

# ***AUTONOMOUS SHIP***

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**ABSTRACT**---Shipping industry is always subjected to evolution. From using sails for propulsion to fuel cell propulsion. Now, autonomous shipping is the future of maritime industry. As, disruptive as smartphone, the smart ship will revolutionize the landscape of ship design and operation. A ships ability to monitor its own health, establish and communicate what is going around it and make decisions based on that information is vital to the development of autonomous operation. The need is to develop a set of electronic brain which allow to navigate safely and avoid collision. As per statistics, 80% of ships mishaps happen due to human element. Autonomous ship will not only eliminate this drawback but will also reduce the crewing cost. Hence, our focus will be on advancement in autonomous shipping, the challenges and their remedies.

**Keywords** – *Dynamic Autonomy, Autonomous Navigation System, Radars, Sensors.*

## **I. INTRODUCTION**

Our roads are ready for Autonomous cars, Airways are ready for Drones and sea is for Unmanned or Autonomous ships. As compare to land and air, we can see autonomy in sea first. Rolls Royce already takes initiative towards its dream project, to bring autonomous ship in coming decade. The initiative named as Advance Autonomous Waterborne Application (AAWA). In the whitepaper company shows how remote and autonomous ship became a reality. Company also signed a deal with Google to further develop its intelligent system and with ESA (European Space Agency) to pursue space activity to support autonomous, remote control shipping to promote innovation in European digital logistics.

According to Waterborne TP an autonomous ship is described as:-

“Next generation modular control system and communication technology will enable wireless monitoring and control function both on and off board. These will include advance decision support system to provide a capability to operate ships remotely under semi or fully autonomous control.”

## **II. AUTONOMOUS CAR VS AUTONOMOUS SHIP**

So we all are aware of Google car, the car which can take passengers to their desired location with just minor inputs from user. Google car will be equipped with Artificial Intelligences, and take transportation to next level. Armed with Artificial Intelligence, car can take full control over three main parameters of driving i.e. Steering, Acceleration and Braking. Input to computer will provided by number of sensors which are able to detect road signals, traffic signal, lane indicators, Global Positioning System (GPS), pedestrian tracking etc. Short range radar will use to compute the distance of vehicle surrounding the car on move and they will help to get the 3D image of road ahead for irregularities. All the data gathered from these sensors will then compile and an output will generated in the form of acceleration, braking and steering as per the

condition. The sensors will so agile that they can correct the parameters 100s of times in a second, much faster than human brain. Some sensors will be so advance that they can catch the hidden hazards for ex. a cyclist in front of a truck or animals crossing road in dark night. Human factor remains major factor behind accidents which leads to loss of life, economy and environmental issues. Using these sensors we can expect drastic drop in number of accidents occurring on road. Since neither Aviation nor ship industry is intact with accidents so both the sectors are finding their way towards autonomy.

Ship industry is also not exempted to being autonomous; in fact adoption of autonomy in ship industry is much quicker than other mode of transportation. Why? Because the challenges in sea somewhere is easier to meet and sometime harder than the condition on road and air. The traffic condition in open sea is not so complex and doesn't require much effort until the weather is favorable and all machinery are working efficiently and properly.

But the future agenda of ship industry is not to make a big ocean going vessel but is to make remote control and unmanned small cargo ships and ferries which will operate in inland waterways and coastal areas, channels and seas. Master can take control of these ships from shore through satellite or land based communication system.

What does this means? This mean we are not going to install a high level of Artificial Intelligence in ships, but instead of this a remote control bridge will be there which perform its function from a virtual bridge locate on shore. So, why don't call them remote control ships? We can't call them remote controlled ships because the level of autonomy will depend upon the state of vessel. The ship will be partially remote control (like during berthing and unberthing) and partially autonomous (in open water or in canals where traffic is not congested). In some circumstances, close surveillance is required on ships action. During all the time ship will share live video with the other important data like wind speed, draft, Position, Gyro Reading, ship speed, route to the control room. Engineers can also keep their watch on ship's health. They can monitor the Engine Control Room (ECR) from shore and can control the parameters of machines for continues and effective working of ship. To accomplish this requirement each machine will send data like pressure, temperature, working fluid level, lube oil level, Current, Voltage to the virtual Engine Control Room on shore. If there is any breakdown in Engine Room then alarm will raise and engineer will then deploy robots (which are present in Engine room) to perform the maintenance.

