Ingress of Industry 4.0 in Indian Naval Ship Design and Building - Prognosis of VR / AR technologies

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Synopsis

The transition from the erstwhile steam era to the modern digital era has been well documented. The adoption rate of cyber-physical systems under the aegis of Industry 4.0 (I4) has been breathtaking in every industrial field and certainly, it does not preclude the shipbuilding industry. Indian Navy (*IN*) and the strategic shipbuilding Indian shipyards have always been enthusiastic towards tapping the opportunity offered by soft computing, albeit in silos. It can be seen that the Indian shipbuilding landscape has been swift in comprehending the opportunity I4 offers. The authors Rana and Chhabra (2019) have examined this aspect in the developing navies and highlighted several consequential challenges linked to the process reengineering, an inevitable transformation whilst transitioning from standalone digital systems to interconnected Cyber-Physical Systems. In light of the above-mentioned challenges, the shipbuilding industry in its entirety has not exploited, the cradle to grave automation opportunity, offered by the I4 technologies.

In the last six decades, although *IN* has excelled in developing Warship designs in-house and has reached a certain level of maturity in construction at the Government shipyards. *IN* continues to face several unique challenges in the adaptation of I4 technologies both at design houses and shipyards. The paper, therefore, attempts to examine some specific challenges being faced at the tactical level whilst embracing the 3D modeling in the immersive environment *viz* Virtual and Augmented Reality (VR / AR).

There has been a global rise in the use of VR/AR Shipbuilding authoring tools as it offers an incredible opportunity to accelerate the ship design process, production, training, monitoring, and quality assurance. This paper explores the experiences of the leading shipyards across the globe whilst using the AR / VR technologies in their processes. The evaluation will also attempt to decipher the issues and challenges faced by users during the adoption and exploitation of these AR/VR systems. The authors have chosen to examine the ground level blind spots and challenges being faced whilst this technology is making inroads into the Indian shipbuilding scenario and summarise the tradeoffs and approaches taken so far to overcome these tribulations and speculate on the future direction.

Further, as the immersive technologies cause a quantum growth of data transactions it naturally induces latency in data processing in the legacy networking architecture. This has been experienced by almost all the stakeholders *viz* designers, planners, production teams, overseers, etc as perhaps they were not in the position to interact with the databases concurrently. It was possibly due to the existing organisational structure and extant networking protocols and policies. To overcome this challenge the Fog Computing architecture seems to show promise.

Keywords Virtual Reality, Augmented Reality, Shipbuilding. Digital Transformation, Industry 4.0, Fog Computing, Warship Overseeing Team, 3D Modeling

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Authors Biography

Commodore Sanjay Chhabra, an alumnus of Sixth Naval Engineering Course, was commissioned on 27 Nov 1993. The Officer has been exposed to the nuances of Ship Design, Ship Building, Management of Information Systems and Military Strategy through his career and has been felicitated twice by Naval War College, Goa for his academic excellence with a gold and silver medal respectively. He is presently entrusted with warship building as Additional Warship Production Superintendent at Mumbai and is part of the digital transformation of the Warship Overseeing Team (Mumbai).

Commodore (Dr) R K Rana, an Indian Navy veteran with 33 years of an illustrious career on board ships, naval dockyard, training, research, staff duties, design of warships and indigenous products development organisation. A 4 years stint with the oldest and best British Classification Society, Lloyd's Register of Shipping, has given him a global experience. He is presently, a Honorary Senior Advisor at the Foundation for Innovation and Technology Transfer of IIT Delhi, where he is helping the startup community in connecting with the Military so that all can leverage each other’s strength. - Linkedin - https://www.linkedin.com/in/commodore-dr-r-k-rana-23b7a741/

1. Introduction

1.1 Industry 4.0 (I4) or fourth industrial revolution is a technology vector which has more than adequately proven its efficacy in the industry, infusing robust efficiency and creating unforeseen value chains. In the last decade, certain elements of digitization and automation have made inroads into the entire gamut of ship design, shipbuilding, maintenance, and operations albeit in isolation (Rana 2019).

