their eyes. Since there is no red light available in the deep ocean, most creatures there aren't receptive to it. This lets dragonfish light up their prey without their prey seeing the light, which provides them stealth capabilities.

This capability along with the additional hinge in the neck that enables extended mouth opening of up to 120º helps them to swallow large prey. Counter illumination is one of dominant methods of underwater camouflage. Certain deep sea fishes emit light ventrally to match the down-welling light from above producing light to match their backgrounds in both brightness and wavelength.

Recent developments feature back-illuminated charge coupled device (CCD) sensor and advanced imaging processing technology having low light performance (0.5milli lux) in subsea environments. However, development of deep ocean sensors and cameras mimicking the mechanisms in deep-ocean living fishes could help in developing more efficient deep ocean AUV imaging systems.

DISCUSSION AND CONCLUSION

Autonomous navigation, intra-swarm intelligence, energy-efficient locomotion and soft robots are the key requirements for realising next generation subsea swarm robotic systems. Understanding the biophysical sensors such as magnetite and light-sensitive retina cryptochromes proteins, transducing mechanisms and the associated neural processing aiding the directional and true navigation capabilities in sea animals and migrating trans-ocean birds based on magnetic, olfactory, visual and inertial clues to trace back their way home, when displaced several kilometres helps in improving the navigational capabilities of autonomous underwater vehicles.

Path integration with reference to the coordinate frame, recognition of visual landmarks, building in-situ cognitive maps and utilising geomagnetic field gradient maps provide interesting inputs for realising intelligent autonomous underwater vehicles with machine-learning capabilities. Although determining the longitude is still challenging for the humans, the means by which the sea animals and birds determine the longitude and derive true navigation map using geomagnetic and olfactory cues and their internal clock requires further detailed research.

Integrative studies of fish locomotion and bird schools using machine-learning and artificial intelligence could offer significant contribution in modelling their non-linear dynamics, drawing together the physiological and mechanical data.

Quantitative data obtained through the use of modern fluid mechanics experimental aids such as digital particle image velocimetry, theoretical advances such as vorticity control, efficient propulsion systems with vectored thrust mechanisms, oscillatory propulsors and fusiform body design with polymer composite materials for improved agility and muscle-like actuators could help in developing more efficient robotic designs with performances approaching extreme capabilities found in sword fish, archer fish, pike fish and trans-ocean bird flocks.

Octopus, star fish, jelly fish, manta rays and sea snakes are remarkable sources of inspiration to design and build continuum robots with soft arm, capable of pushing-based locomotion and object grasping aided by soft materials and actuators. Precise analysis of the rapid opto-motor response mechanisms and understanding the intra-swarm communication in fish shoal and bird flocks while achieving synchrony with neighbour's kinematics, decision making, construction, synchronisation and the spontaneous emergence of leader-follower relationship, predation and foraging capabilities are essential.

Their distributed perception and quorum decision processes in robust swarm decision making could help in realising improved particle swarm optimisation and fish school optimisation algorithms. Understanding the photonic-level vision capability of fishes inhabiting below the mesopelagic zone could aid in designing imaging systems for deep-water autonomous underwater vehicles.

Thus increasing synergy between engineers, biologists, physicists and mathematicians, advancements in the numerical modelling capabilities for analysing non-linear dynamics, precision sensors and efficient actuators will certainly bring innovative bioinspired technologies in the strategic marine sector.

ACKNOWLEDGEMENTS

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MASSA Academy Chennai Inaugurates Refurbished Electrical & Electronics Laboratory

On Friday 12th August 2022, MASSA Academy in Chennai inaugurated its Refurbished Practical Electrical & Electronics laboratory at the hands of Capt Deepak Correa, COO, Elegant Marine Services, Mumbai.

The refurbished and augmented laboratory has equipment to enable the following training capabilities:

PLC - Construction of ladder network, Programming and HMI. Programming of on board control panels and simulation (Package boiler, OWS, Purifier and Sequential start after blackout).

VFD & SOFT STARTER - Understanding of various types of start-up and speed control methods of motors. Pulse width modulation & Firing of scr and thruster. Understanding of Electrical propulsion system & Flow controls.

FAULT MODULE STARTERS - Troubleshooting practice given in various types of starters, understanding of various types of electrical circuits.

DEMO MODULE STARTERS - Retro fit practice to handle the emergency situation to build own bypass circuit, small control and power circuit.

TRANSDUCERS (Sensors) - Familiarisation of types of sensors and testing methods.

BATTERY - Types of batteries, Testing and routine maintenance of battery.

MOTOR OVERHAULING - Types of motor, Routine test and maintenance of motors, Before and After tests to be conducted in rewound motor. Overhauling of motor, Insulation resistance and coil resistance test.

TRIP & INTERLOCK COILS OF ACB - Understanding the arrangement of protection system and ACB tripping and interlocks.

ELECTRONICS - Familiarisation of electronic components and testing methods, Soldering and desoldering practice.

PARALLEL OPERATION OF ALTERNATORS & PROTECTION DEVICE TEST - Practice given in parallel operation of alternators in various mode and methods, simulation of reverse power, under voltage, overload, preferential trip, over frequency,

HV BAY - Operation and Maintenance procedure in HV system, Familiarisation of switchgear, measuring device and special test equipment in HV system in on board. Demo and practice given in 6.6KV HV panel.

MASSA Academy Chennai delivers a 6 days Practical Electrical & Electronics Workshop at it academy that is targeted at ETOs and Engineers up to 2nd Engineer level.

BRIDGING THE LOGISTIC DIVIDE: TIME FOR INDIA'S OWN CONTAINER SHIPPING LINES?

Sudhakar Unudurti

Abstract

At a time when post-pandemic trade recovery is accompanied by skyrocketing of ocean freight, this paper strongly advocates the need for rapid building of India's own tonnage in container shipping and developing the country's own 'hub-and-spoke' network. It draws from a series of recent interviews of various stakeholders involved in port-based transportation of containerised cargoes.

Global Trade on the Rebound

As can be seen from **Figure.1**, the recovery in global merchandise trade volume has been as dramatic as the steep fall triggered by the pandemic. The recovery path is obviously poised to revert to the original trend line. While the recovery *per se* is undoubtedly a welcome by all the stakeholders involved, a number of issues that have been exacerbated by the pandemic, continue to trouble the traders accessing global logistics. The most significant factor in this respect is the unprecedented hike in ocean freight – coupled with scarcity of containers. Consequently, exporters and importers the world over are saddled with high ocean freights at a time when they are frantically trying to recover the losses that they suffered during the pandemic.

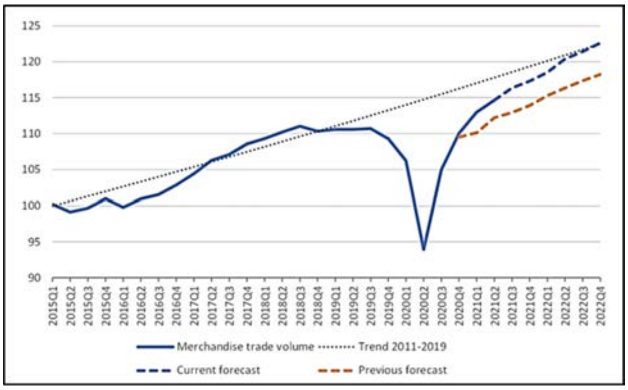

Figure 1. World merchandise trade volume rebounds post-pandemic
Source: World Trade Organisation (WTO) Press Release 889, Oct 2021

Driven by the hike in ocean freight, the steep rise in the charter rates for container ships (weighted average of six selected container ships and represented by a single number, the New ConTex Index) had matched exactly with the steep rise in the merchandise traded in the one-year period June 2020 to July 2021 (**Figure.2**).

All Exporters are NOT the same

Low-volume, low-value exporters, who often deal in heavy-weight cargoes such as granite or minerals, are marginalised by the liner companies, who assign higher priority to high-volume, high-value cargo exporters that often weigh less. **This preference for lower weight cargoes by the shipping companies arises from the deadweight (or payload that a fully-laden ship can carry)**

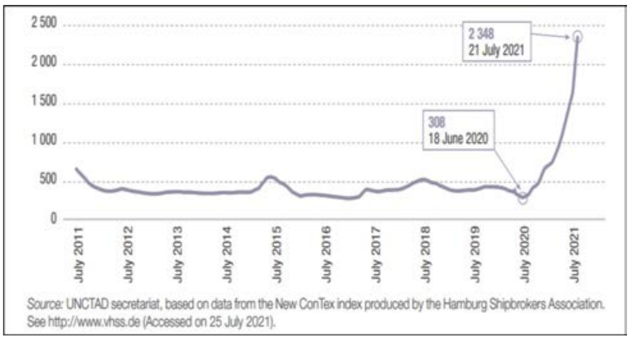

Figure 2. The New ConTex Index over the past decade (Base: October 2007 at 1,000 points)

limitation. Shipping companies naturally wish to maximise the number of containers carried since they get paid by the TEU (Twenty-foot Equivalent Units). They wish to avoid reaching the maximum draft marks *before* accommodating the fullest number of containers in terms of TEU.

Exporters of low-value, low-volume cargoes suffer further since they are not bound by contractual arrangements with the liner or 3rd Party Logistics (3PL) companies but depend on the spot market which invariably costs 10-15% more. Such marginal exporters approach Clearing and Forwarding (C&F) agencies who assist (for a charge) in consolidating Less than Container Load (LCL) consignments into Full Container Load (FCL) by combining the cargoes of a number of exporters together.