### III. ADVANTAGES

Among three mode of transportation, ships are the slowest one then air and land. But what make ship to carry 90% of world trade is their transportation cost. Transportation cost to carry goods from one place to other via sea route is very less as compare to others. Since other industries are progressively becoming more and more efficient, there is rise in requirement in ship to bring to cost down and hold its market. Lower the costs of operating the ship lower the cost of carrying goods and hence better the growth of ship industry. Cheaper freight will open new area and opportunity for the business. So, for the betterment of ship industry, Autonomous Ships will perform an important role and help to bring down the operating cost. Following are the rewards which we can expect from autonomous ships:-

1. *Reduction in Crewing Cost:-* The operation cost of ship has two main factors, one is fuel cost and other one is crewing cost. Crewing cost became more important in small ship / boat but in bigger vessel crew cost is not much important because there are other potential which will give more cost reduction then crewing cost. Elimination of crew will not happen suddenly, first reduction of crew will be there to check the reliability of ship. May be only one man will take control of whole ship and after testing and validation, we can eliminate the last crew also.
2. *Increase in efficiency of ships:-* If we talk about efficiency of ship this always doesn't mean to use efficient engine and machine, but to use efficient design and space utilization. If there is no requirement of crew on board then makers can adopt a new design language which will more streamline and aerodynamic then the current design because of elimination of bridge. If Bridge, which is above the deck, will get eliminated then ship became more lighter and more aerodynamic. There will be more room for cargo and loading and discharging of cargo will be faster. Cargo carrying capacity also gets increase due to elimination of machinery space use for human comfort. So we can estimate that current ships will not directly convert to autonomous ships but complete ship design will be re-envisioned. Robots will be there to fix issue and perform daily routine task but human must be in loop initially. In upcoming decade we can see human and robots working together. During this period robots will gather all the information and make their database strong. At the end of the time when their database became sufficient strong then they can perform tasks on their human will be removed from the cycle but close monitoring will be there always.
3. *Reduction in Human Error and Risk:-* As vast as the oceans are and as huge as ships sailing on them, the probability of accidents occurring on those ships is also massive. Main motto to bring autonomy in ships is the percentage of ship

accident cause by human error. As per statistics 80 – 90% of maritime accident is happen due to human error. Error like collisions, fire, explosion, ship lost and tanker accident are caused by human. Natural cause may be unexpected storms and tides, high wind are totally beyond the human control but this factor play very less role in ship accident.

Costa Concordia capsizing is famous example of how much damage human error can cause when dealing with massive ships. This doesn't mean that machine would never make mistake but the chances are less because machine will cope with the factors like fatigue, emotions, decision based on incomplete information, overconfidence, hazardous environment etc.

A ship accident is most dangerous situation, as ship is very costly and carrying millions of dollars of cargo and fuel oil with it then in case of accident a big loss occurs. Leaking of fuel oil in water like Atlantic Empress Oil Spill will damage the ecosystem and can kill millions of sea and land based creatures.

4. *More efficient crew:-* To bring the operating cost down, companies are recruiting the crew who are not well qualified. Recruiting these crews results in increase of accidents at personal and ship level. Since in autonomous ships, the crew requirement will not high, hence owners can deploy more efficient crew to run the ships.
5. *Reduction in Piracy:-* In 2010, economic cost of piracy was around 7 Billion dollars, which reduces to 1.7 Billion dollars in 2015. If there is no crew on board, pirate attack will go down and

#### **IV. CONCEPT OF DYNAMIC AUTONOMY**

There are numbers of definition of autonomy and machine intelligence in the literature Level of Autonomy (LoA). Basically we can say autonomy as what degree; the machine can act on its own. The fully autonomous ships don't require any input from the human and in the system where human interaction is require will depend on the state of vessel. This type of autonomy called as 'Adjustable' or 'Dynamic' autonomy. Taking the example of unmanned engine room, machine will operate on its own for a period of time depending upon the tolerance given to machine to make decision. For that particular tolerance machine execute decisions on its own. But when the situation became complicated, then machine raise an alarm for human interaction and then human physically go there to sort out the problem.

