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Opportunities Provided by the Informatıon Sector in the Development of Autonomous Ships

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Abstract

The IT sector, which gave its name to our era, has led to very important changes and developments in the Maritime Industry as well as in many other areas. These changes have been clearly seen in the management of ships and the structure of maritime trade in recent years. Developments in communication, one of the most important elements of the IT sector, have also significantly facilitated communication between ships and land. Today, especially the opportunities provided by wireless data communication and broadband technologies significantly affect the activities of Maritime Operations and the management of ships.

As a result of these developments, there have been very important changes in the management of ships traveling in international waters in recent years and in the quality and number of seafarers working there. As a result of the opportunities provided by developing technology, it is now possible to manage and manage a large-tonnage ship, where dozens of seafarers used to work, with a staff of less than 20 people. This situation has led to very important changes in the structure of maritime trade and the management of ships. It is inevitable that the most important contribution of these developments in technology and informatics in the recent period will be seen in studies on "Unmanned Ships".

In an environment where labor costs are constantly increasing, unmanned land management of ships is an extremely important development area. Today, the technical possibilities and capabilities reached in the information sector easily allow this. Especially in the field of communication; Developments in the fields of Internet of Things, Artificial Intelligence, Machine Learning, Machine to Machine Communication, etc. offer very important opportunities to maritime operations in this regard. The important issue in this regard is to benefit from the developments in the information sector to the maximum extent. In this way, it will be possible to evaluate the possibilities and capabilities of existing ship systems in the best way and to use ships autonomously in a very short time.

Keywords: Autonomous Ships, Marine Communication Systems, Information Systems Maritime Businesses, Ship Management

Introduction

One of the two elements of the IT sector is communication, the other is content. Because the international definition of IT is "Information Communication Technology". Due to these two elements, there is no area where the IT sector is not affected individually and institutionally. Because all technological developments in this sector are reflected to different extents in all sectors affected by IT [1]. For this reason, in our age where competition is getting stronger, businesses closely follow all developments that will provide them with an advantage and aim to benefit from these developments to the maximum extent.

Today, the most important development in this regard for the Maritime sector is “Unmanned Ships”. Especially the fact that the cost of seafarers still working on ships is increasing in the total expenses of the ships, the importance of this issue increases even more. In the meantime, the technical development of ships every passing day also causes the qualifications of the crew that will work on these ships to increase.

The increasing qualifications of seafarers working on ships, on the one hand, leads to an increase in the wages of these personnel, on the other hand, it makes it more difficult to provide this personnel. For this reason, many countries today employ foreign seafarers on ships under their own flags. This situation is still one of the most important problems of maritime businesses.

In addition, developments in the industry and the information sector in recent years have enabled significant changes and opportunities in the maritime sector, as in many other sectors. In particular, developments in wireless data communication provide great opportunities in terms of remote monitoring and control of ships. As a result, autonomous ships have become a very important area of interest for maritime businesses today.

Literature Review

Development of the IT Sector

Economic flows and financial resource flows are of great importance in the world economy. The common denominator of these flows is known as "Industrial Revolutions" or Industrial Revolutions. These developments, which have been increasingly influential especially since the early 1800s and have reshaped all country economies, have reached a new stage today. This process is currently defined as Industry 4.0 [2].

The Following Figure Shows the Processes in Technology and their Contents Graphically.