1.2 The merger of *Industrial Production* with *Technology* has seen melioration of breathtaking proportions and the trajectory of mutuality is inevitable and irreversible. The Immersive Technologies, an important part of I4, have already proven to be extremely effective, efficient and engaging in the field of healthcare (Eckert et al 2018), architecture (Sai 2016), gaming & entertainment (Clark 2019), aviation (Loughran 2018), automotive industry (Morozova 2019) and many more. Augmented Reality (AR) and Virtual Reality (VR) are emerging as an important tenet of immersive technologies. AR is also referred to as Mixed Reality (MR), which is a technology-based on superimposing virtual constructs onto the real world. It has also been defined as involving the overlay of computer graphics onto the real world. Present generation AR can engage in visual, spatial, and auditory faculties.

1.3 This paper explores the use case experiences of AR / VR technologies of the leading shipyards across the globe and the associated challenges. The authors have examined the unique challenges linked with the ingress of AR / VR technologies into the Indian warship design and shipbuilding ecosystem and suggested recommendations to overcome them.

2. Global scan of VR/AR technologies in shipbuilding

2.1 What started as a marketing tool by several shipyards using animated 3D visuals for the prospective customers, these immersive technologies have covered a lot of ground globally and have emerged as an important aspect of the I4 revolution in the shipbuilding industry globally. A typical 3D rendition of a ship in a VR environment as shown in Figure 1, is being used in the field of training, design, interference checks, habitability assessment, and finally production and quality assurance.

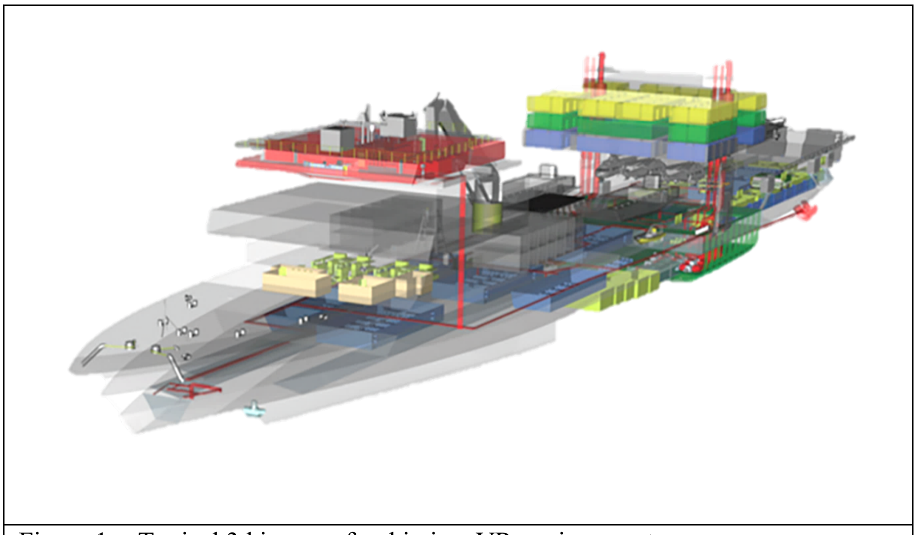

Figure 1 :- Typical 3d image of a ship in a VR environment.
(*Source https://sites.wp.odu.edu/ONRMechTech/wp-content/uploads/sites/1746/2016/06/Celar_Augmented_Reality_Naval_applications.pdf)*

2.2 The Dutch Navy with the assistance of Damen Shipyard (Damen, 2020) has been using the VR environment for training with its latest VR/AR Trainer. The trainer can simulate an entire ship with sub-millimeter accuracy and is being used for training purposes concurrently by engineers, project managers, ship staff, etc as shown in Figure 2 below.

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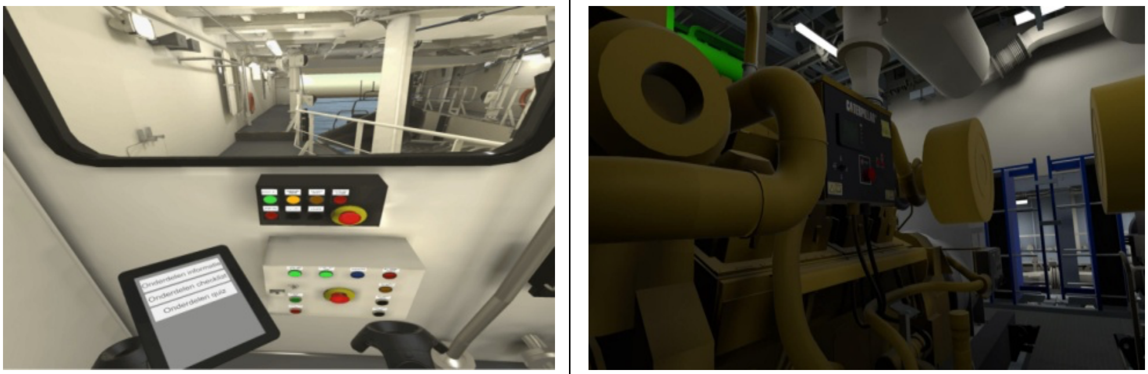