> *Shipping companies naturally wish to maximise the number of containers carried since they get paid by the TEU (Twenty-foot Equivalent Units)*

The Story of 'Empty Boxes'

One of the after-effects of the pandemic that continues to haunt the global movement of goods is the disruption of the circular movement of containers. Port congestions across the world led to piling up of containers in Chinese and the US ports. Exporters everywhere, including India, are struggling to find 'empty boxes' to fill their merchandise with.

As goods slated for export accumulate in warehouses for want of containers, exporters lose out on inventory cost and a delayed billing cycle and risk failure to meet deadlines. If the goods are seasonal or have a limited shelf-life, entire trading proposition becomes unviable. Small-time exporters cannot face financial ruin.

The Tide that Lifted All the Boats

The sole beneficiaries of the steep rise in freight rates have of course, been the shipping lines. In recent years, their clout has extended to terminal operations and they are now offering of door-to-door services to the dismay of local C&F agencies and 3PL operators.

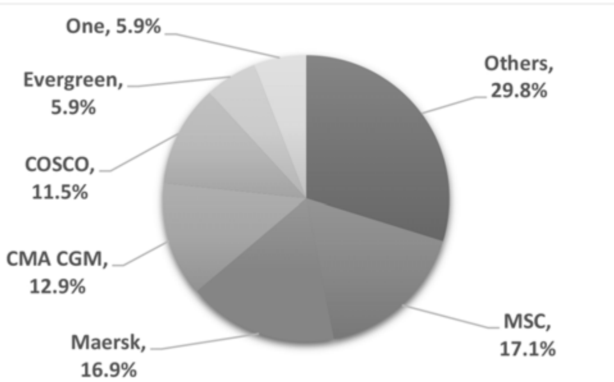

Figure 3. Market Share of Container Shipping Lines

How did the container shipping companies manage to find themselves in such an enviable position – just when the world trade is gasping for container capacity? Besieged by global economic downturn, overcapacity, lower freight rates and rising debt levels, South Korean shipping giant Hanjin went bankrupt in 2016. Japan – a traditional maritime nation, had also been struggling to keep afloat and the country's big three shipping groups, K Line, MOL and NYK, integrated their container shipping businesses in 2018 in to 'One' – in an attempt to consolidate and avoid wars of attrition. This was well before the pandemic had set in. In the decade that preceded the pandemic, ships were chasing cargoes. **Improved capacity management through alliances – coupled with a hold on newbuilding reigned in the supply while the demand soared – leading to galloping freight rates by the time the pandemic had abated**.

China also produces 96% cent of the world's dry cargo containers and 100% of temperature-controlled (reefer) containers. In a welcome move, Government of India announced measures to support manufacture of containers last year and public sector companies Bharat Heavy Electricals Limited (BHEL) and Braithwaite & Co. have commenced production.

Industry experts caution that China's entry and expansion into liner operations is going to be the next game changer. There are indications that the Chinese national carrier Cosco is moving in this direction (**Figure.3**).

Asian Goods, European Ships: Same Old Story

In order to capitalise on economies scale, container ships have been getting bigger and bigger. The TEU capacity of ships has increased by 1,500 percent over the past 50 years (**Figure. 4**). Big ships make demands on ports to deepen approach channels by investing in dredging and to upgrade their handling equipment. In other words, it is the container shipping that drives the terminal development and puts tremendous pressure on all related activities.

Container Shipping: India missed the boat?

India's own foreign trade has also been reporting encouraging sign of recovery (**Figure.5**) and the foreign trade has crossed the Trillion USD mark – post-pandemic. **Despite making remarkable strides in foreign trade, India had not only missed the boat in the initial years of containerisation, but also continues to remain insulated from the world-wide developments in this vital sector.** India's own capacity in container shipping continues to be woefully low and comprises 32 vessels (i.e., dedicated, cellular container ships). Shipping Corporation of India (SCI), is on the verge of being privatised. It is not clear what the new owners have in mind for India's largest and most diverse shipping company.

In contrast, China's national carrier, China Ocean Shipping Company (COSCO) operates 480 container ships with a combined capacity of 2.9 million TEUs – according to the figures reported by Marine Insight for the current year. Present newbuilding ordered by COSCO is expected to boost the capacity by another 0.6 million TEU in 2023. (www.marineinsight.com/know-more/10-largest-container-shipping-companies-in-the-world/).

The figures published by Indian National Shipowners Association (INSA) in their *Annual Review 2021*, the containers handled by the Indian flag vessels in the year 2019-20 stood at a miniscule 2.8% of the overall numbers handled at Indian ports. In the same review, INSA makes a strong statement on the current situation:

"The current container crisis has already seen the freight rates skyrocket with the Indian trade at the mercy of foreign shipping lines...the fact is that today there is no Indian container shipping left...Unlike India, China has a healthy national container fleet".

According to the *UNCTAD Review of Maritime Transport 2021* (p.64) –

Pepper for the US Market: Brazil replaces Vietnam

"In 2020, for exports to the US, the cost per 40-foot container was $2,000 to $3,000 but in the first six months of 2021 this had soared to an average $13,500".

If the US buyers choose to source their imports from Mexico or other South American nations to save on logistics cost, India and other Asian exporting nations would suffer immensely.

South Korea Shows the Way

"In the Republic of Korea, to ensure that small and mid-sized shippers have access to capacity, the government has announced a plan to subsidize shipping rates – a 20% discount on freight rates and guaranteed shipping space if they sign long-term service contracts with domestic shipping lines".

Key Findings of the Survey

Exporters and C&F agencies expressed concern over steep rise in ocean freight. They also felt that the big shipping companies are 'arm-twisting' the terminals by being selective about where their ships would call – forcing the traders and the C&F agencies to often seek alternate land routes for their cargoes.

A coir exporter from Tamil Nadu complained of having to incur a logistics cost of more than double the value of the cargo itself. Small time exporters are particularly distressed by non-availability of empty containers. A leading exporter of knitwear from Tirupur who has been enjoying 'ex-factory' terms – with his billing cycle commencing the moment a consignment is handed over to the 'buyer-designated' shipping lines in the local Inland Container Depot (ICD), is now wondering if his products would remain competitive internationally – given the upsurge in the logistics cost.

Terminal operators felt that our infrastructure planning should be way ahead of projected demand instead of operating forever in the 'fire-fighting mode'. They also expressed concern over the fact that the government-owned ports have adopted the landlord model – interested only in rent-collection. They sought clarity on who will invest in dredging and deepening of approach channels (for accommodating larger ships in future) and infrastructure development – especially in last-mile connectivity and the much-needed construction of dedicated rail and road corridors.

Greenfield ports have a better growth potential compared to older ports where the road access, truck parking, warehousing, CFS-Terminal connectivity and city traffic have become the bottlenecks. Big shipping lines are actively collaborating with privately-owned, newly-developed ports to operate their container terminals. This

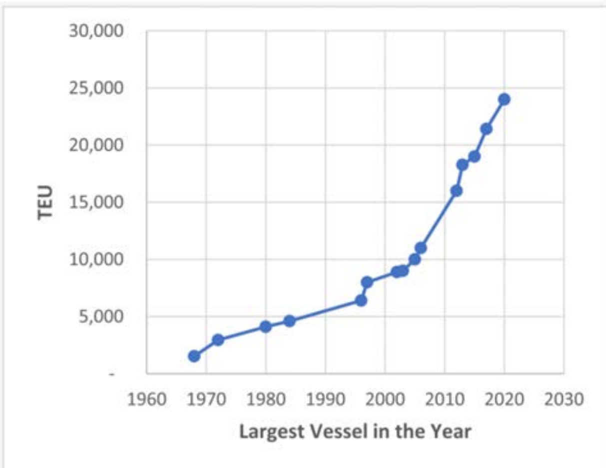

Figure 4. Increasing Capacity (TEU) of Container Ships
[https://www.statista.com/statistics/198206/share-of-leading-container-ship-operators-on-the-world-liner-fleet/]

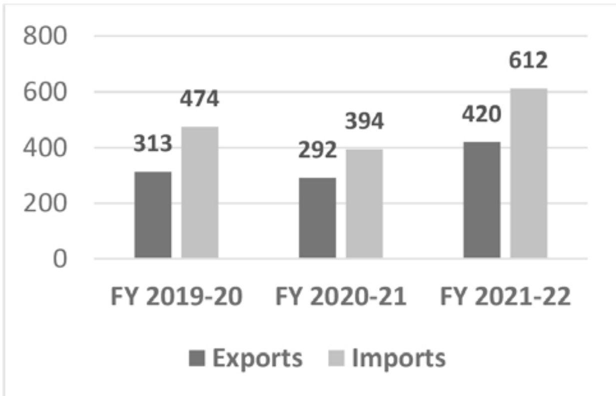

Figure 5. India's Merchandise Trade (in US$ Billions)
Source: Ministry of Commerce, Govt. of India

move is expected to wipe out container operations of older, government-owned, landlord ports.

There was clear agreement that all exporters and importers are not the same. Our maritime logistics need to bridge the *logistic divide* to protect the low-volume, low-value exporters from the onslaught of shipping lines. It was repeatedly pointed out that today's big exporters started as small-timers – not so long ago. Everyone spoke in a single voice when it came to the question of ocean freight: "Why aren't we able to check this?"

India seems to have traversed a full circle from the times of pioneers of national shipping – such as VO Chidambaram Pillai and Walchand Hirachand (**Figure. 6**).