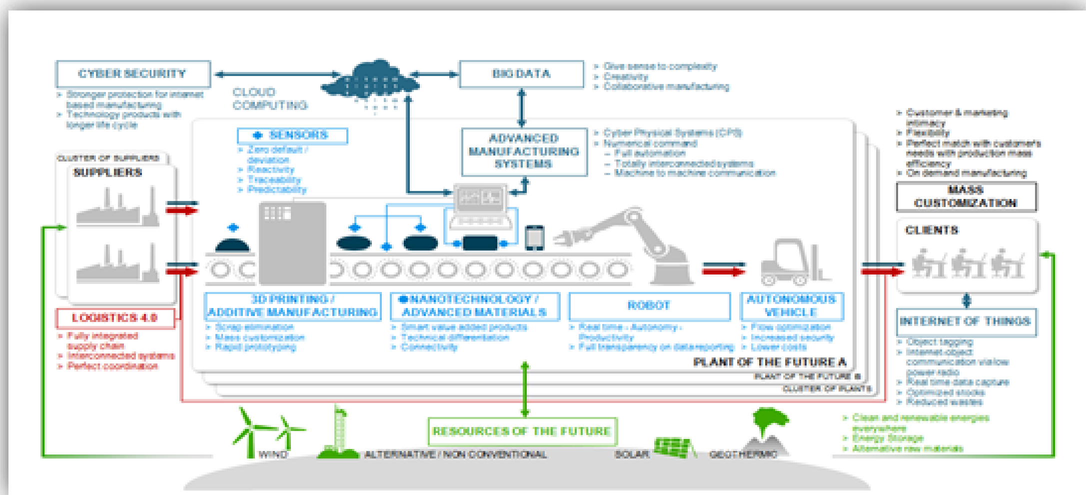


Figure 1: Industrial Revolution Processes [3].

If we summarize the industrial processes in general terms;

- While water and steam power were the main factors in the Industry 1.0.,
- Production with electricity came to the fore in Industry 2.0.
- While production through information technologies and electronics became widespread in Industry 3.0, the first programmable logic circuits became widespread.
- Cyber-physical systems started to be used in Industry 4.0, which first came to the agenda in 2011.

In Industry 4.0, the effectiveness of computers in production and control functions increased even more. In this process, advanced technologies such as machine-to-machine communication (M2M), internet of things (IoT), artificial intelligence (Artificial Intelligence), etc., which started to be used intensively, paved the way for autonomous systems.

Industry 4.0 is defined as a production project developed in Germany. The main purpose of this industry is efficiency, harmony and ergonomics. Another important issue in this regard is the necessity of an uninterrupted internet infrastructure [4].

Industry 4.0 is known by different names in different countries. For example, it is defined as Industrial Internet (IE) in the USA and Society 5.0 in China [4]. The aim is to bring production together with the use of Industry 4.0 and the Internet. For this reason, Industry 4.0 offers a working process integrated with wireless information integration in production, automation process, and all software and hardware whose management is planned autonomously.

As a result of the widespread use of Industry 4.0, the qualifications that employees must have will change significantly and the new professions listed below will emerge.

- Digital Style Consultant
- Personal Data Operator
- Organ Designer

- Virtual Reality Architect
- Drone Operator
- Genetic Consultant
- Robot Repairer
- Astroid Miner
- Remote control operator of transportation vehicles, etc.

Today, Industry 4.0; There are many “Sub-Sectors and segments” such as Logistics 4.0, Health 4.0, Port 4.0, Maritime 4.0, Education 4.0, etc. [5]. It is possible to increase the sub-sectors of Industry 4.0. Especially when these developments are combined with the new opportunities in the communication sector, it is inevitable that Maritime Management 4.0 will appear as a very different transportation sector stakeholder in the near future.

It is possible to evaluate Maritime Management 4.0 in the following sub-segments;
- Port Management,
- Logistics Management,
- Ship Management.

In this study, only the developments related to “Unmanned Ships” will be discussed and also the contributions of the developments in “Ship Management 4.0” to the development of autonomous ships will be examined.

Developments in the Communication Sector
Internet of Things
In recent years, the use of IoT (Internet of Things), defined as communication between devices, has been increasing. This system largely works according to wireless network technologies [6]. Today, with the increasing developments in the software and hardware sector, there has been a great increase in the number of addressable objects and devices [7].

Meanwhile, the economic size of the Internet of Things (IoT), whose application area is increasing day by day, is also increasing. While approximately 20 billion devices were connected to the internet in the world in 2020, this number increased to 50 billion in 2025 [8].