Figure 2 :- Typical training module of a ship in a VR environment. . (*Source https://www.damen.com/en/news/2020/02/virtual_training_becomes_reality_for_royal_netherlands_navy)*

2.3 The potential of VR to finalise initial ship design was realized by the Royal Navy in collaboration with BAE Systems. BAE started with VR system created by Virtalis called Visionary Render 2 (VR2) for warship design and has now embedded the system into their design process for Type 26. The design of the Type 26 frigate was created in the virtual format using the cutting-edge digital model wherein the planners, engineers and the production teams were able to walk through a real-life digital version of the ship by wearing 3D glasses (Jessica 2019). The team was able to identify flaws and interferences in the extremely complex systems even before the ships went into production with extreme ease and speed as shown in Figure 3.

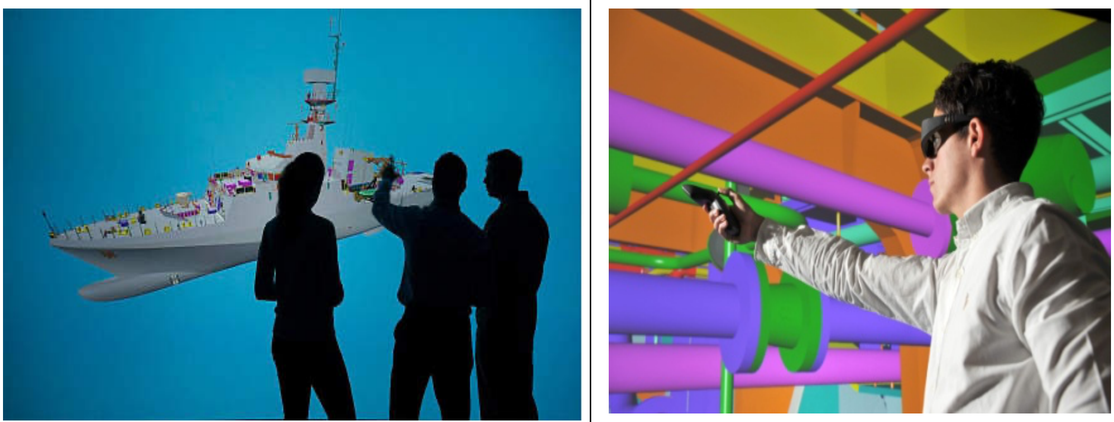

Figure 3 :- Typical warship model being reviewed in VR environment. The engineer can inspect the ship for all the aspects even before it is constructed. (*Source https://www.naval-technology.com/features/feature3d-software-making-virtual-a-reality-in-royal-navy-shipbuilding-4569419/)*

2.4 While building the U.S. Navy aircraft carriers, the Newport News Shipbuilding (NNS) shipyard innovatively used AR technologies to improve the end of the production cycle inspection process. NNS has reported that the erstwhile inspection procedure involved tedious recurrent comparison of the actual ship structures with the complex 2-D blueprints. Now with AR, the final design can be rapidly superimposed on the ship, which reduces inspection time by 96% ie from 36 hours to just 90 minutes. It was reported that the overall time savings were of the order of 25% in any typical manufacturing process in a shipyard (Porter 2017), one such inspection process post-installation of a junction box is depicted in Figure 4. Index AR Solutions (Index) teamed with NNS to provide AR based engineering services (Prnewswire 2015) and has now custom-developed augmented reality app built by the partners using PTC's Vuforia AR platform among other softwares (Stackpole 2017).

