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C4ISR SET-UP IN MARITIME DOMAIN EXISTING SYSTEMS, CHALLENGES, PATHWAYS FOR FUTURISTIC WARFARE PREPAREDNESS

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Introduction

Modern maritime warfare is characterised by stand-off engagements with increasingly versatile precision-guided weapons, which rely heavily on integrated electronic systems. Technological advancements in military systems and advantages provided by the Information Age have brought about a revolution in military affairs (RMA). In such a technologically catalysed environment featuring increasingly capable weapon and sensor systems, the initiative in naval warfare will rest with the side which can act faster and respond quicker than the adversary by shortening the Information-Decision-Action (IDA) cycle.[1]

In order to measure up to this aspect of modern warfare, the command and control architecture of a Force, duly supported by the communication networks– which in turn, are built on the increasingly powerful computer systems – would be the key determinant factor between winning and losing a war/conflict. All these together form the first side of a proverbial coin – termed as 'C4' in short – and remain at the core of all operational naval activities.

The building of an efficient maritime domain awareness (MDA) grid

to facilitate quick and correct decision-making by the 'Command and Control' hierarchy forms the other side of that coin. The effectiveness of such MDA effort in providing vital actionable inputs is predicated on the Intelligence, surveillance and reconnaissance infrastructure, spread, connectivity and their exploitation capabilities – termed as 'ISR' in short. The complementary aspects of both, viz. the 'C4' and 'ISR – termed together as C4ISR –when exercised synergistically across vast seascape have brought about an essential transformation in modern war-fighting.

The Indian Navy does acknowledge the immense advantages that could accrue in adopting this RMA and has taken proactive steps in incorporating its constituents within its combat preparedness strategy. The constant and focused effort of the Indian Navy in translating the all-encompassing Network Centric Warfare (NCW) into full operational capability has started to bear good results. The Navy has ensured that a wide range of operational activities, spread across all dimensions and vast areas, are controlled and coordinated through secure and efficient maritime C4ISR network. This Paper seeks to take stock of existing C4ISR structure in the maritime domain; analyse the technological, organisational, functional, cultural and procedural challenges that need to be addressed, and explore the possible and ways forward to meet the requirements of futuristic warfare.

Understanding C4ISR

At the outset, C4ISR is expanded as Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance. 'Command' as a concept is the exercise of authority and direction over forces assigned, by an individual so designated, for the accomplishment of a mission or task. 'Control' on the other hand, is the process through which 'Command' is exercised by the Commander; and involves the activities for organising, directing and coordinating the

given forces. C2 structures enable individuals to accomplish missions that require collective skills and energies. Its elements span all domains of warfare – physical, informational, cognitive and social.

Effective all-domain 'Communications' and 'Computerisation' are critical enablers of Maritime Command and Control (C2), particularly for the conduct of naval operations in distant waters and for prolonged durations. The addition of these two integral components has led to the acronym of C4 (Command, Control, Communications and Computers). The hierarchies of Maritime C2 correspond to the levels of maritime operations. These could either be overall C2, operational C2 or tactical C2, as per the demands of the situation.[2]

ISR activities form the key ingredients for achievement of maritime domain awareness (MDA); and encompass the process of integrating the intelligence process with surveillance and reconnaissance, in order to improve a Commander's situational awareness and assist in his decision making. Surveillance involves the systematic observation of a defined area of interest by various means – visual, electronic or photographic. Reconnaissance also involves the similar activities to collect combat information; the difference being related to time and specificity. Surveillance is a more prolonged and deliberate activity; while reconnaissance is generally conducted in a limited time frame with an aim to retrieve specific information. The objective of both activities is to locate and identify a target at longer ranges with sufficient confidence, so as to enable standoff engagement without collateral damage.

The combat information collected by surveillance and reconnaissance effort is analysed, evaluated, compared with historical data, and fused with inputs available from other sources. The end-product, relevant to the prosecution of a mission then becomes intelligence, and is passed on to the decision-makers.

Existing C4ISR Structure in The Maritime Domain

The scale and scope of the C4ISR has to be commensurate to the spread of area which has to be covered. In addition, the war-waging capabilities of the adversary, which define the extent of the 'threat in being' must be considered. It therefore, becomes imperative to assess the characteristics of the domain in which the Indian maritime C4ISR endeavour has to play out.