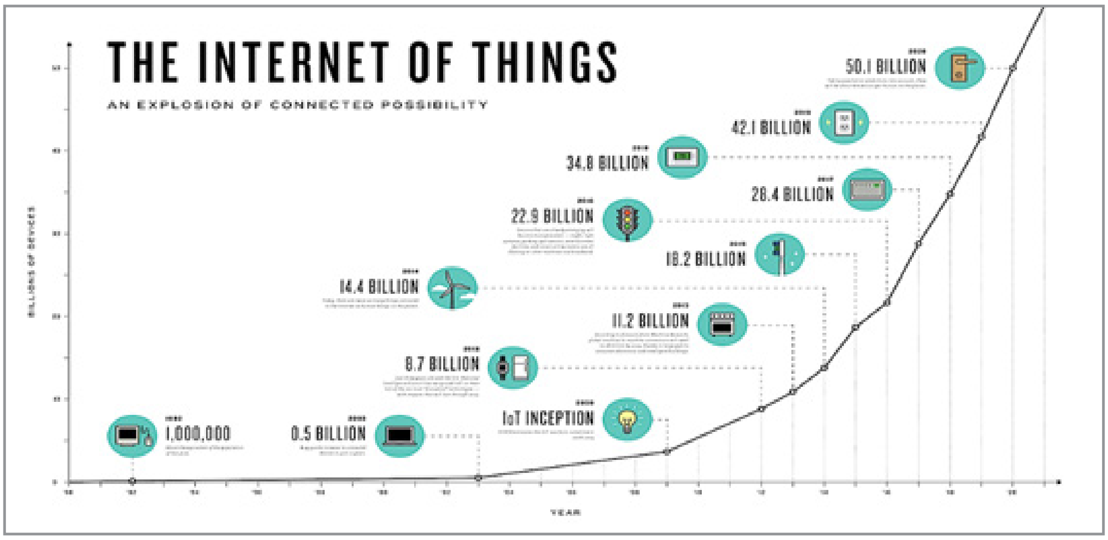
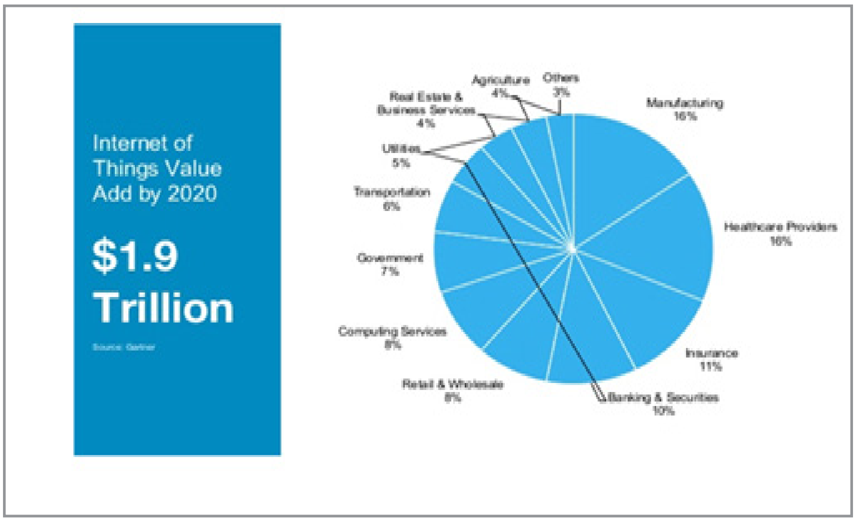


Figure 2: Number of Devices Connected to the Internet [9]

The economic volume of the IoT market is growing very rapidly in the world. This value reached 1.9 trillion dollars at the beginning of 20



Fgure 3: Economic Volume of the Internet of Things [10].

It is inevitable that the Internet of Things will find a large application area in the “Unmanned Ship Management 4.0” in the near future. In addition, the fact that Ship Engines and Navigation Systems can operate remotely with the developing technology will further increase the rate of Things using the Internet on ships.

As can be seen from Gartner's data above, one of the sectors where the Internet of Things finds the most application in 2020 is the transportation sector. For this reason, it is predicted that “Autonomous Ships” and their remote control management will become even easier.

In addition, the increase in the use of IoT in many systems, the fact that the infrastructure used is IP (Internet Protocol) based and the developments in the IPv6 (Internet Protocol Version Six) process will further develop the Internet of Things applications. For this reason, it is inevitable to provide a serious data flow between many systems on ships with M2M applications.

Big Data

Today, data is defined as the “raw material of our age” [11]. Because with the internet, data collected with different tools is also increasing. Another important factor in the increase in data is the gradual shift of communication to wireless systems. Because mobile equipment is one of the most intensively used devices in our daily lives [12].

Accordingly, the amount of data coming from computers, mobile phones and other mobile access devices is increasing day by day. This increase is doubling every two years.