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Figure 4 – Depiction of AR use case of carrying out inspection prior exploiting an equipment set. (*Source https://www2.deloitte.com/content/dam/Deloitte/in/ Documents / about- deloitte/in-about-deloitte-Digital%20Reality%20in%20 Defence_ Final%20 print .pdf)*

2.5 *Shipboard Maintenance* and *Training* is another aspect where VR and AR technologies have had significant impact during construction and life cycle management of the ship. The learning curve of the maintainers has improved significantly and the rate of inaccuracies in maintenance due to oversight has also reduced. A typical example of training on fire fighting is shown in Figure 4 and maintenance on an engine is shown in Figure 5. The Newport News Shipbuilding (NNS), USA has reported that there was an overall improvement in the learning curve of the trainees by over 50% at the NNS Apprentice School (Mia 2019).

Figure 4 :- Trainees virtually experience and deal with emergency situations in a safe environment. (*Source https://www.isa.org/intech/20171004/?utm_campaign=s InTech-blog-referral-20171004-Virtual-reality&utm_medium=referral&utm_ source=blog)*

Figure 5 :- Maintainer undertakes maintenance activities on the equipment in a safe AR environment. (*Source https://hbr.org/2017/11/a-managers-guide-to-augmented-reality)*

Similar initiatives have also been taken by the Indian Armed Forces where the soldiers and sailors are trained using VR / AR aids to gain real-world experience (Sharma 2020). The training of marine engineers in ship maintenance procedures is being actively pursued at INS Shivaji (a premier marine engineering training establishment of the Indian Navy) to improve the comprehension of the subject matter by the under-trainees as shown in Figure 6.

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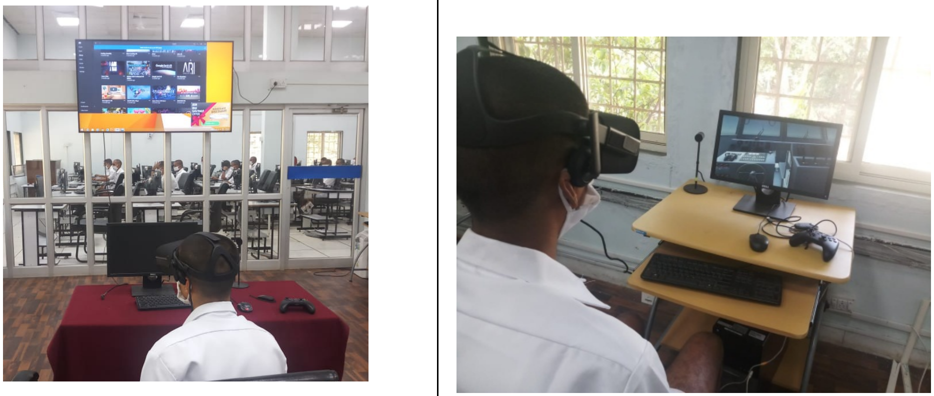

Figure 6 :- The trainees donning VR Head Mounted Display (HMD) during the class room training session on centrifugal pump maintenance and other marine engineering equipment at INS Shivaji, a premier marine engineering establishment of Indian Navy. (*Source, Centre on Marine Engineering and Technology , INS Shivaji)*

2.6 The key point that has emerged in the last decade is that the immersive technologies have the potential to be a key process enabler for a collaborative enterprise such as a shipyard. It has been proven that the entire virtually designed ship can be made accessible from the single source of truth to the key personnel who can all be in different locations anywhere in the world whilst performing their roles and responsibilities. This gives the designers, engineers, OEMs, integrators, quality inspectors, maintainers, trainers, testing, and trial agencies much greater flexibility than they have had before. However, the transition from legacy to immersive AR/VR systems has been challenging. In the next section of this paper we will review each of these from an Indian shipbuilding perspective.

3. Indigenous Shipbuilding Environment

3.1 There is a fundamental difference in the warship design and production approach in India as compared to the other advanced navies across the globe. The Indian Navy has its own Naval Design office since the 1960s which forms the nucleus of all warship design activities in the country. Since then this multi-disciplinary team has successfully developed over 20 warship designs of which more than 90 platforms have been constructed (PW 2019) majorly at the government shipyards.

3.2 Therefore, the early stages of the shipbuilding spiral covering staff requirements to initial design is solely controlled by the IN and the ship's detailed design and construction is led by the shipyard. The shipbuilding activities are overseen by the IN warship overseeing team which is geographically co-located within the premises of the shipyard. These organisations then operate in unison iteratively through the construction phase up to the commissioning of the ship.