A freedom fighter inspired by Gandhiji, Tilak and Vivekananda, V O Chidambaram Pillai (popularly known as VOC), established the Swadeshi Steam Navigation Company way back in 1906. His company provided shipping services between Tuticorin and Colombo. In 1911, while he was in prison on charges of sedition, the shipping company was liquidated by the British.

Walchand Hirachand fought against all odds and founded the Scindia Steam Navigation during the British rule and S.S. *Loyalty* sailed from Bombay to UK on 5 April 1919 – a day which is celebrated as the National Maritime Day.

Time has come perhaps to seek inspiration from these and other pioneers and stalwarts of Indian shipping.

Never too late

Thus far, the thrust of the sectoral reforms and investments has been focusing on the land-side: ports, highways and port-hinterland connectivity. Time has come perhaps to look beyond our shores and aim at rapidly building capacity in container shipping. This certainly has been the message delivered by the pandemic-induced crisis in global logistics. Captive container shipping capacity is India's guarantee in ensuring an uninterrupted flow of the country's global trade.

To begin with, it would be a good idea to aim at building India's own, regional 'hub-and-spoke' network of container shipping – combining initially with the needs of coastal shipping and focusing primarily on connecting with Singapore on the East and Dubai on the West. Typical vessel sizing for this purpose could be 1,500 to 3,000 TEU capacity, combined with 'mother' vessels of 7,500 plus TEU. Further studies would of course be needed to go over various options and finalise the vessel sizing.

V.O. Chidambaram Pillai
(1872-1936)

Walchand Hirachand
(1882-1953)

Figure 6. Pioneers of Indian Shipping

The next challenge would be to identify the roadmap for expediting vessel acquisition. Possible options would be to charter and then buy from second-hand market and simultaneously order newbuilding. A mega project such as this cannot take-off unless all the stakeholders come together. It calls for a long-term commitment expressed through conducive policies and legislations that are matched by comprehensive financing options and soft funding.

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TECHNICAL NOTES

LUBE MATTERS # 16
GREASE

Sanjiv Wazir

Introduction

Lubrication is essential to promote efficient operation and prolong the life of moving machinery components. The most common types of lubricants are oils and greases. Lubricating oils have been covered in some detail earlier in this series. Here we look at greases.

Grease

Liquid lubricants are difficult to retain within the area of contacting/rubbing/rolling surfaces and must be replenished frequently, often continuously. If the liquid lubricant where thickened, its retention in the contact area would improve, and lubrication intervals could be extended. A lubricating grease can be defined as a lubricating liquid that has been gelled with a thickener so that it can be retained in the required working area.

Base Oil

Essentially a lubricating grease is a semi-solid to solid product of the dispersion of a thickener in a liquid (base oil). Additives are usually included in the composition to improve its properties.

Figure 1. What is grease

The base oil is an extremely important ingredient of grease. It can comprise more than 95% of a grease. Base oils of viscosity between ISO 100 & ISO 220 are the most common. For special applications higher or lower viscosity grades may be used. A large variety of base oils can be used to make greases. Greases may be classified by the type of base oil used in its manufacture.

Mineral oil-based grease

Many types of mineral base oils are used, including naphthenic, paraffinic, hydrocracked, etc. By far the largest volume of greases are made from mineral oil base oils.

Synthetic oil-based grease

Synthetic oil-based greases are used for certain conditions where conventional mineral oil grease falls short in desired properties (low-temperature property, heat resistance, low-torque, or longer life). Synthetic greases come with many different characteristics depending on the type of the synthetic oil used. Esters, PAOs, PAGs, Silicones are all used for manufacturing specialised greases.

Base oil type and viscosity is a key consideration when matching grease types to specific applications and replacements.

Thickener

As described above, grease consists of a liquid phase (base oil) into which a solid phase of finely divided thickener has been uniformly dispersed. The liquid is immobilised by the solid dispersion, which must remain relatively stable with respect to time and usage. At operating temperatures, thickeners are insoluble in the base oil. But there must be some affinity between the thickener and the liquid to form a stable gel-like structure.

The thickener structure can be constituted of fibers (such as various metallic soaps) or plates or spheres (such as certain non-soap thickeners). The components are not in chemical solution but co-exist, like water in a sponge. The thickeners in grease work like a sponge, releasing the lubricating fluid (base oil and additives) when force is applied, and reabsorbing the fluid when force is reduced. Many products have been used as thickeners.

Metallic soaps were the earliest thickeners and are still the most widely used.

Soaps are present in the greases in the form of fibres. The thickness and length of the fibres depends on the metal and the conditions under which the soap was formed. Soap is formed by the neutralisation of fatty acid with a base. If a single fatty acid is used, the soap is known as a simple soap. If two dissimilar acids of widely different molecular weights are used, the saponification reaction will result in a complex soap. The most common basic components used are hydroxides of lithium, calcium, sodium, and aluminium. The most common fatty acids used are derived from animal tallow or vegetable oils.

Grease is often classified by the thickener type as Soap type or non-Soap type.

Some common soap type greases are:

Calcium Soap Grease

The earliest known greases were made from calcium soaps. In a typical manufacturing process of making calcium soap grease, the mineral oil, fatty acid, calcium hydroxide (hydrated lime) and water are mixed and cooked to bring to saponification. The process is complete after adjustment of water content. Due to its poor heat resistance, it is used for general plain bearings operating under rather low speed and low load where service temperature would not rise far above 70°C. Its water resistance is good, and thus the grease performs well in applications exposed to water.

Lithium Soap Grease

Lithium soap greases were the first "multipurpose" greases providing better water resistance than calcium soap greases and higher temperature properties than sodium soap greases and good mechanical stability. It consists of mineral or synthetic oil and lithium stearate or lithium salt, a hardened fatty acid derived from castor oil. Used widely for general industrial applications, in automobiles, bearings and home electric products. It is the most widely used simple soap grease.

Aluminium Complex Soap Grease

Aluminium complex grease is made from a complex soap which is formed by reaction of aromatic carboxylic acid and stearic acid on aluminium hydroxide. Aluminium complex grease is characterized by a very fine fibre structure, high dropping point (200°C or above), excellent heat and water resistance and mechanical stability. Widely used in steel mills and other wet applications. Compatibility with other greases is a problem.

Lithium Complex Soap Grease

The soap is formed by reaction of lithium hydroxide with the mixture of a fatty acid and a dibasic acid. The dropping point of the finished grease can be >250°C. Lithium complex grease has excellent heat and water resistance and rust preventing property, as well as longer life at high temperature than lithium soap grease. It is the most widely used complex grease.

Calcium Complex Soap Grease

The soap is made by reacting acetic acid and a fatty acid with lime. The resulting grease has inherent EP properties and provides good friction and wear performance. Thickening efficiency is not as good as other complex soaps, so a relatively high soap concentration is required. Used within its limitations calcium complex greases are cost effective multi-purpose grease.

Some common non-Soap greases are:

Polyurea Grease

Typical urea grease formulation uses reactants (isocyanates and amines) that are hazardous, but the

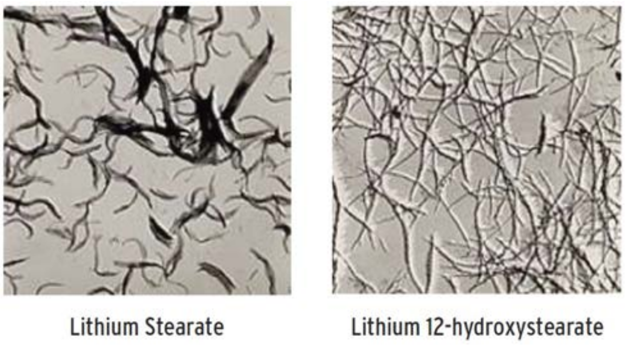

Figure 2. Soap fibre structure in grease

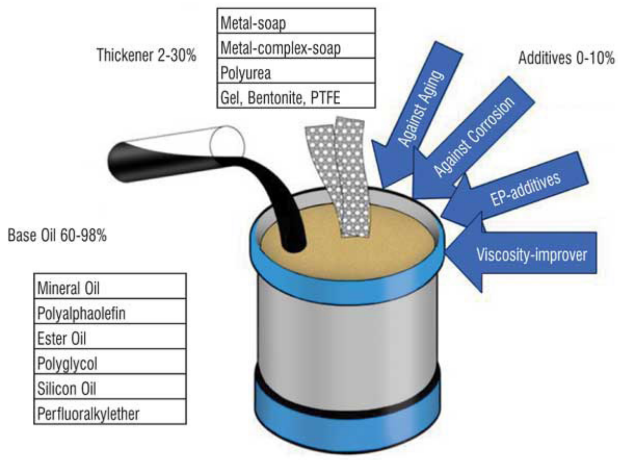

Figure 3. Grease ingredients

resultant thickener is considered quite safe. They have good oxidation resistance, water resistance, pumpability, and high temperature performance. They are the most widely used non-soap grease. Although used in all types of bearings, they have proved especially useful for the lubrication of "sealed-for-life" ball bearings in electric motor bearings. Urea grease is also widely used for automotive electrical components. For high temperature conditions, synthetic oil-based urea grease is preferred. One weakness is its incompatibility with most other greases.

Bentonite Grease

This grease, thickened by organic bentonite is often called "grease without dropping point" or "grease without melting point," because it does not lose the grease structure even at extremely high temperature. The grease can offer other advantages like good shear stability, but its application is limited because of rather poor rust prevention, hardening tendency when exposed to high temperature condition (200°C or above) for a long time, and poor ability to keep oil film on the bearing race surface during high-speed rotation. Not compatible with most other greases.