Nowadays, the storage of accumulated data is as important as the meaning of this data. Because data that is not commercialized has no meaning, even if it is large. For this reason, if the data coming from sources is processed at the desired time and evaluated quickly in management systems, it will be possible to commercialize this data and make maximum use of it.

Artificial Intelligence

Artificial Intelligence has the potential to directly affect many sectors and cause serious changes in their structure. Artificial Intelligence is also defined as “technology that will shape the future” [13]. There are four important areas where artificial intelligence is used today

Machine Learning

Communication between machines allows machines to work in synchrony with each other. In this way, a problem in a machine can be detected and the necessary units can be warned in order to solve this problem. With the development of “Artificial Intelligence” applications today, “M2M” opportunities, which have taken on a completely different structure, will be one of the most important components in the “remote controlled” operation of ships without humans.

Blockchain Technology

Blockchain is a database with a structure where data is stored in blocks that are unchangeable and irreversible. In this form, Blockchain has a chain structure feature that includes all transactions made. This structure is kept open and accessible to everyone and includes all transactions made. The transparency and traceability of transaction processes is the most important factor in the increasing trust in this system [14]. The basic components of Blockchain technology are a certain consensus mechanism that will manage communication in a network of computers [15].

This technology has many advantages. However, the advantages of Blockchain outweigh its disadvantages (Crosby, 2016). Although the applications made in the Blockchain can be followed by everyone, the identity of the person who makes this transaction is not disclosed [16].Today, cryptocurrencies have become one of the most popular applications of Blockchain technology. In the blockchain structure, transactions awaiting confirmation are collected in the block structure. Miners solve this problem for this block to be valid. The first miner to solve the problem adds his block to the end of the chain and obtains the bitcoin reward defined per block [17].

Today, the problems in the blockchain structure have become more difficult over the years, and the reward given to miners is reduced by 50% every four years [18]. Transactions made in the blockchain are kept by all users within the network. With the approval of all users or the majority, the accuracy, security and integrity of transactions with past transactions are ensured. With this method, it is also aimed to reduce today's commercial risks [19].

Case Study Area

The type of communication and navigation devices on ships is increasing with the developing technology. A significant portion of these devices are mandatory on ships due to the regulations and decisions of IMO (International Maritime Organization). Since its establishment, IMO has been determining the minimum standards required for personnel and ships in order to prevent maritime accidents [20]. Another important issue in this regard is that such monitoring and actions are not carried out directly by IMO, but by member countries [21].

Although IMO's assignment of this responsibility to administrations has caused various problems due to the differences in approaches of administrations, it has not been possible to follow a different implementation approach [22]. In some countries, although they are not mandatory according to IMO regulations, additional devices are installed especially on large and new ships because they provide convenience and speed in navigation and communication and contribute positively to navigation safety.

Navigational Devices Mandatory on Ships

Radars are the most important navigation devices that are mandatory on ships. These devices have a very important function for the safe navigation of ships of all tonnages. In fact, according to IMO regulations, navigation devices that are mandatory for each type of marine vessel are defined separately. Among these, Radars are the most important and highest electromagnetic field producing devices on ships. The main navigational devices installed on ships are as follows.

- Radar
- Electronic Chart (Ecdis),
- Arpa Radar
- Auto Pilot,
- Eco Sounder,

- GPS,
- AIS

Antennas of all devices used for navigation purposes are installed near the bridge. All navigational devices have different independent antennas.

Mandatory Communication Devices on Ships

The regulations made in 1974 on this subject were transformed into maritime communication rules under the title of SOLAS-74 (Safety of Life At Sea) [23]. The main communication devices that must be on ships are listed below [24].

- VHF,
- MF/HF,
- DSC,
- Portable VHF,
- Navtex Receiver,
- Inmarsat devices,
- Iridium,
- EPIRB and
- SART / AIS SART.

Each of these devices operate at different frequencies and their most important common feature is that they have a wireless communication mode. The antennas of portable VHF, EPIRB and SART devices are located on their own. When these devices are used, each produces electromagnetic fields of different strengths. The antennas of other communication devices are mounted outside the bridge, unlike each other.

Wired Access Systems on Ships

Wired communication (mainly coaxial cable) equipment on ships is used to transmit data from large systems (Main Engine, Auxiliary Engine, Navigation, Communication devices, etc.) to the "Management Computer". For this reason, a serious cable infrastructure is established between different equipment on the ship and computers related to management systems.