3.3 The indigenous shipyards, like their global competitors, have been using the classical 3D CAD modeling tools through the usual concept-to-build cycle (Rodrigo 2015). The sheer size and complexity of 3D CAD models were overwhelming to handle and it took considerable time to design, validate and set the production in motion. In short, the gestation period from concept design to final design was excruciatingly long. In this concept, the databases were being maintained in silos in multiple formats and it was extremely difficult to cross-reference and ensure version control, often leading to delays. With the introduction of comprehensive 3D modeling tools and access to the state-of-the-art VR facilities at the disposal of the Design Organisation and the shipyard, all this is set to change. The endeavour for the future is to identify these and other use cases for the VR /AR application to optimise the most expensive or most time-consuming design and construction processes to extract the maximum bang for the buck.

4. **Implementation of VR at the Design House and Shipyard**. Mazagon Dock Shipbuilders Limited (MDL), one of the leading shipyards (MDL 2018) in India, producing warships and submarines for the Indian Navy and international customers, has fully embraced Virtual Reality (Maïssoun 2018). The Implementation of VR has completely transformed the workflow between the naval Design Group and the shipyard. The 3D models are being created in rapid succession and assessed at the recently setup VR lab (MDL 2018) by the

shipyard and then these data files are seamlessly used by the Design Group for iterative compartment layout inspection. The Design group having the compatible hardware and software can view the entire 3D model on the Viewer and can annotate their comments, suggestions and design changes on the model. This transformation itself is considered revolutionary, in the Indian context. The stakeholders have embraced this new methodology and feel excited about the whole process.

4.1 MDL has taken significant strides using the VR Lab having all basic VR components such as VR headsets, multi-channel high-resolution Powerwall, optical tracking system, a full-body suit to track user's body, and movement in the virtual space and TechViz real-time visualization software. The Virtual Reality Lab, as shown in Figure 7, includes easy head & body tracking in the 3D environment, having a dynamic interface with AVEVA 3D modelling software for model view for enhancing the accuracy (GOI 2019).

Figure 7:- The inspection of compartment at the VR lab at M/s MDL, India. (*Source https://mazagondock.in/Design-Facilities.aspx)*

4.2 MDL was able to increase the inspection throughput, as reported in MDL annual report (2018) from 08 compartments to over 22 compartments per month leveraging the capability of a VR environment. The virtual environment also provided flexibility in conducting multiple 3D audits before the actual execution of the work thus enhancing the ergonomics by raising the quality of layouts of the ongoing projects. A typical example of deckwise layout and inspection is shown in Figure 8 and 9 respectively.

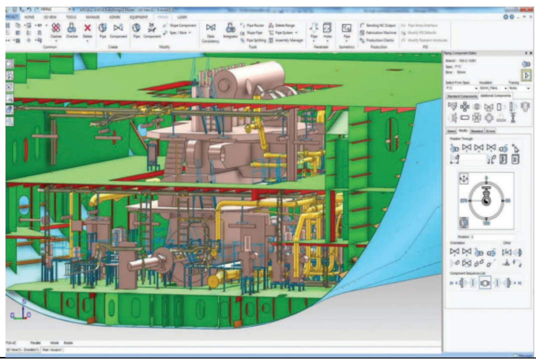

Figure 8 :– Deckwise layout of a ship created in 3D environment.

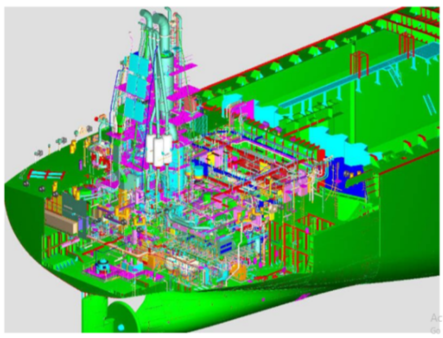

Figure 9 :- Typical 3D layout created in the VR lab and used for accuracy checks

5. **Challenges experienced while using VR / AR technologies and recommendations.** Several unique challenges were experienced by the global shipyards whilst transitioning from the legacy systems to the VR based 3D environment. Whilst consolidating these challenges, it emerged that their challenges almost matched with the challenges faced in the Indian Environment. The study in this section also highlights the experiences of the seasoned stakeholders of the *INs'* Design and Warship Overseeing Team and the Shipyard Team. The authors have proposed feasible and effective solutions to address these challenges which have been categorised under Human resource, Technical and administrative heads for the ease of analysis