India's Maritime Military Environment

India has been endowed with a huge maritime area where its Exclusive Economic Zone (EEZ) extends to about two million square kilometers. The oceanic environment has also become a multi-dimensional battle space, with space and cyber-space domains getting increasingly integrated with the traditional surface, under water and aerial dimensions – in which naval forces generally operate. The presence of neutral shipping in the sea area further confuses the maritime picture, which necessitates enhanced ISR effort. The near-permanent naval presence of extra-regional powers in the primary areas of India's maritime interest, makes the MDA picture even more complicated. These factors affect all facets of maritime warfare, be it surveillance, localisation, classification, targeting and weapon delivery.

Current Indian Maritime C4ISR capabilities

Since the maritime medium comprises interconnected oceans without fixed boundaries and inseparable borders, and it is simply impossible for a single State to cover the entire oceanic space; India – like other countries – has defined its maritime areas of interest for ensuring better coverage and management of C4ISR effort. India's primary maritime areas of interest broadly span the maritime zones of India, the Arabian Sea, the Bay of Bengal, the Persian Gulf, principal international sea

lanes (ISLs) crossing the IOR, and the choke points leading to/from the Indian Ocean via these choke points.[3]

The Current Indian Maritime ISR capabilities revolve around the need to keep continuous watch in its primary maritime areas of interest. The first principle is to establish a baseline datum of the level of maritime activities by various players in the domain over a period of time, which would be considered as normal. The aim is to readily discern any deviation from this normal pattern of activities. The means to achieve this objective are grouped into following categories:-

- **Static Surveillance**. Coastal surveillance radars and automatic identification system (AIS) receivers are mainly employed on the Indian coastline, outlying islands and offshore installations. Additionally, radars at major ports as part of the Vessel Traffic Management System (VTMS), monitor and manage the ships approaching respective harbours. These static surveillance systems provide active information on vessels operating in their vicinity and feed into the overall MDA development process.

- **Dynamic Surveillance**. This is undertaken by deployment of the Indian Navyand Coast Guard assets in Indian areas of maritime interest. These assets comprise ships and their sensors, maritime patrol aircraft, helicopters, unmanned aerial vehicles (UAVs) and even submarines, in some cases.

- **Space Based Surveillance**. ISR is also facilitated by use of space based AIS systems, with the Indian Navy having integrated this technology towards MDA development., such surveillance can additionally be expanded by fitting satellite transponders on smaller ships, including fishing vessels. Space-based assets can also be used for imaging by Synthetic Aperture Radars (SAR), Electro-Optic (EO) and

Electronic Intelligence (ELINT) sensors.

- **Position Reporting Systems**. Merchant shipsat high seas and those approaching Indian ports / islands report their positions by manual or automatic means, under voluntary and mandatory mechanisms. The information from these systems is also linked and correlated to MDA development process.

- **Air Domain Awareness Processes**. Air Domain Awareness (ADA) is a vital component of maritime situational awareness. Technologies such as Automatic Dependent Surveillance-Broadcast (ADS-B) and e-flight plans are integrated into the MDA network architecture. Integration of the Indian Navy's operational network with that of the Indian Air Force is planned so as to enable feeding of the Air Defence Identification Zone (ADIZ) picture in the national ISR grid.

- **Intelligence collection and data analysis**. Measures for analysis of the information are also vital to develop a common understanding of the maritime operating environment. Intelligence gathering and sharing on continuous basis between intelligence agencies is also being tried for developing effective MDA.

- **International Maritime Information Exchange**. India has signed 'White Shipping' agreement with 22 countries for sharing information on movement of their ships, so as togenerate a comprehensive regional and global maritime picture.[4] The Indian Navy's Merchant Ship Information System (MSIS) enables the collation of white shipping information from various sources. The Indian Navy's Information Fusion Centre–Indian Ocean Region (IFC–IOR) which was established in December 2018, is presently

engaged in stellar collaborative venture with global stakeholders, with liaison officers from 10 countries working and training together.[5]

Challenges in Effective Implementation of C4ISR

C4ISR aims at increasing the combat power of a force by networking the entire command and control chain right down to the unit level, through all-domain communication systems. C4ISR systems strive to share information, build shared domain awareness and ultimately achieve complete hierarchal synchronisation. But the real importance of C4ISR lies in how the military uses its constituents to shorten the Information, Decision, Action (IDA) cycle to gain operational advantage over the adversary.

However, the changing technology and newer concepts of operations should not allow the Command chain to digress unduly from the time-tested – and still very much relevant – Principles of War. The Adoption of C4ISR concepts and technology will not always ensure getting the better of the adversary in modern warfare. The implementation and conduct of C4ISR activities are also fraught with challenges and pitfalls, which the entire command and control chain must understand and consider whilst conducting military operations. The succeeding paragraphs bring out some of these technological, organisational, functional, cultural and procedural challenges and pitfalls related to the execution ofC4ISR effort.