This type of autonomy is going to introduce in ship navigation also. Like navigating the ship in open sea, we can set the navigation system in full autonomous mode to let the machine to make its own decision, but while passing through some parts of voyage like canals, channels, ports or in rough weather, a close supervision or even full tele-operation will require from human operator.

Following is the example where we can understand the level of autonomy with respect to different phase of voyage.

##### *1. Voyage planning and initiation*

There are certain things which could be taken into account by the operator while planning voyage for a remote control or automatic ships. There will be mix of different satellite and land based communication network. High bandwidth satellite communication system provides the capability to operate the ship in adverse weather condition. In some situation there will be requirement of latency and bandwidth that exceed the capability of satellite system. The operator has to ensure that he will get enough connectivity throughout the route. Operator also has to plan the voyage in parts defining in which lag the ship will be fully autonomous and in which lag there is requirement of close monitoring.

In case of loss of connectivity, there will be strategy called fall back, in which ship will trace the path form which it comes and return to area where it again get connected to the satellite. Fall back strategy is executed only when the ship face unexpected network reduction. The fall back and voyage plan can always be modified during the voyage using the satellite commutation link.

##### *2. Maneuvering*

When ship is maneuvered out of the congested harbor area the operator can direct the ship remote control or by supervision. In this stage network with high bandwidth and low latency is required. In some area the network can be provided from land and in some place satellite will be used.

##### *3. Operation mode at sea*

In normal autonomous mode the ship execute the planned mission according to the plan. In this mode the data transfer between the operator and ship is minimum and limited to only relevant status data such as ship location, heading, and speed. This means

the autonomy level is high as long as the mission execution is as per plan. Additional information will be provided automatically in case of user intervention is required. This means that autonomy level is dynamically adjusted in open sea. It can be expected that there will be complex scenario where autonomous navigation system path planning and algorithm can't solve the situation then the vessel will send urgent message to the operator to indicate the urgent need of assistance. In the case if there is no input from operator then ship will go back as per the fall back strategy immediately. These algorithms will get mature over time and then can solve most of the problems on their own. With the increase of autonomous fleets of ship, each ship can communicate to each other and help system to solve the problems on their own. This action will reduce operator load.

#### 4. Port approaching and docking

On port approaching again operator have choice to take tele-operation type control or increase the supervision level of the vessel. Piloting can in future be organized in number of different method for autonomous ships. One alternative is that pilot has capability to take control of autonomous license to boats to operate piloting task for a specific kind of ship in specific area.

When operation the vessel near shore then it is again possible to relay on the land based system for communication. Camera and radar system can be used to navigate the vessel safely alongside deck.

## V. TECHNOLOGIES USED IN AUTONOMOUS SHIPS

Technology for realizing remote and autonomous ships exists. The task is to find the optimum way to combine them reliability and cost effectively.

The most progress has been demonstrated in the autonomous cars. One of the key features for any reliable autonomous vehicle navigation is sensor fusion. Taking the famous example of google car, the car will extract data from its surrounding through multiple sensors and camera to create a virtual local map of its surrounding vehicle and obstacles. These enable computers to well familiarize with the surrounding and take action more accurately.

Now talking about the vessel, which are larger, slower and less agile, is present with both advantages and challenges. Since the ships are slow hence the Situational Awareness sensor doesn't have to be fast like automobile application. But the sensor must be capable of making decision to avoid collision, dodge heavy weather, maneuvering through static and moving obstacle in advance because ship are slower to respond and if the path is not planned accurately then this can create serious accident. So there must be a well study of different planning and strategy.