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5.1 *Human Resource*

5.1.1 *Initial Training Challenges*. It was observed that the initial effort to train the shipyard personnel was significant and not all personnel displayed flair and aptitude to grasp the nuances of handling the complex 3D VR software. The skill set of the design group had to be elevated to a level such that they could perform in the 3D environment with ease. Some of the designers who had earlier worked on 3D Auto CAD and 3D Tribon environment were able to grasp the tenets of VR 3D environment more swiftly than others.

5.1.2 *Training in production processes*. Immersive training using VR environment on the shipbuilding areas such as welding of units/blocks, alignment technique, engineering equipment installation, shaft alignment can be an immensely engaging process. The creation of any number of scenarios can improve operator's skill set, the operator can respond appropriately to emergencies and practice complex procedures without any physical training aid. The system could accurately assess a trainee and suggest the areas of improvement as this can bring real value to the operations and eventually reduce costs of on the job training, by 30 to 40%. Some studies have also identified that such training could easily contribute towards maintenance savings of 1 to 3% (Richmond 2017).

5.1.3 The authors collated responses from the workforce and field-level supervisors after they were subjected to extensive VR based training. One such team who had undergone training on the subject of shaft alignment and integration stated that though the overall experience was engaging, the VR scenarios still lack the direct hands-on experience and face-to-face interactions that real-life exercises provide. The authors believe that with the greater use of AR and Mixed Reality (MR) by the workforce, these concerns will be resolved.

5.1.4 *Adoption rate and spread.* The overall adoption rate and the extent of the spread of VR / AR technology were observed to be measured after its initiation into the shipyard. The sluggish rate of spread was also attributed to the psychological aspect related to the organisational resistance to change among the workforce typically when a new technology is capable of disrupting an existing well-proven process. Over the last 60 years, the yard has evolved a high degree of craftsmanship through its specialist workers which are unique to the shipbuilding industry. This reliance upon craftsmanship creates difficulties in the adoption of specialist technologies such as VR /AR. All these challenges are being addressed by educating the workforce on the value and opportunity which these technologies can offer.

5.1.5 *Cultural Change.* Alteration of culture is an issue, the shipbuilding industry is largely traditional and the mindset of the organisation does conflict with the modern digital-enabled ways of working (Andrian 2017). Besides, the shipbuilding industry's intrinsic cultural characteristics of producing bespoke products in low volumes on long production cycles, with high levels of customization, which can often deter acceptance of newer technologies. The impasse of cultural change can be addressed by having a top-down approach wherein the Top Management visibly endorses the merits of VR /AR technologies to all the key players and encourage the organisation to remain flexible to adapt to these modern technologies. The Indian shipyards have shown resilience in addressing this issue at the moment and how does the future pan out, remains to be seen.

5.1.6 *Interim Vendor Support*. In the Indian context, another unique challenge came to the fore where it was observed that the shipyard personnel needed prolonged steady support from the technology partners for a smooth transition from legacy to the modern virtual work environment. It was primarily attributed to the language barrier between the workers and the syntax of software solutions acquired from overseas as well as indigenous vendors. This challenge has largely been addressed by positioning a resident software engineer at the premises to assist the shipyard and the overseeing staff, albeit at an additional cost. This has generated the following short-term benefits: -

- Smooth transition
- Onsite immediate resolution of issues
- Confidence building of shipyard staff
- Reduced dependency on the legacy systems

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5.1.7 *Internal re-organisation and future deployment*. It is suggested by the authors that for future use cases, it would be prudent to create an exclusive VR/AR team within the shipyard. A new position of a dedicated AR/VR Engineer, AR/VR Designer and an AR/VR Developer is recommended by the authors based on a similar configuration adopted by the NNS shipyard. The roles and responsibilities of the engineer would be to identify the areas where AR/VR can further add value to the existing processes, the designer would identify the relevant databases available and how to interface the new requirement into the existing digital environment of the shipyard. Finally, the developer would develop the system using the tools available to create the system.