Other Non-Soap Greases

Other non-soap greases include Na-terephthalamate Grease, Copper Phthalocyanine Grease, Teflon (PTFE) Grease, Mica Grease and Silica Gel Grease.

Figure 4. Cone penetration test (4)

Grease consistency

Consistency is the degree to which a plastic material, such as grease, resists deformation. In a grease it is a measure of the firmness or rigidity of the thickener structure of the grease.

Grease consistency is measured by a cone penetration test and is reported as its NLGI* Consistency Number. Several types of penetration measurements (unworked penetration, worked penetration, prolonged work penetration, block penetration) may be carried out on grease samples. NLGI has standardized a scale as a method for classifying a grease according to its worked penetration. Worked penetration is measured after a grease has been worked for 60 standard double strokes in the standard grease worker. The test measures, in tenths of mm, how deep a standard cone penetrates a grease sample. Each NLGI grade corresponds to a specific worked penetration value range. Higher penetration values indicate a lower NLGI grade number.

Grease properties

When choosing a grease for an application, several of its properties need to be considered for the expected operating conditions. They are:

1. Required base oil viscosity at temperature of the bearing.
2. Grease consistency for the operating temperature.
3. Soap base which is best for the application.
4. Availability of EP and other desired additives.

Grease advantages

"Grease is better than oil" may be considered to be a rash statement, but there is a kernel of truth in it. Grease cannot be used as a coolant or as engine oil. However, its multi-phase structure does impart some advantages over liquid lubricants.

Table 1. NLGI Grease Consistency Grades

NLGI Grade	Worked penetration after 60 Strokes at 25°C (0.1 mm)	Appearance	Food Analog
000	445-475	Fluid	Cooking oil
00	400-430	Fluid	Ketchup
0	355-385	Very soft	Mustard
1	310-340	Soft	Tomato Paste
2	265-295	Moderately soft	Peanut Butter
3	220-250	Semi-fluid	Margarine
4	175-205	Semi-hard	Hard Ice Cream
5	130-160	Hard	Fudge
6	85-115	Very hard	Cheddar Cheese

Note: *Grease consistency is greatly influenced by the amount and type of thickener and the base oil viscosity. Under force, a low NLGI grade grease will release the base fluid more readily than a grease with higher NLGI grade. The right grease consistency is important for ensuring that the appropriate amount of lubricating fluid is provided and maintained in the working area for proper lubrication (4).*

- Stays in place, acts like a reservoir, shortens relubrication intervals, may continue to provide some degree of lubrication even if relubrication has been forgotten!
- Higher dynamic viscosity and elasticity provided by thickener result in higher temperature and load performance.
- Multi-phase nature prevents wax formation in paraffinic oils at lower temperature
- Consistency provides tackiness, prevents leakage, and prevents entry of solid or liquid contaminants into the working area
- Can carry insoluble solids like graphite and MoS2 to the working surfaces.

Conclusions

Grease is a highly complex product, as important as any other part of a machine, and to considered from the machine design stage itself. A modern high quality multi-purpose grease may cover up to 80% of all greasing applications. For the remaining 20% of demanding and special applications a wide variety of specialist greases are available. With the advent of electric vehicles, grease will start replacing oil as the main automotive lubricant.

*NLGI: National Lubricating Grease Institute

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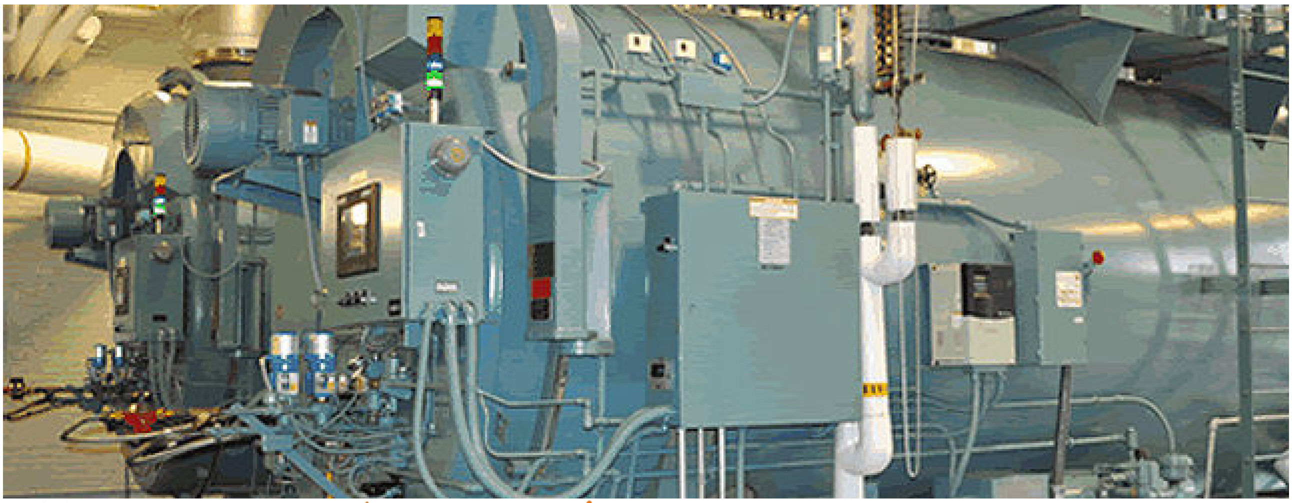
TECHNICAL NOTES

EMPIRICAL ANALYSIS OF MARINE AUXILIARY BOILER TUBE FAILURE



Anshuman Sen

Abstract

Marine auxiliary boiler failure on ocean going vessels is well known in the Technical ship management fraternity. Although not widespread, most vessel managers will come across a few such cases during the span of their caeeers. The cost for re-tubing can run into hundreds of thousands of dollars which is normally not budgeted for in the OPEX by the vessel manager & is a major addional expense for the ship owner, This article examines the reasons for boiler tube failure, discusses preventive measures which can be implimented to avoid them, details the most common reason for tube failure based on statistical evidence and practical real world examples that I have witnessed in my professional practice. It also covers why remedial measures for the most common cause of tube failure is oftentimes unsuccessful & what can be done to correct this. Lastly, it briefly touches on additional optional safety measures which can be incorporated to avoid tube failure.

1. Introduction

The auxiliary boiler is essential to the safe operation of ocean going vessels and is therefore classified in the "critical machinery" category. Given its importance the IACS rules require marine auxiliary boilers to be subject to separate mandatory annual, intermediate and renewal surveys.

However, despite stringent detailed inspections by calss surveyors, continuous monitoring during operation by ships engineers and recent advances in material science and technology during the manufacturing process, the industry still continues to witness a fair number of boiler break downs due to tube failure every year.

Ideally re-tubing should not be required during the life of the boiler which in some cases can stretch to 20+ years. In addtion to this I have observed marine eingineers onboard are by and large dilignet in operating and maintaining the boiler during their tenures in accordance with the maintenance intervals specified in the instruction manual. For e.g. the burner is regularly cleaned, the furnace inspected, water testing & dosing done, gauge glass & water drum blow down carried out, lastly safety alram and trips tested. Despite all of the above, we still have incidents of boiler breakdown due to tube failure. Why is this ?

The reasons could be because of caustic attack, oxygen pitting, hydrogen damage, acid attack, stress corrosion, waterside corrosion, fuel ash corrsoiosn, fatigue, errosion, mechanical failure, overheating, graphitisation & weld failure. These aforementioned reasons can be broadly classified into 5 major categories, namely overheating, corrosion, erosion, mechanical stress & material defects.

2. Method

Let us examine the symptom, causes & solutions of these 5 major reasons individually.

2.1 Symptoms, Causes & Solutions

1) Overheating–Symptoms are rupture of the tube material. Caused due to flame impingement, elevated temperatures due to reduced heat transfer across the tube walls because of scale deposits, oil contamination & refractory failure. Solution is to adjust correct flame angle, to ensure no blockage in the tubes or contamination in the boiler water, which can reduce

heat transfer as well as proper boiler feed water testing and treatment.

2) Corrosion – Several forms like caustic / acid attack, stress corrosion, oxygen pitting. Symptoms are pitting, loss of ductility, deterioration of metal due to chemical process causes the tubes to thin down. Causes are because of improper water treatment, oxygen in the boiler, moisture on the outside of tubes combining with Sulphur in the fuel to form H_2SO_4. Solution is proper feed water testing & treatment, and to maintain feed water at elevated temperatures.

3) Erosion – Symptoms are wearing a way of tube metal by flow of water & steam or gas & ash. Solution is to use fuel with low ash content, ensure regular soot blowing & boiler water blow down.

4) Mechanical Stress - Symptoms cannot be easily detected Failure results due to stress on tubes, already weakened by wear down from corrosion / erosion. Causes are a result of pressure, thermal expansion, vibration & fatigue. Solution is to ensure boiler is not subject to excessive fatigue i.e. cyclic reversible stresses.

5) Material Defects – Symptoms are once again not easily detected. Caused by a weak spot in tube material during the manufacturing process, that cause failure during operation. Solution is to ensure tubes are correctly inspected during class approval survey for the raw material.

Statistical analysis of MSC Ship Management fleet data over the last 5 years, indicates overheating due to oil contamination in boiler feed water to be the major cause of the above listed 5 causes for failure. It was observed in 37% of vessels in the fleet, whereas failure due to reasons other than overheating was observed in only 5% of vessels in the fleet. (**Figure.1**).