The cable network in question is currently available to a large extent, especially on new ships, and these cables will be slightly larger on "Unmanned Ships".

Due to the characteristics of coaxial cables, the resistance of these cables is lower than copper cables. To put it more accurately, fiber optic cables theoretically have no resistance.

Again, in order for the cables to be installed for Autonomous Ships to be protected against interference and have a more flexible structure, it is important for these cables to have a "Coaxial cable, Cat cable, etc." structure. In addition, it is also possible to use the radio infrastructure for the data to be transferred to the management computer by the M2M systems and IoT (Internet of Things) equipment on the ship. However, if radio systems are used in the ship's communication infrastructure, an infrastructure that will create an independent network for this purpose, especially in large-bodied ships, must be established.

In other words, it is mandatory to establish an internal radio "intranet" structure within the ship and to associate it with the "Unmanned Ship Management 4.0" system. For this reason, a "Hybrid Structure" model, which is a combination of a wired infrastructure and, if necessary, a radio infrastructure in suitable systems, is considered the most suitable on-board network structure.

In the wired/wireless communication system to be established within the ship, the connection of the Ship Management system with the land unit must also be ensured. For this purpose, the data collected on the ship must also be evaluated in the relevant units on land. In addition, it is mandatory to establish a separate long-distance radio communication infrastructure between the ship and the land in order to intervene in the Ship Management system when necessary.

Wireless Access Systems on Ships

It is possible to use different systems in remote control of ships depending on whether the ship is close or far away. Wireless access systems, which must be mandatory on ships and are used in both Ship/Ship and Ship/Land communication, can be grouped into two basic groups as [1].

- Terrestrial wireless systems (VHF, MF / HF, Navtex) and
- Satellite Systems (Inmarsat and Cospas Sarsat systems)

The most widely used and best-known of terrestrial systems are VHF (Very High Frequency) radio devices. These devices are generally fixed on the bridge. In addition, Hand VHFs, also called Portable VHFs, are also widely used. These devices, which generally operate according to the principle that their antennas optically see each other, have limited communication range.

As can be seen from the drawing below and the formulas here, the communication distance between two ships with a VHF System is approximately 25 nm (notical mile) [25]. The distance of portable VHFs varies from a few hundred meters to a few nm depending on the environment and the openness of the surroundings.

Below are the formulas for determining the distance of communication between ship/ship and ship/shore stations via VHF radio systems. In communication between ships and shore stations, this distance reaches 60/80 nm, or even 100 nm, depending on the height of the shore station antennas.

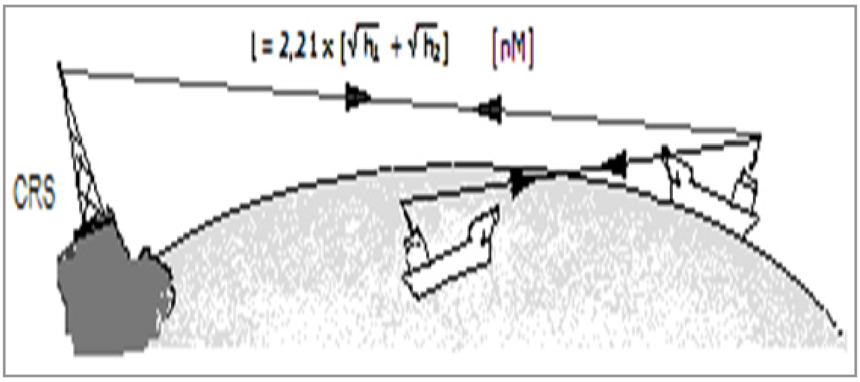


Figure 4: Coverage Area in VHF System [26].

MF (Medium Frequency) and HF (High Frequency) bands are also used between ship and land. However, due to the fact that the coverage areas of the frequencies used in these systems change depending on day and night, they are heavily affected by atmospheric conditions, the antenna sizes of these systems are large and they draw too much energy, etc., their use has been gradually decreasing in recent years.

If the distance between the ship and land is long (25 nm or more), medium or long-range radio communication systems are generally used. In addition, it is possible to use satellite systems for this purpose. In long-distance communication by ships, generally either devices related to the Inmarsat satellite system or long-distance (HF) terrestrial systems are used.