5.1.8 *Anthropometry and physiological challenges*. It was observed from the feedback from multiple users that the VR / AR wearable gadgets were cumbersome. The prolonged use of 3D glasses often caused severe eye strain and also caused motion sickness. While research in VR hardware has advanced rapidly in the past few years, users are still experiencing VR-related visual fatigue. There have been studies to measure visual fatigue during immersion and the statistical analysis reveal that a user is not able to perform VR based activities in a sustained manner.

5.2 ***Technical Challenges***

5.2.1 *Security of Data remains an issue.* Data security is of paramount importance at the shipyard, therefore a high level of security and data sovereignty remains an imperative. While there has been no recorded high-profile hack or cyber-attack conducted via VR/AR, but it does provide a new surface for malicious attacks (Corey 2017). As these technologies are venturing over 4/5G networks it is considered pertinent to invest in the means to secure the data from all types of cyber-attacks All AR VR solutions are to be critically examined for vulnerabilities and the extant cyber security of the Shipyard must be updated considering that the operating environment would either be on a cloud data-center or an on-premise data center. The overall cost of implementation must include a high level of data encryption, intrusion detection system, firewall monitoring, and tamper-blocking infrastructure. The software must have access control based on the roles and responsibilities of the managers, operators and other users. It was observed by the authors that the rate of ingress of VR / AR technology in the shipyard was visibly hindered by this aspect which is unfortunate.

5.2.2 *Collaboration Challenges*. There are important challenges pertaining to collaboration among the key stakeholders in the ship design and production. This is especially true when dealing with heterogeneous data structures (multiple, discrete authoring systems). Also, the high collaboration efforts in the construction and detail design stage (especially for distributed, collaborative projects) and the high degree of interaction between the shipyard and customer during the development and production phase (triggered by the time and cost pressures) are important issues to be considered. Now with the advent of agile VR / AR environment which has enough flexibility to interact with multiple authoring systems, the way we do collaboration is set for a complete overhaul. The authors have noted that all the stakeholders are slowly realising that the premise of success in I4 or specifically AR/VR, is collaboration and hence are becoming more collaborative, in their behaviours.

5.2.3 *5G Connectivity and data streaming*. The new generation AR/VR applications demand a high degree of portability hence the devices do require more than ever high wireless bandwidth. As these technologies continue to rise on the wireless maturity curve, there is an added requirement of reliability and security of data communication. In some AR use cases, the positional accuracy of the 4/5G enabled handheld device is crucial for the comparative measurement and analysis. Degradation of signal quality inside metallic structures or underwater where the wireless signal attenuates significantly is yet another constraint (Vasilijevic 2011). It is pertinent to mention that a faster, reliable and secure 5G connectivity with higher positional accuracy will become an absolute necessity and it will also have larger implications as the Internet of Things (Iota) expands. So, there is a need to further customize the 4G/5G spectrum for faster wireless communication (Orlosky 2017), but some of the data streaming challenges discussed in this paper are beyond the responsibility of the shipyard and is dependent upon telecommunication infrastructure and regulation of a Nation-State.

5.2.4 *CAD tool to VR /AR.* 3D modeling is not new to the shipbuilding industry. It has evolved over a long period of time and it is considered to be quite mature in both ship

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design and production. However, the visualization has been limited to 3D models on a 2D interface. In the last 20 years, this technology has been well understood by ship designers and builders. Thus there is now a large amount of databases already available with all the leading shipyards across the globe. The first challenge faced by several shipyards was the migration of the legacy CAD databases into the VR/AR environment. In the last few years, the majority of these interoperability issues between the two systems have been addressed by making the VR software more flexible and compatible.

5.2.5 *VR mobility*. Another concern raised by several users across the globe is that the gadgets associated with AR and VR have not matured in mobility. In a Shipyard enterprise setting where multiple teams sharing the same database, the limited mobility has emerged as a constraint. A user is not able to have the real immersive experience if the user has to remain tethered to the PC inside the VR lab (Wiltz 2017) wearing the cumbersome stereoscopic Head Mounted Display (HMD) connected to an array of sensors and gadgets.