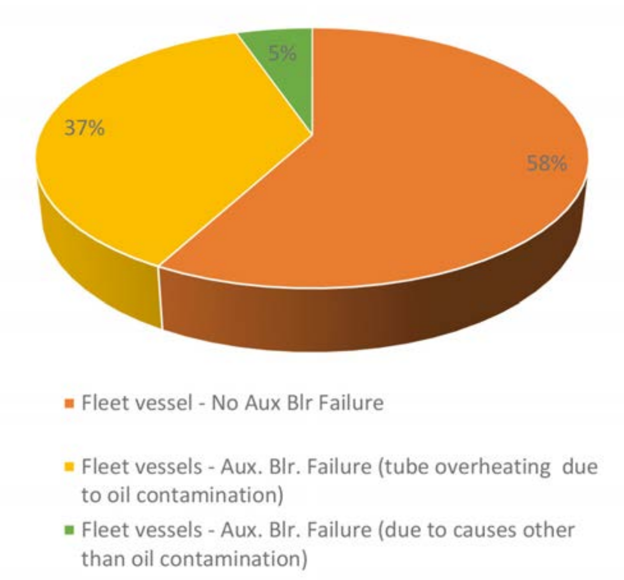


Figure 1. Statistical Distribution of Aux Boiler Failure of MSC Ship Management Fleet-3 Data from 2015-2020

2.2 Tube Failure due to Oil Contamination of Feed Water

As we have now established overheating of tubes due to oil contamination in feed water to be the number one reason for auxiliary boiler failure, let us look into the symptoms, cause, reason & remedial measures to be taken.

From case studies on vessels which experienced tube failure due to oil contamination, the source of oil leakage was traced to (**Figure.2**) .

- Leakage of fuel from Bunker heating coil in bunker tanks into the steam return line
- Leakage of fuel from fuel oil purifier heater into the steam return line
- Leakage of fuel from the main engine fuel oil heater into the steam return line

In all cases ships staff immediately rectified by replacing the heater. Boiler water side was then de-pressurised and opened for inspection, found very thin oil film adhering to the outside of the smoke tubes. The boiler tubes were cleaned by hosing down with kew machine & chemicals. Feed water tank, cascade tank were cleaned and water replaced. (**Figure.3**).

Despite the effort, the tubes continued to fail over the course of the next few months to a point where the only solution was to re-tube the boiler.

A thin film of oil, only 0.5mm can reduce heat transfer by 40%, across the tube wall, compared to limestone, which requires a 7.0mm coat for the same reduction in heat transfer. (**Figure.4**) This reduction in heat transfer will cause overheating and ultimately tube failure.

Figure 2. Fuel leak in heat exchanger & boiler water sample showing extent of oil contamination in the system

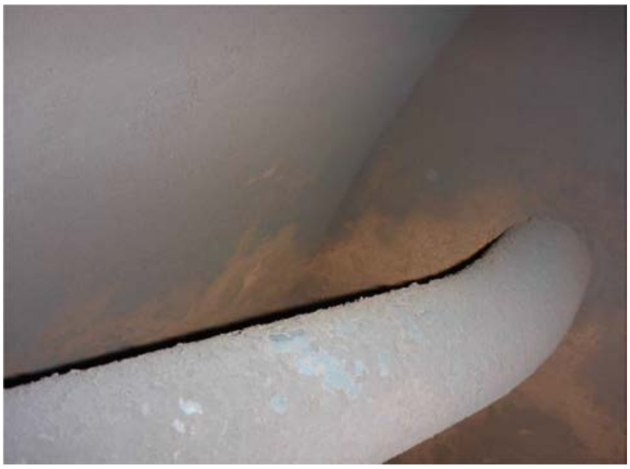


Figure 3. Thin barely visible Oil film adhering to outside of smoke tubes

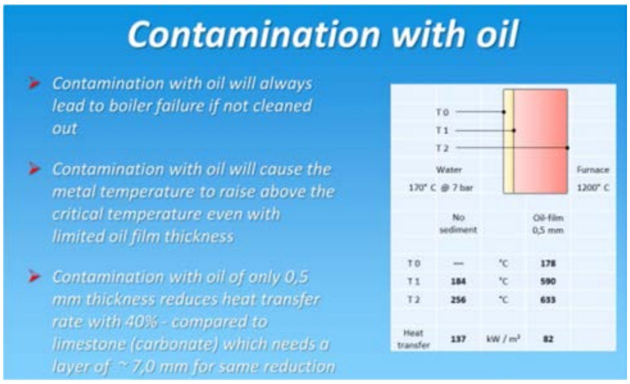


Figure 4. Devastating Effect of a thin oil film on the heat transfer capacity of boiler tubes

3 Results

The most important takeaway from this article is that, the most common cause for tube failure is oil contamination (refer **Figure. 1**) In the event of which the boiler waterside must be cleaned as early as possible by mechanical as well as chemical means, preferably by shore specialists. If a high degree of cleaning is not done at an early stage the boiler will eventually fail within a few months of the incident due to tube overheating as explained in **Figure.4**. The later the cleaning commences the harder it is to eradicate all oil traces from the system, particularly the tubes. Manual brushing with chemicals is ineffective; recirculation with special chemical de-greasers at elevated temperatures is necessary for effective cleaning.

In addtion to cleaning, the below measures can also be implemented to avoid tube failure from overheating.

1. Regular testing and treatment & blow down of boiler feed water.
2. It may be prudent to install oil in water sensors in the observation tank & connect to the ships Alarm Monitoring system to detect contamination in the early stages.
3. In the event of oil contamination, the boiler water drum must be isolated as quickly as possible.
4. Regular inpsection of the cascade tank through well illumonated sight glass.
5. Another cause of tube failure though not related to oil contamination which is often overlooked is tube failure due to thermal stress particularly in horizontal tube boilers, there is an allowance for expnasion by means of an elliptical sliding foot which should be tightened follwing the proceudre in the maker's instruction manual.

4. Conclusion

Although this article has touched on various reasons for boiler failure, most of them are well documented and engineers onboard are aware of preventive measures which can be incorporated to avoid them. From our data, the most common cause for auxiliary boiler tube failure is due to overheating because of oil ingress in the system.. Oil contamination must be avoided and the article lists preventive measures which can be follwed to ensure this. In case of contamination, a through clean up operation is essential without which the boiler will most likely fail a few months down the line. In the overwhelming majority of cases, the clean up operation is not carried out to a high standard which is critical, particularly for the boiler tubes, as discussed even a oil film of 0.5 mm will dramatically reduce the heat trasfer and result in slow but sure tube failure due to overheating in due course.

Acknowledgments

[1] Data, MSC Ship Management, Cyprus

About The Author

Anshuman Sen is a Marine Engineer and Technical Maritime Consultant for FMC International based out of New Orleans, USA. Prior to this, he held the positions of Technical Superintendent for several multinational ship management companies based out of Cyprus, Singapore and Dubai, wherein he developed and implemented innovative solutions for vessel operations and technical repairs.

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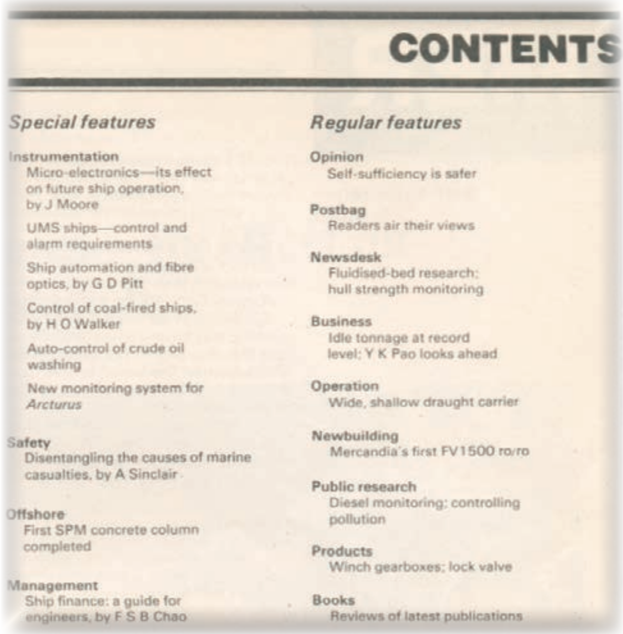
GOING ASTERN INTO MER ARCHIVES



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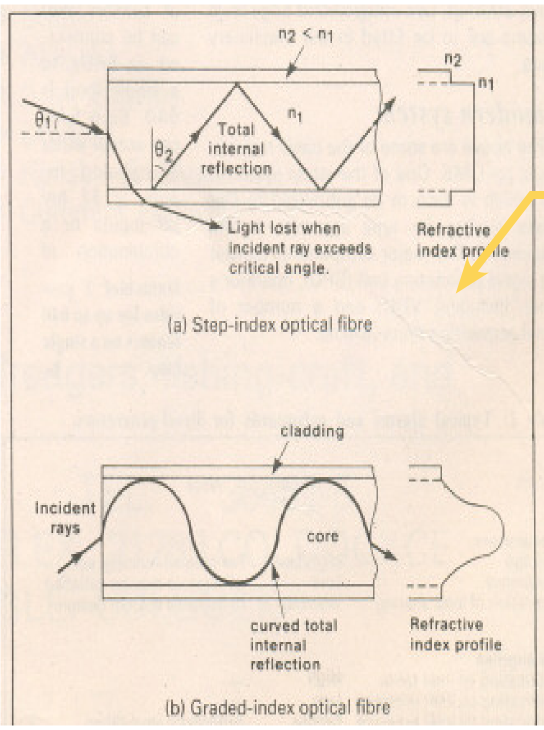
MER... Four decades back...
The October 1982 Issue

The first article sure makes an interesting reading. It has couple of photographs of shipboard computer (then) and mimic diagram screen displays etc. The excitement of the time could be felt even now wherein centralised controls and condition monitoring are touching different frontiers of digital twins etc. The second article is even more interesting with descriptions of UMS Systems and their architecture being explained. These are followed by another interesting article on fibre optics (Selected figures are inserted). With few articles, we plan to insert few present day snippets and figures to kindle the interest. In today's internet era, there are multiple sources to casually learn a thing or two.