The general operating principles of the access types made via VHF (Short Range), HF (Long Range) and Inmarsat Satellite systems are shown in the figure below. In the VHF System, access is provided based on the principle that the antennas of the devices see each other (Optical vision), while in the HF System, access between the devices is provided based on the principle of “reflection of electromagnetic waves from the ionosphere”.

In the Inmarsat system, the principle of “reflection of electromagnetic waves from the satellite” (the satellite system is used as a transmitter) is used for access between satellite devices.

Inmarsat Devices Used in Data Communication on Ships
Technically, it is possible to use the Inmarsat system and HF system for long-distance access. However, the Inmarsat system has more advantages in terms of communication due to both ease of search and higher access probability.
The names of long-distance Inmarsat satellites system and the areas they cover [27];

- AOR - E (Atlantic Ocean Region East)
- IOR (Indian Ocean Region)
- POR (Pacific Ocean Region)
- AOR- W (Atlantic Ocean Region West) satellites.

The Locations of Each of these Satellites and their Distances from the Earth are Shown in Detail in the Figure Below.

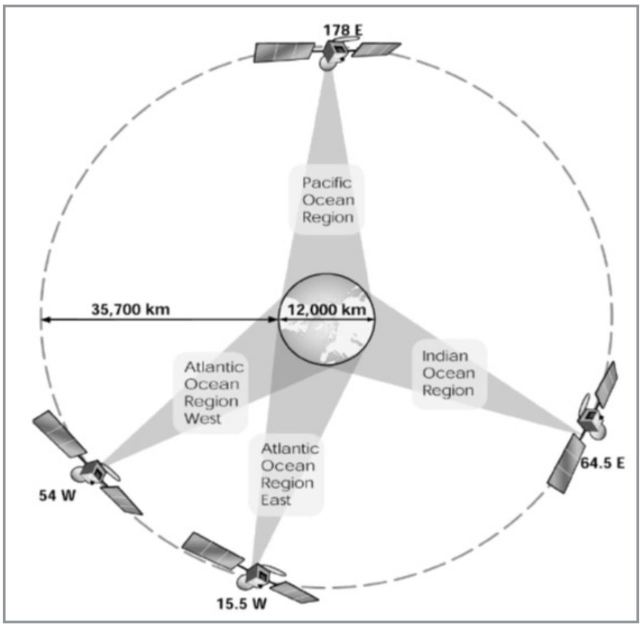


Figure 5: Locations of Satellites and Their Distances from the Earth [25].

The communication methods provided via Inmarsat are used in land, sea and air communication. The main services are;

- Wide and narrow band data communication,
- Voice,
- M2M (Machine to Machine) and
- Emergency communication.

It is also possible to use Inmarsat systems in M2M functions. Especially in M2M communication within the ship, wired/wireless systems can be used, while in communication between Ship/Land, it is possible to benefit from Inmarsat systems. For this purpose, it is possible to collect the main Inmarsat terminals used in data communication in maritime communication and M2M (Machine to Machine) services and their features under the following headings [26].

- BGAN (Broadband Global Area Network - Broadband Services)

With BGAN link service, IP-based voice and broadband data communication services up to 512kbps are provided. This system is operated with 99.9% uninterrupted rate via I-4 satellites. Voice communication, internet access or e-mail sending operations are also carried out simultaneously. Many BGAN terminals also support 64 Kbps mobile ISDN service.

These devices are compatible with VPN and encryption devices in military and public standards. They also have various quota tariffs. The reason for using L-Band frequencies is that they have high satellite finding tolerance. Therefore, they are suitable for use in regions with seismic activities and strong winds. SMS, Voip, Broadband Internet access, e-mail, VPN, telephone, Video Conference, and tracking services can be provided via BGAN Systems.

- BGAN Terminal
- BGAN Systems, unlike other satellite internet access systems, allow communication without the need for large and heavy satellite antennas.
- BGAN M2M

A service offered for automation and scada applications over the BGAN infrastructure. It supports up to 448 bps connection speed. It is used intensively in various industrial branches such as energy lines and pipelines where delay and data loss are of critical importance with 800 ms latency. The main features of this system are; ECDIS, GPS tracking and IP SCADA functions.