Technological Challenges

Developmental Challenges. Communication and ISR systems are expensive because of the costs involved in research, development and procurement. The development of C4ISR systems in the backdrop of rapid obsolescence in the field of information and communication

technology (ICT), will remain anall-timechallenge. The high costs of replacing legacy combat systems with C4ISR enabled ones also makes total transformation economically unviable. Given these constraints, a modular development cycle using indigenous technology, with open inter operable standards and protocols should be attempted to enable progressive upgrades and stepwise refinement.

Maintaining the Technological Edge. While it is posited that effective C4ISR cannot be accomplished solely by technology, the fact remains that the concept is highly dependent on technical advancements and capabilities. It is imperative to maintain a technological edge over the adversary, in terms of flexibility, innovativeness and redundancy.

Organisational Challenges

Thinking beyond the network. When one talks about C4ISR, it is easier to think about the network that facilitates connectivity rather than the networking. Changing the mindset from thinking about the network as an element of Information and Communication Technology to considering it as a multiple-source composite grouping that needs to be designed and operated in an integrated fashion, is a challenge. If C4ISR development focuses only on technology without system organisational changes, the true benefits may not accrue to the military force.

Qualified Manpower. The optimal utilisation and maintenance of C4ISR systems requires technically qualified and trained manpower at all levels. The human resource needs to be adequately trained and sensitised to operate in relatively flatter hierarchal structure engendered by time-critical demands of modern C4ISR systems. Consequently, they need to handle increased authority and responsibility without looking for higher direction. On the other hand, senior levels of command need to operate at higher organisational and cognitive levels, and allow the tactical Commander to operate independently.

Over-reliance on networks. As C4ISR operations become increasingly complex, the operators become more dependent on technology for maintaining operational efficiency, to sometimes, total exclusion of manual/ semi-automated processes. As a result, valuable conventional means and techniques of data collation and analysis – which may have to be resorted to in the event of major network breakdown / failure – are being progressively forgotten. Therefore, the force needs to identify and maintain old procedures, in order to build adequate redundancies for these networks, and include these in training exercises.

- **Excessive centralisation and micro-management**. As technology matures and large amounts of real time 'tactical' information becomes available to the higher Commanders, They tend to get pulled towards purely tactical decisions; and start interfering with or bypassing the subordinate tactical leaders. Repetitive interventions of this type could render the subordinates either unwilling or unable to take the required initiative commensurate to the developing tactical situation. It is posited that even superior combat power and potential can be considerably compromised by excessive centralisation of C2 and micro-management.

Functional Challenges

- **Information Overload at Higher Command Level**. As data flows from the tactical battlefield to the strategic levels of command, it leads to information overload. The resultant glut of rapidly flowing data could leave the Commander quite overwhelmed to the point where his operational vision may be obscured, clarity of thought may get clouded and decision-making ability could be compromised. Therefore, it is necessary to filter the data with an aim to provide only the most relevant and 'actionable information' to the Commander.

- **Information Overload at Tactical Levels**. The reverse is equally true, if data is passed to the subordinate Commanders without adequate processing. Since his domain of action is quite limited, he needs to receive the most actionable information on priority, to the relative exclusion of other usable assessments.

- **Inadequacy of decision-making tools**. The decision support systems (DSS) are essential statistically enabled tools to analyse vast number of inputs and to make sense of the dynamically changing operational situation. While modern Artificial Intelligence (AI) systems based on Neural Networks have shown promise in decision support mechanisms, it would still be prudent to choose those which provide consistent output of required quality suitable to the peculiarities of the Indian maritime domain. It is also necessary to determine an appropriate balance between automated and manual decision-making processes, to arrive at the best possible mix.

- **Determining the Optimal Mode of Operation**. C4ISR systems are complex systems of systems, and their fool-proof optimal performance cannot always be ensured because of interplay between a large number of constituent elements. Any change in backend parameters like network speed, bandwidth and connectivity, may affect the system adversely. Therefore ensuring optimal mode of uninterrupted operation of critical C4ISR systems must remain the top priority for a Force.

- **Difficulties in holistic testing**. The success of C4ISR efforts depends on complex networks that integrate the elements of various data grids within the Indian Navy as

also those of other armed forces and national agencies concerned with domain related data generation. Since so many organisations are involved, it would be natural to face difficulties during system integration and testing, as the various organisations' subsystems could be operating at different parameters. The ultimate challenge therefore would be to test the integrated national C4ISRsystem as a whole.