6. Future possibilities and other recommendations

6.1 ***Overseer's Quality Inspections***. The quality inspection whilst the ship is under construction and also the final inspection normally known as the zero-defect inspection (ZDI) just before a ship is delivered is a rigorous and manually intensive activity. Typically, the overseers' inspections are based on the physical comparison of drawings and bill of material vis-à-vis the actual layout and the fitted inventory. The analog data is then saved in an electronic database after manually punching in the observations. AR can ease this tedious and manpower intensive process by conducting an in-situ assessment using a portable hand held device preloaded with the 3D drawings and the bill of material as shown in Figure 10. Mobile devices such as phones, tablets and AR headsets have enough onboard processing power to collect, store and manipulate data, which can easily obviate the above stated manual process. When the overseer has collected, reviewed and acted on all the required information, the processed data can be uploaded to a server as soon as a network connection is established, thereby making the entire process efficient, swift and seamless. This is now being proposed by the authors for the staff of the Warship Overseeing Team.

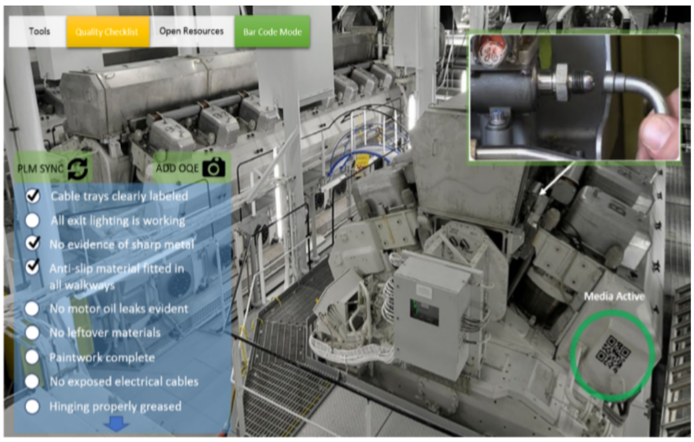

Figure 10 :- Typical AR view of a ship compartment quality checklist through the eyes (and headset or tablet). . (*Source https://www.dxc.technology/workplace_and_mobility /insights / 146155-5_ways_to_use_ar_for_building_a_digital_shipyard)*

6.2 ***Viability of Fog Computing architecture for IN and Shipyards***. Fog computing paradigm refers to a decentralised computing structure, where data processing happens at the edge of the network between the data source and the cloud (Cisco 2015). With the advent of cyber-physical systems and digitalization of virtually every shipbuilding process, the data transaction continues to escalate over the network and now with the ingress of VR / AR technologies the data transmission and analysis are further constrained thereby inducing latency and affecting the Quality of Service (QoS).

Navantia's Shipyard Industrial AR (IAR) architecture, which is based on cloudlets and the fog computing paradigm, has indicated encouraging results in IAR communication with demanding

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payload generated by Microsoft HoloLens applications. The results show that, in terms of response delay, the fog computing system is the fastest when transferring small payloads (less than 128 KB) (Tiago 2018), while for larger file sizes, the cloudlet solution is faster. Navantia shipyard (Fraga 2020) reported encouraging results in another pilot project in one of their pipe workshop with Fogging architecture

Fog computing is yet another proposed initiative of the authors for the Indian shipyard as it would adequately complement the data volumes generated by the physically-distributed VR/AR gadgets with low-latency and Quality of Service (QoS). This novel architecture would decrease overall network traffic and decrease the computational load on the server of traditional network systems. Fog computing also has security benefits, as it can segment bandwidth traffic, and introduce additional firewalls to a network for higher security.

7. Conclusions

It is an innate aspiration of any maritime nation to design and build ships faster and better than ever before. The collective endeavour is to continually improve ship design and construction approaches. The ambition of the Indian Navy has always been to constantly strive for greater performance, lower ownership cost, higher fleet availability and reliability exploiting the prowess of the modern digital tools.

The AR and MR technologies are also ideally suited for maintenance, operations, education and training where the user can perform these activities by means of 3-D holographic images within the applications that blend in with the contents of the real world across functional areas of shipbuilding. Further the Fog computing architecture holds a lot of promise to resolve the data latency issues produced due to the interplay of extensive VR/AR data payload within the enterprise network.

Though at this juncture the success of VR technologies is limited to the pre-production shipbuilding processes and that of AR is confined to post-production processes and training, it is the opinion of the authors that the present generation VR/AR ecosystem can be purposefully deployed in the entire shipbuilding design and construction spiral. This immersive technology has proven its efficacy globally and it does have potential to introduce process efficiency thereby curtailing cost and time overruns in the Indian warship building environment.

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