- Isatdata Pro

A two-way messaging service used for vehicle tracking systems. Inmarsat I-4 series satellites are used in this system. Isatdata Pro has a data sending capacity of 6400 bytes and receiving capacity of 10000 bytes. Message transmission time varies between 15-60 seconds depending on the message size. Its main features are; GPS tracking, SCADA, telemetry, weather reporting and short message e-mail communication.

- IsatData Pro Terminal (ISATM2M)

IsatData Pro Terminal is an Inmarsat terminal that works with store/send logic and has the ability to send messages at low data rates. 100-byte messages can be received in the download direction through these terminals. The main features of this device are GPS tracking, SCADA and short message e-mail.

- Inmarsat Fleet Services

Services are provided with three sub-services: Inmarsat-Fleet77, Inmarsat-Fleet55 and Inmarsat-Fleet33. GMDSS conditions are also provided with Fleet77 terminals. The main reasons for preferring the Fleet service are; low space segment cost, e-mail communication, 64 kbps mobile data packet service (MPDS), and having a lighter and more useful structure.

- Inmarsat Global Xpress (Ka Band)

Satellites operate in the “Ka frequency” band (20-30 GHz) and each satellite has 89 small Ka band spot coverage. In addition, each satellite can create Ka-Band traffic collection centers at different points with 6 steerable coverage areas. GlobalXpress provides service at 50 Mbps download and 5 Mbps upload speeds via 60 cm antennas.

These values mean high-speed data communication in data communication. High-speed data communication is provided to air and sea vehicles with the Global Xpress system. If the Inmarsat Satellite system is used for access between ships and land;

- One terminal will need to be used in the ship and land unit.
- It is beneficial for this terminal to be an Inmarsat-F77 type terminal, which preferably has high-speed data communication capability.
- Inmarsat calls are charged. Therefore, if continuous data is to be received from the ship, it is beneficial to withdraw it at certain periods and receive it in packages.
- Inmarsat C System

INMARSAT C system, which uses digital technology communication technique, entered service in 1991. It is used as a system that provides low-cost global communication by making it suitable for yachts and fishing boats as a small-sized terminal. Voice telephone communication cannot be made in INMARSAT C system. With this system, only messages prepared in written form at low data speed are transmitted with the Store and Forward technique.

In the Inmarsat C system, in the communication between ship/land and sea/ship, the signal is transmitted to the other party via the “Land Earth Station” called LES (Lans Earth Station) after the satellite. In this system, data is transmitted by LES via an INMARSAT satellite at a communication speed of 600 Bits per second. The most important feature of this system is that it is kept in long-distance ships and ships navigating in the A3 sea area as required by GMDSS. The most important feature of the Inmarsat C system is that it has the EGC (Enhanced Group Call) and LRIT (Long Range Identification and Tracking of Ships) broadcasting features, which are mandatory on ships according to GMDSS rules.

Long Range Idenitification and Tracking System (LRIT)

With this system, ships are recognized and tracked by signals they send periodically from long distances. In this way, it is possible to recognize and track ships from long distances and to report accurately to flag states. The LRIT system has been made mandatory for ships of countries that are parties to the SOLAS

(Safety of Life At Sea) Convention by the decisions taken by IMO and MSC (Maritime Safety Committee). This system became mandatory for ships on international voyages on January 1, 2009 and the relevant regulation was made in Solas Chapter 5, Section 19.1.

The basis of the LRIT system is each flag state's own data centers. Ships with this system send signals to data centers via Inmarsat satellites at certain intervals and report their locations.

In Turkey, Türksat A.Ş. It provides data center services to users via comprehensive and low-cost LRIT web interfaces. The General Directorate of Coastal Safety has been determined as the responsible and accounting authority for the national data center center of this system.

- The services provided with LRIT can be summarized as follows.
- Monitoring and Tracking Applications
- Mobile Solutions
- Technical Support and Maintenance Services
- Statistics and Pricing

With the LRIT system, it has been possible to increase the safety of navigation and maritime security of long-distance vessels. In this way, it is possible to contribute to search and rescue activities and to combat environmental pollution more effectively.

With this system, it is possible to periodically obtain the identity information of the vessels, the location information of the vessels (in terms of latitude and longitude) and the time information of the vessels.
Vessel Types that can be monitored with LRIT;

- Passenger vessels including high-speed passenger boats
- Cargo ships (300 Gross Tons and above)

In order for the LRIT System to be operated regularly and the above-mentioned data to be received from ships in a healthy manner, the following points should be particularly taken into consideration [28].