Ship automation and fibre optics

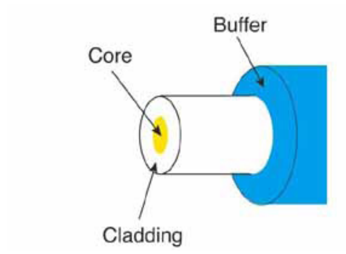


(a) Step-index optical fibre

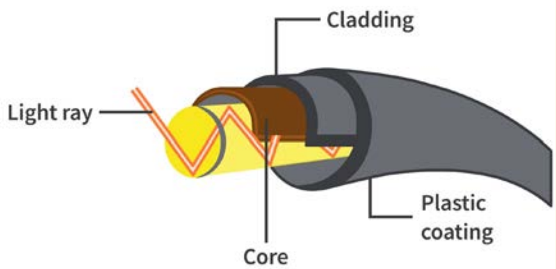
(b) Graded-index optical fibre

Inputs for further

Principle: Total Internal Reflection



(Source: FOA Reference Guide)



(Source: circuitBread.com)

There is one write-up on coal fired ships, which have virtually gone out of fashion.

Another inetersting one is, 'Ship finance-a guide for engineers'. A couple of cartoons from the article...

An observation from the article for those who are in the top rungs of Shipping Companies:

The Author holds the view that there are no disadvantages in giving a personal guarantee as security for getting a cash-flow finance loan.

The Rudder failure from the Postbag must be familiar. And any thoughts on the Manning letter?

(a) A first mortgage on the ship or, in the case of a newbuilding, assignment of the building contract; and also of the refundment guarantee from a financial institution until the vessel is delivered and the first mortgage becomes active

(b) Assignment of the charter party

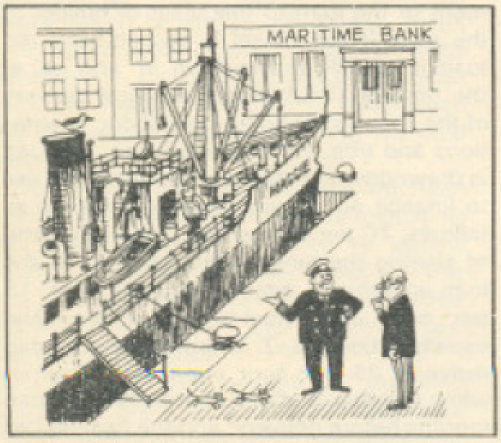
(c) Assignment of all marine insurances, which includes hull and machinery, war risk, P&I (Protection & Indemnity) Club insurance, subject to those insurance institution until the vessel is delivered and the first mortgage becomes active

Banks will also require:-

(d) Corporate guarantees, if the owner is to be an offshore one-ship company without any other material assets

(e) Personal and individual guarantees from those executives responsible for the company, for example, the financial controller or chief executive. I consider that there is no disadvantage to giving a personal guarantee as I would not undertake a commitment unless I was confident that I could successfully fulfil it.

". . emphasis is on good personal relationships."



". . . investing in an old second-hand vessel."

'The fracture occurred just above the bronze liner in way of the gland and consisted of two diametrically-opposite fatigue crack areas; the remainder being a brittle crack fracture. The fatigue crack areas were of dark brown colour, indicating old cracks, and the rest of the fracture had the colour of fresh rust, indicating that it was quite recent.'

Sounds familiar? Can share such failures with MER under, 'Spanner in the Works' column.

Rudder stock fractures

Sir,

Further to the article by Mr Fowler in the August MER. I have recently been involved with the fracture of an upper rudder stock in a C-4 class vessel of the Mariner Type. This is a semi-balanced on-horn type rudder, as shown in the sketch. The upper stock is a straight shaft attached to the rudder by a tapered coupling with key and nut, similar to a propeller shaft, with the steering gear tiller shrunk on to the upper end.

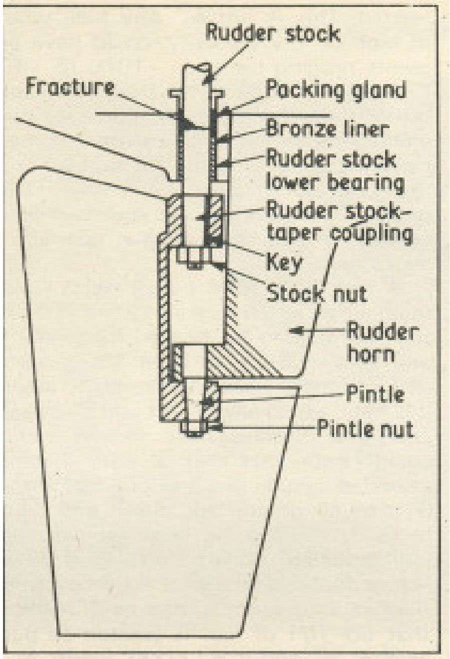
The fracture occurred just above the bronze liner in way of the gland and consisted of two diametrically-opposite fatigue crack areas; the remainder being a brittle crack fracture. The fatigue crack areas were of dark brown colour, indicating old cracks, and the rest of the fracture had the colour of fresh rust, indicating that it was quite recent.

A metallurgist determined that the fatigue originated from many initial cracks, suggesting high crack sensitivity of the surface of the rudder stock. He concluded that the failure of the rudder stock was due to simultaneous action of alternating bending stresses and corrosive attack by sea water (corrosion fatigue).

It was also noted that there was a slight reduction of cross sectional area in way of the fracture, probably caused by corrosion and galvanic action of dissimilar metals (bronze liner and steel shaft).

At the previous dry docking, the clearance of the top and bottom pintles was 3 mm and 6 mm, respectively.

The vessel's past history involved two casualties to the rudder, one caused during heavy weather and the other by striking a submerged object. In both cases, repairs were carried out to the fractures of the horn



of the stern post. However, neither record indicates whether or not the upper rudder stock was examined. In my opinion, either one or both of these casualties could have caused initial fractures which ultimately resulted in the failure of the rudder stock at a later date. If the upper stock had been crack-detected at the time of the repairs, the initial cracks might have been discovered and dealt with and the casualty, involving a long ocean tow, could have been avoided.

Since the rudder stock is constantly subjected to torsional and bending stresses it would appear to be a prudent measure to crack-detect the cone of the upper stock at regular intervals, as is done for propeller shafts.

Because the steering system is one of the most reliable systems onboard a ship, its examination, at dry docking, only receives a somewhat casual inspection. However, in attributing casualties, too much emphasis is being put on steering gear failures and not enough on the loss of propulsion power.

S Cook

Union Marine Inc, New York

Manning

Sir,

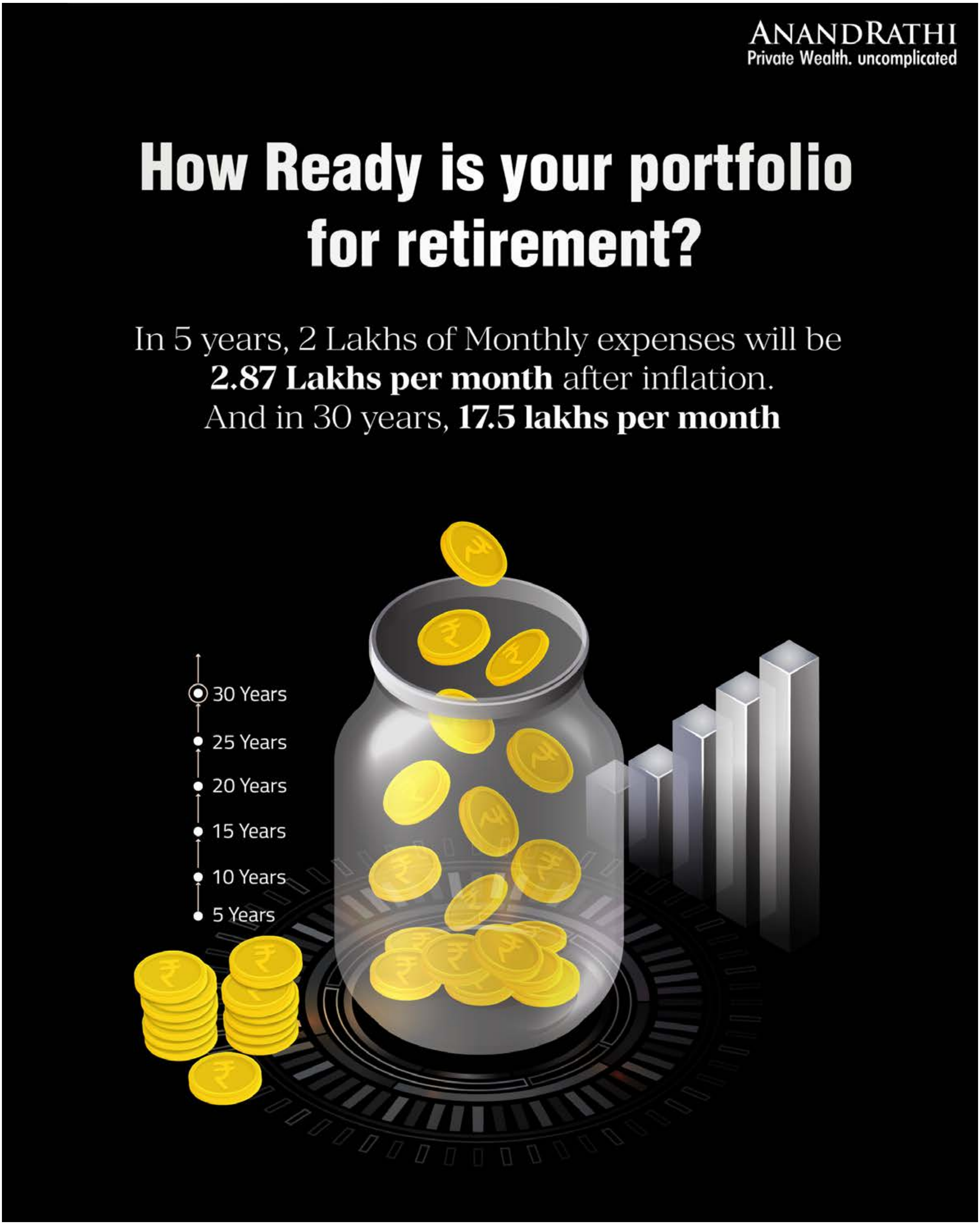
Although I appreciate the concern of the various Seamen's Unions in regard to reduced manning, there is no question that if Britain wants to regain leadership in shipbuilding and ship operation, crew numbers must come down (shipbuilding workers also).