## VI. AUTONOMOUS NAVIGATION SYSTEM (ANS)

The autonomous ship will use Ship State Definition (SSD), Dynamic Positioning (DP), Situational Awareness (SA), Collision Avoidance (CA), Rate Planning (RP) for safe navigation of ship.

1. *Ship State Definition (SSD)* :- This is highest level of ANS, combine information from different ANS sub system and form other ship sensor to determine correct or current state of ship.
2. *Dynamic Positioning (DP)* :- It allows the ship to automatically maintain its position by using its propeller, rudder and thruster. For rough condition ship will use Global Navigation Satellite System (GNSS) combining with Inertial Measurement Unit (IMU) and wind speed to maintain its position.
3. *Route Planning (RP)* :- It is the software module which is responsible for planning the path from start to finish via predefined waypoints, while avoiding static obstacles defined in electronic navigation chart.
4. *Collision Avoidance (CA) Module* :- it is used for safe and collision free navigation. It uses information from RP Module to follow a path but can deviate from the course if a risk of collision detected. It has basically two function :-
  - a. Assessment of Collision Risk
  - b. Navigate the ship safely both in Harbor in open sea.
5. *Situation Awareness (SA) Module*:- This module is connected to multiple sensor device of different type. The SA Module fuses the sensor data and extracted relevant information on the ship surrounding to be used by CA system. Method for the fusion of multiple sensor types, such as Light Detection and Ranging (LIDAR), cameras and radars have been actively studied for automotive applications.

## **VII. SAFETY OF AUTONOMOUS SHIP**

Safety and security of autonomous ships is required as stringent as possible. The autonomous ship must ensure that they will not harm the marine environment and other marine users. International Maritime Organization (IMO) and other bodies related to marine world has to study to an extensive range of issues like

1. Ability of autonomous ships to reliably detect small vessels and floating objects en route.
2. Ability to avoid collision in case of counter with multi ships.
3. Ability to handle emergencies such as firefighting or failure recovery and repair at sea or malfunctioning of software.
4. Ability of autonomous ships to navigate safely.
5. Disturbance malfunctions in data communication connections.

## **VIII. CHALLENGES**

To implement the Autonomous ships in future, maritime industry can face following challenges. Industry and the regulating body require to think on this challenges and try to look over these.

1. *Regulations:-* Implementation of unmanned ship is illegal according to the minimum crew requirements regulation. UN law of sea convention article 94, Safety of Life At Sea (SOLAS) regulation 14 chapter 5, International Regulations for Preventing Collisions at Sea (COLREGS) rules 2 and 5, and Standards of Training, Certification and Watchkeeping (STCW) chapter 8 all pose certain problems COLREGS in particular, felt Veal, requires “contemporaneous human sentience”. So, there is need to amendment is required in this regulation.
2. Seafarer’s Unemployment Issues
3. Accessing the risk of environment disaster without a crew, a disaster containment response team may be hundreds of mile away.
4. Cargo management and cargo safety in the absence of crew.
5. Changes in human emotions toward the ships.
6. User center design and validation of shore center operation.
7. It will be very interesting to see the decision making ability of computer will match with the human or not.
8. What will be the incentive for ship owners and operators to invest in autonomous vessel?
9. Who is responsible for accident?

## **IX. CONCLUSION**

After examine the current state of maritime industry the initial conclusion are as follows:-

1. There will be no single remote or autonomous ship solution but rather a hybrid of two which will depends on the type and function of vessel.
2. Initial focus must be on making small vessel autonomous.
3. Autonomous technology is exist we have to find the optimum way to combine them reliably and cost effectively.
4. Operation of remote and autonomous ship will be as least safe as existing vessel. These will reduce the human error but at the same time new risk and error will raise which should be identified and addressed.
5. Remote and autonomous ships have the potential to redefined maritime industry and the role of players in it with implications for shipping companies, ship builder, maritime system provider and technology companies from other sectors.
6. Legislation can be change if there is a political will. The legal challenges of construction and operating a demonstration vessel at national level need to be explore whilst simultaneously considering appropriate rule changes at IMO.

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