Cultural Challenge

- **Resistance to Change**. The most important challenge to adoption of modern C4ISR structure based on net-centric backboneis the cultural resistance from within the organization/s. Adopting the concept of networked centricity requires significant changes in the thought-process of leaders and men alike about war fighting. It may require substantial restructuring of military organisations and review of doctrinal procedures to engage the adversary as a 'joint and integrated entity'. The existence of established and time-tested operational procedures does engender the tendency of the human resource to resist change. Therefore, any change can only be brought about in a gradual and controlled manner, when the benefits of change are recognized, appreciated and imbibed.

Procedural challenge

- **Interoperability**. C4ISR systems envisage seamless connectivity and information exchange between platforms and systems. In addition to the general requirement of inducting interoperable systems, the specific requirements during joint operations with other Forces and during combined operations with forces of different nationalities,

need to be catered for. This can be achieved by the adoption of open standards and interface protocols, which needs to be implemented in a progressive manner.

Way Forward to Meet C4ISR Requirements for Futuristic Warfare

Emerging Command and Control systems will be valuable assets for managing the entire battle space with emphasis shifting from platform centric operations to network centric operations. Cooperative engagement capabilities will seek to exploit the range advantage provided by modern weapons and networked sensors, which may be decoupled from the weapons platform. 'Network Centric Operations' is emerging as a tremendous force multiplier, which will enable availability of all relevant information in near real- time to decision makers permitting substantial compression of timelines for decision making.[6]

The architecture of new generation Command and Control (C2) Systems will need to be modular and scalable with adequate built-in redundancies. They will need to be integrated with other ISR equipment with varying interface protocols. Their architecture should hence, support 'plug and play' features for ease of integration. The software will need to include expert algorithms with AI and auto-learning features to support fast decision-making, and for adapting to the dynamic scenarios. the application software should also be subsequently upgradable to incorporate 'Cooperative Engagement Capability' as the Indian naval C4ISR systems transit from platform-centric to network-centric operations.

The Indian Navy's aspirations to become a truly blue-water Navy in coming years can only be realized if naval commanders at sea are able to synchronise and integrate their high-intensity operations across the world through a network of efficient communication systems. This would require secure global end-to-end information exchange mechanisms

among the units as a critical mission capability; and would also serve as a force multiplier for worldwide readiness, mobility and responsiveness. The most important requirement of naval communications is ship-to-shore and extended-range (beyond line of sight) ship-to-ship communications.

The extended ranges and prolonged duration of ship deployments create unique challenges and complexities. These need to be met by satellite communications (SATCOM) resources. Communication systems designed to support voice, data and video exchanges– including video conferencing– will place High demands on the communication network and large bandwidth. This trend will only grow, leading to a point where earmarking a dedicated channel for each communication task will become increasingly untenable.

Advances in C4ISR have been primarily driven by the commercial sector through tremendous improvements in ICT. Communications technology has already progressed from wire lines to al- digital and optical-fiber or digital microwave. Networks are now electronically switched; and Communications applications and related termination equipment now form a virtual continuum spanning voice telephony, data, imagery and live video. In such a fast-paced technological environment, the Indian Navy needs to pursue the following areas of communications Development for ensuring effective C4ISR:

- **SATCOM PCS**. Fully indigenised SATCOM Personal Communication System (PCS) enabled with capability to exchange voice, video and high speed data links worldwide needs to be realised. This will require a constellation of satellites which could be developed and placed in orbit through coordinated efforts of the Defence Space Agency and ISRO.

- **Security Overlay and Interoperability**. As part of development of Joint Services Interoperable Waveforms for

tri-service interoperability, DRDO has been nominated as the development agency for the waveforms which will be ported over the software defined radios (SDRs).

- **Electronic Warfare**. The indigenous design and development model has worked well for the Indian Navy. Since sufficient expertise about one of the most capable EW systems worldwide, now resides with the developmental agency, the Defence Electronics Research Laboratory (DLRL) and production partner, Bharat Electronics Limited (BEL)); an Advanced Integrated EW system incorporating future technologies needs to be progressed to meet the future challenges.

Intelligence, Surveillance and Reconnaissance mechanisms and systems must be able to provide timely, credible and usable input to enable naval forces to out-think and out-manoeuvre the opposing forces. However, the information gathered is also required to be disseminated to the relevant units at sea in near-real time and in a format, which can be readily utilized for action. This would require high speed modems and reliable, high-bandwidth communication backbone.

A C4ISR system is, in effect, a network of systems at platform level with linkages to the outer world through tactical data links. The technology now exists to integrate all such platforms by a high speed, high bandwidth network so that the firepower of all netted units can be effectively utilised. Towards this, important technologies that need to be developed for Network Centric Warfare include tactical data links, and higher capacity algorithms for Command & Control systems that would facilitate decision-making.