With today's very advanced technology and very reliable high powered main and auxiliary diesel engines; crews of 12 men for all sizes of ocean-going ships, except passenger vessels, is now practical. However, absolute simplicity of engine room and ship layout with the minimum of other plant, is the keynote.

N J Pollock

Australia

We invite observations, discussion threads from readers, taking cues from these sepia-soaked MER pages – Hon.Ed.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25 Years
20 Years
15 Years
10 Years
5 Years

PORT SECURITY MANAGEMENT

Shashwat Dev, Mrinal Nigam
School of Marine Engineering & Technology, Indian Maritime University, Chennai Campus

Abstract: — This document aims at analysing facts and figures relating to the various security measures that are currently being under taken and could be taken in order to improve the efficiency and maintain the security of the ports.

Keywords: — Computer Stimulation, port security management, nuclear detention technologies, quick reaction team, automated locomotives, microchip installed identification card, cyber security.

I. Introduction

It is imperative for any country that wishes to extend its economic influence to protect its maritime interests. Ports play a vital role in the development of a nation, as it is here where most of the economic activity takes place. The growing maritime traffic and ever enlargement of demands only adds to the stress.

The money involved in the activity increase the potential threats to the ports. Hence, security and proper management can aid to preventing any disruption in the smooth growth of a nation. The threats that ports face can range from a disaster due to minor human error, to a well-planned terrorist attack. Ports just like airports can act a gate for the entry of an epidemic into a country. With the plethora of container and various resources it all comes down to efficiency in managing and security of the port.

The number of people that work on a port also add to the risks. Effete practices are something that is very characteristic of a human and depends upon an individual's moral values. Security management can be made more efficient by reducing human presence and increasing the process of integration of technology to various port related activities. Building of a complex relation between technology and human can ensure security of the port to a great extent.

II. Trades

In this contemporary world, 90% of the international cargo is transported through ships. Every year the port traffic is increasing by the rate of 6 to 8%. Developing countries like India and China are major drivers for port development due to their high economic growth rates. India is having large growth in international trade (about 25% during 2003 to 2009).

Different ports in India plays vital role in the economy of the country. Some major ports like Mumbai port, Ahmedabad port etc. exports tonnes of carriages. The capacity of 13 major ports in India is likely to increase to 1459.53 million tonnes by 2020 while it was 616.73 million tonnes in 2009 to 2010.

In India, 200 minor ports are playing their vital role as well. Current scenario in shipping industry is giving overwhelming results. Some of them are mentioned below: -

a) 118 maritime projects requiring $ 7.7 billion investments have been approved in the last four years
b) Major ports recorded highest ever capacity addition of 100.4 MMTPA in 2016-17.

III. TRAFFIC

Traffic management in ports help in improving the efficiency of port's security. The global traffic at the ports is increasing every year. Countries like China, Singapore, South Korea, United States of America etc. are among the top world container ports. Handling millions of TEU traffic per year also increases the amount of global money that is at stake. With so much at stake a gradual increase in the port handling capacity is also imperative.

Technology and its improvement will help in the steady management of port activities and also its security. The increase in maritime traffic is vital for global economy but,

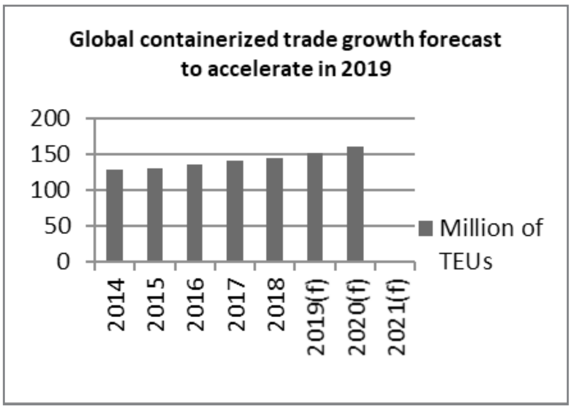

Fig 1. Total world container volume with year over year change

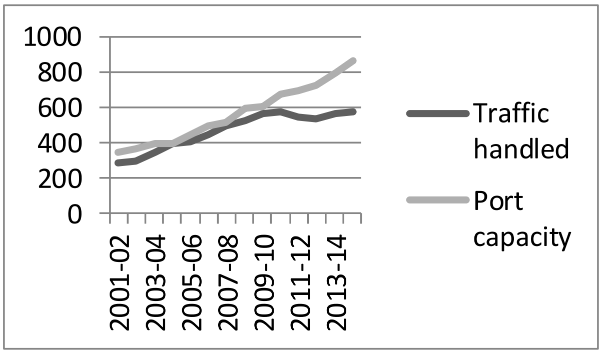

Fig 2. Port capacity and traffic handled in Indian ports, 2001-02 to 2014-15.

increasing in the number of vehicles and humans on ports can make port security management difficult.

In order to make sure that the security of the port is intact, proper investigation of port capacity is important. Technology can aid to this approach through computer stimulation. It helps in evaluating the performance of a container terminal in relation to its handling techniques and their impact on the capacity of terminal.

Automation of activities that are otherwise handled manually can increase the efficiency and reduce risk to the port. The ever growing traffic needs to be managed by an ever evolving port management system.

IV. POTENTIAL TERROR THREATS

After 9/11, the world changed drastically and has been in a state of exceptionally heightened security ever since. The attacks left the authorities that govern the world bewildered. It forced them to re-access the arrangements and threats that a new group possessed.

Terrorism is something that brings almost every country on one page. While assessing the potential of these groups, one is forced to look into the possible loss to the economy that an attack on any port could cause.

The global economy grew by 30% in 2019 compared to the previous year. This means approximately 87 trillion-dollar worth of economics was undertaken by the world.

Now, in such a sensitive world where a minor dispute between two nations can bring the entire world economy at halt; one can only imagine the disaster that would unleash if the security of a port was compromised.

The possibility that terrorists could compromise the maritime transportation has caused several agencies to pursue initiatives to manage the risk. Surveillance on ports has increased; better co-ordination between agencies has led to efficient reaction to any unfortunate happenings.

The ISPS (International ships and port facility security code) is an amendment to the SOLAS (Safety of Life at Sea) convention on minimum security arrangements for ships, ports and government agencies. Having come into force in 2004, it prescribes responsibilities to government shipping companies, shipboard personnel and port/facility personnel to detect security threats and take preventive measures against security incidents affecting ships or port facilities used in international trade.

IMO has released a code of practices on security in ports in its Tripartite Meeting of experts on security, safety, and health in ports, Geneva, 2003.

It contains guidelines on port security assessment (PSA) such as: -

i. Identification, selection and prioritisation of measures and procedural changes and their level of acceptance in reducing vulnerability.
ii. Identification of the ports perimeter and where appropriate, the identification of measures to control access to the port at various security levels.
iii. Identification of the nature of the expected traffic into or out of the port.
iv. Identification of threats to assets and infrastructure in order to establish and prioritize security measures.

It also contains guidelines on Port Security Plan (PSP): -

The port security plan should be based on the PSA and include-

a) Details of the security organisation of the port.
b) Details of the security levels, measures, both operational and physical that will be in place.
c) Identification of restricted areas and measures to protect them at different security levels.
d) Procedures for the verification of identity documents.
e) The PSP should be protected from unauthorised access or disclosure.

Smuggling is yet another problem that threatens port security. Concerns about terrorists smuggling nuclear bombs into the US in container freight have led to demands for 100% inspection at either US or foreign ports. Under some circumstances, it may be possible to deter nuclear smuggling attempts with less than 100% inspection.