The key to Co-operative Engagement Capability (CEC) is the development of a Common Operating Picture (COP) and distributing the same along and across the entire command and control chain – right

down to the unit level. The concept of CEC is particularly relevant during a theatre-level operation or during a joint missions like amphibious operations. CEC comprises hardware and software that enables real-time distribution and fusion of weapons and sensor data so that individual units can also act as a unified force. The main advantage would be greater reaction time for forces as there would be an early detection of targets. However, robust communication systems with high bandwidths, resistant to electronic countermeasures with a highly accurate positioning system would be the prime requirement of CEC.

A common weapon grid can increase the combat power of the Force by exploiting the capability of high-speed automated weapon-target pairing algorithms. These algorithms can rapidly determine near-optimal weapon-target pairings after taking into account the quantum of threat and resources available–such as number of targets left, remaining rounds, and the probability of kill using remaining rounds.

The command & control systems, tactical data links, associated communication systems, algorithms used for data fusion and data presentation must be standardized and inter operable. this is a major challenge, as it requires that the currently modern systems be downward compatible with existing (legacy) systems; and should be upward compatible with future acquisitions. It is therefore essential that the requirement of interoperability is duly considered while inducting newC4ISR systems.

Protection of C4ISR and NCO systems against deliberate, inadvertent, unauthorised acquisition, disclosure, manipulation, loss or modification of sensitive information has to be ensured through development of secure firewalls. Capabilities such as automatic network intrusion detection and response also need to be developed. The data encryption techniques like key distribution and management by public/private cryp to systems also assumes greater salience. There should also be a provision for

dynamic allocation of network resources to enable continuous operation even in a degraded environment – by isolating the affected system– in case of local breach of network security.

A full-fledged disaster management system needs to be developed so that valuable data generated over a period is not lost due to intentional/ unintentional disaster. Suitable redundancies for data storage and recovery systems locally or in remote locations need to be created for uninterrupted systems operation.

Conclusion

Effective Command and Control is an essential ingredient for conduct of naval operations, both in peace and in war. With improvements in surveillance capabilities, communications, weapon application and networking technologies, timely availability of all relevant information for conduct of naval operations is no longer a constraint. In the existing net-enabled warfare scenario, it is difficult to quantify the benefits of C4ISR, as they are not sequential or singular. Rather, the results are an aggregation of lesser individual factors, adding up to significantly improved effectiveness of overall operational advantage over the adversary in warfare.

The Indian Navy has achieved a lot in adapting to the modern C4ISR requirements in the maritime domain which directly impacts upon India's national security. The geopolitical nature of India's neighbourhood– wherein certain countries either by themselves or in collusion could threaten the national interests of India –increase the demand on the Indian C4ISR architecture. There would always be many challenges in ensuring that the Country's maritime C4ISR network meets the requirement of national security and enable the Indian Navy fleets to erect an appropriate response. However, national security can not be compromised for want of hardware wherewithal or insurmountable challenges.

India has for historically paid a heavy price on account of for its proverbial 'sea-blindness'[7]. The national endeavour should be to ensure that this sordid chapter of history never repeats itself by comprehensive adoption of robust C4ISR concepts, acquisition of capable C4ISR systems and hardware, and integrating them with the national and other services' C4ISRarchitectures in the Navy's operational preparedness matrix.

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Endnotes

1. The IDA cycle is an evolution of the OODA loop (Observe, Orient, Decide, Act) loop. The OODA loop was devised at the tactical level, in relation to air combat. The IDA cycle covers the larger ambit of modern operations at all levels.
2. IHQ MOD (Navy), 'The Indian Maritime Doctrine (INBR 8) -2009,' p. 73.
3. Indian Maritime Doctrine 2009 ibid, pp. 65-68.
4. Parliament of India: Lok Sabha, Unstarred Question No. 4818, answered on 24 March 2021, http://loksabhaph.nic.in/Questions/QResult15.aspx?qref=23710&lsno=17 accessed 01 August 2022
5. Indian Navy, "Information Fusion Centre- Indian Ocean Region", https://www.indiannavy.nic.in/ifc-ior/about-us.html (accessed 03 August 2022)
6. Indian Navy, 2020, 'Swavlamban: Ship's Systems, Weapons, Aviation and Electronics Atmanirbharta Abhiyan' (New Delhi, Naval Headquarters,), p.9.
7. Admiral Arun Prakash, 'China has become a maritime power: It's time India caught up,' Indian Express, 21 June 2021, https://indianexpress. com/article/opinion/columns/india-china-rivalry-maritime-power-navy-7367947/ (accessed 01 August 2022)