Based on a publicly available data, a game theoretic model can be quantified of terrorist decision making to understand the role of nuclear detention technologies in deterring nuclear terrorism. The results suggest that unless the defender imposes high retaliation costs on the attacker. When defender can credibly threaten the attacker with costly retaliation, partial inspection may be sufficient to deter nuclear smuggling attempts.not be listed in columns nor group by affiliation.

V. Cyber Attack

With the introduction of technology in port management, the scope of it being compromised also increases. Cyber-attack is always a concern for any field that deals with technological aids. In terms of cyber security, the maritime industry has a range of characteristics that makes it difficult to implement solid cyber defenses.

When a container is moved from point A to point B, the information related to this movement may pass through between 10 and 50 different systems, each being controlled by different entities such as ports, custom offices; trucking companies etc. any breach in this system could lead to loss of hundreds of thousands of dollars.

An incident reported by cyber keel based on a forensic analysis performed by clear sky, a cyber-intelligence company (cyberkeel, 2014). A number of maritime companies- principally shipping lines and bunker fuel supplies- were infiltrated with a remote access tool. This remote access was used to monitor email communication and subsequently spoof the communication resulting in a change of bank account information pertaining to large payments. This type of incidents is also known in other industries but, was first reported in maritime sector in late 2014.

Therefore, with introduction of technology it is highly suggestive to develop independent systems that are not a part of any network. Information should be predefined in a system as long as it does not depend on real time decision making system. Cyber aid can increase efficiency in multifold but, their breach can jeopardise a complex system worth billions of dollars.

Cargo handling is at the heart of port operations, but the system travelling cargo is not the only port system that is subject to cyber-attack. Today, ports rely much on computer network as on lifting and hauling of goods. Special network control system controls the loading and unloading of cargo. All kinds of devices such as cranes now use technologies such as optical recognition to manage port operations, including locating cargo, transporting it, inspecting it, etc. containers are automatically placed and moved using GPS. Trucks that have cargo away from port are also dependent on GPS. This modern port operating system makes the entire port vulnerable. Indeed, easily available GPS jammers could potentially close down the entire port, from cargo handling to truck to crane movements. The cost of shutting down a port for one day has been estimated to be on the order of somewhere between 1 billion and 2 billion dollars a day. At least one instance of GPS description having a major impact on port operations has been reported. Sometimes in 2014, two cranes at a major US east coast port were idled for 7 hours when they were unable receive GPS signals.

The cyber threats to the maritime domain we have described are serious and they are not well known. In November 2011, the European Network and Information Agency (ENISA) reported that, "the awareness on cyber security needs in the maritime sector is currently low to non-existent".

VI. THE WAY AHEAD

In order to keep the multibillion dollar industry safe and to keep the interests of nations safe it is imperative to adopt new changes. These changes shall not be drastic but just an upgrade to what has been the norm. Ports face potential threats from human activities, thus, restricting the

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1st in India and 2nd in the world to receive distinction by DNV SeaSkill Benchmarking number of people on port is important. Proper knowledge of the identity of every person is suggestive

Proper identity disclosure enables quick tracking and complete knowledge of the condition of the worker. No blind zone in any corner of the port is also essential to enable complete control over the security. Since, the installation of CCTV's has its own limits due to the installation location use of drones and other means of vigilance is important.

Prohibited entry of unauthorised person is the primary level of maintaining security. Because of the adoption of effete practices by authorised officials, a breach in security is possible. An insider that could help plan out an attack is the last thing one would want. The location of every person working on the port should be known at all times. Every person that enters the premises of the port should be given a microchip installed identification card that will track them throughout their visit. The chip shall enable real time data of every person and their location. This increases the efficiency and helps security forces track every movement. Suspicious activities can be monitored easily and sudden disappearances of beacon can raise alarm.

Another step towards ensuring the safety of port can be the establishment of a Quick Reaction Team (QRT). QRT can be kept at standby for carrying out operations in a hostile situation. Drones can also act as an aid in such cases and can prove to be very handy to the QRT for carrying out operations.

The most important part of a port is the cargo. Finding a way for the smooth movement of cargo to and from the port can only add to the effectiveness. Hassle free and smooth cargo transport can decrease chances of error. It is perhaps another sector where technological influence can come to the rescue.

The path to achieve automated handling of cargo is to build automated locomotives that move around the port handling cargos. The data of the consignment is fed from an office central system that in turn specifies the path of the locomotive using GPS. This system will also look into real time traffic on ports to make sure serious accidents are curtailed. The locomotive reaches the section of the port from where the cargo is transferred with the help of cranes. In all of this process the movements of trucks within the cargo holding area will be restricted. The cargo will therefore be delivered to the outer campus of the port through the same locomotive. This is where the trucks come in; the cargo is then transferred to the trucks.

This method shall enhance efficiency and the process is already underway in the northern Chinese city of Caofeidian. Caofeidian was set to become the world's first fully autonomous harbour by the end of the year 2018. The US – Chinese start-up TuSimple, a specialist in developing self-driving trucks will replace human- driven terminal tractor or trucks with 20 self-driving models.

The potential for effectiveness has many ports interested in automation. This system allows the terminal to operate in complete darkness and have reduced labour costs by 70% while increasing the efficiency by 30%. The number of workers required to unload the cargo ship has also gone from 60 to 9 in some cases.

The system primarily uses cameras to gather data about its surroundings. It uses currently ten cameras including forward facing, backward – facing and wide lens. They produce 360 degree view of the vehicle surroundings. The cameras can further be used as an additional surveillance method to maintain and carry out port security operations.

This lays out a clear blueprint of how the integration of technology and automation of daily port operations can aid to increased efficiency and ensure better security.

VII. CONCLUSION

Ports are an essential establishment that helps the global economy function. The security of the ports is akin to that of the global economy. After the 9/11 incident, heightened movements among radical groups caused the world to realize how un – secure and un – prepared it was. Managing port security effectively in this era is possible with the intervention of state of the art technology and proper simulation. The cost of closing a port for a day can be enormous and no nation would take the risk of its vulnerability of its assets, especially in today's world of closely linked complex form of global economy. With the introduction of technology stimulated on a network, the threat of a cyber-attack comes handy. Therefore, a new type of cyber threat is the next concern the world is and in the near future will be facing in its improved form. Thus, the process of port security is a never ending one and requires a periodic update and there could be no better time than now to ignite the process.

V. ACKNOWLEDGEMENT

We wish to acknowledge our professors whose benevolent suggestions and expertise helped us frame this paper. We wish to display our gratitude to our esteemed institution, School of Marine Engineering and Technology (SMET), Indian Maritime University, Chennai for providing us with this opportunity. We would specially like to thank our Head of Department, Mr. K Sivasami, SMET, Indian Maritime University, Chennai for hosting this conference and providing us with the opportunity to present our paper.

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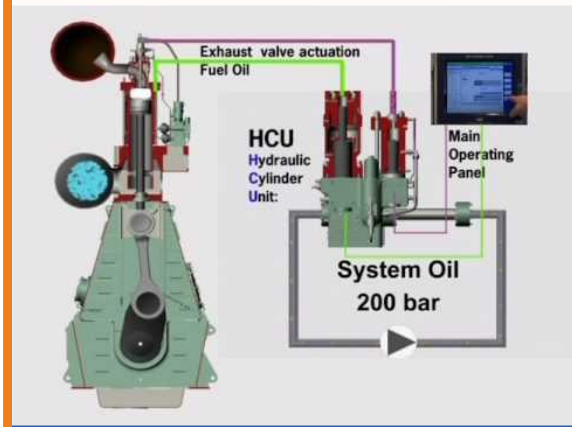
MASSA Maritime Academy, Chennai

The Institute of Marine Engineers (India)

Electronic Engine Familiarisation Course (ME-Type Engine) Delivered online with Cloud access to ME Engine Simulator



This 3 days course is designed for all Ship's Engineer Officers and Electro Technical Officers responsible for the operation of ME Engine. This course consists of technical lessons and practical instructions on the design, principles, operating procedures and maintenance activities for the safe, efficient and optimal performance of the engine system.

Course Aims and Objectives:

The course aims to provide practical understanding of the principles, design, operation and maintenance of the ME Engine System, enabling participants to safely and efficiently operate the engine and perform fault-finding in the control system.

Coverage / Program Focus:

This course deals with the following training areas:

- **Introduction to ME Engine**
- **Hydraulic Power Supply (HPS)**
- **Hydraulic Cylinder Unit (HCU)**
- **Engine Control System (ECS)**
- **Main Operating Panel (MOP)**
- **Standard Operation**

Entry Requirement / Target Group:

Entry is open to all Ship's Engineers and Electro Technical Officers with basic knowledge of diesel engines.

DATE & TIMING : **18th, 19th, 20th October 2022; 22nd, 23rd, 24th November 2022; 20th 21st, 22nd December 2022 8:00 am - 4:00 pm IST**

VENUE : Web Platform / Zoom**. APPLICATION LINK:** https://forms.gle/e4As7kCucR5xoJBm9

REGISTRATION & PAYMENT : Rs. 15,000/- /- per participant – inclusive of taxes.
For IME(I) Members 13,500/- per participant - inclusive of taxes.
Payment to be made to: https://imare.in/buy-online.aspx
(Under Category - Value added Courses) *10% discount available for IME(I) members*

FOR MORE INFORMATION : **@IME(I)** - **email:** training@imare.in, Ms. Anukampa
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@ MASSA Maritime Academy Chennai - email: mmachennai@massa.in.net
Ms. Saraswathi, **(T)** 8807025336 / 7200055336 .

After registration and payment, please email the details of the receipt to: ***training@imare.in***

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