- Ships that change flags should be reported to the Administration immediately,
- Terminals on ships should be kept open at all times,
- Terminals should be occupied as little as possible for e-mail and other communication processes,
- Terminal models that are problematic in terms of LRIT should not be preferred in possible terminal changes,
- Terminals should be closed and opened by making a log out/log in instead of cutting off the power directly,

Ships that make international voyages and have an AIS device may be exempted from being included in the LRIT system. However, it has been decided that existing ships that make international voyages in A2, A3 and A4 voyages must fulfill these obligations before the first "Radio Security" inspections after December 31, 2008. Ships operating only in the A1 sea area and equipped with AIS do not have to be included in the LRIT system.

As long as these ships operate in the A1, A2 and A3 areas, they must meet the requirements required for compliance with the LRIT system before the first Radio Safety Survey after 31 December 2008. (IMO 2006: MSC.202(81) Annex 2)Main components of the LRIT System;

- Terminals on ships are the most important components in the LRIT system that transmit position, identity and time stamp information to data centers. Although the communication method between the ship and the data center has not been determined in the LRIT system, many ships currently send position information to data centers using Inmarsat C terminals. One of the most important issues in data transmission is that the terminals can be programmed remotely. In this way, it can automatically send position information to the data center without the intervention of the ship's personnel.
- In addition to tracking ships from a distance, the LRIT system is also frequently used in search and rescue operations. In addition, the use of the LRIT system as a data source in studies on measuring ship-sourced air emissions can be given as an example of the use of the LRIT system in different areas [29].
- Another example of the possible use of the LRIT system is the use of satellite-supported tracking systems in the fight against illegal, unregistered and irregular fishing activities [30].
- The LRIT system is designed to operate automatically and can be easily integrated with other systems. This system is not only for security purposes but can also be used in different areas such as combating environmental pollution and smuggling. It will not be surprising to see new uses in the near future [28].

Materials and Methods

Possibility of Using Mobile Communication Devices on Ships
Mobile communication devices are used very intensively in our daily lives. It is possible to realize very different forms of communication with these devices, also called mobile phones. Today, mobile communication technologies (3rd Generation, 4th Generation, 5th Generation systems) are used. However, since the coverage of the base stations of these systems will be at most 3/4 km from the shore for sea areas, there is a possibility that these systems will be used in limited ways in ship/land communication at close ranges [31]. However, it is impossible to communicate with ships at a greater distance since the coverage area will be exceeded. For this reason, it is possible to say that mobile communication systems are only used in very close distances to the shore or in close-range sea areas such as strait passage.

Autonomous Ship Management
The components of Autonomous Ship Management can be grouped as;

- Navigation and Machinery Equipment,
- M2M,
- IoT,
- Artificial Intelligence,
- Management and Remote Control Equipment and Software and
- Communication Systems.

Among these, "Navigation and Machinery Equipment" is one of the components most positively affected by technological developments. Because technological developments today provide very positive contributions to all machinery systems and their remote control operation. These developments are still ongoing. Today, the machinery systems of new generation ships can be easily operated from the bridge or other locations. In this way, it has become possible to control machinery systems, observe system alarms from different locations and troubleshoot problems other than mechanical failures with remote control. This issue provides great convenience and opportunities for "Autonomous Ship" systems [32].

Navigation and Communication Systems That Can Be Used in Autonomous Ship Management

As a result of technological developments in recent years, positive developments in the navigation and navigation aid systems of ships have become even more than in engine systems. Especially among these devices listed in article 3.2, the AIS device is of great importance for autonomous ships. Because the AIS Equipment detects other AIS devices within the coverage area (approximately 25 miles between ships), receives navigation information such as position, speed, route, etc., while sending its own information to the surrounding ships and CRS (Coast Radio Station), if any.

The query period of AIS devices depends on the ship's speed of movement, and the query above a certain speed is automatically every "6 seconds". The information received via AIS;
Static Information;

- .MMSI(Maritime Mobile Service Identification Number)
- IMO Number
- Call Sign and Name
- Length and Beam
- Type of Ship
- Location of GPS Antenna

Dynamic Information;

- Position of Ship
- Time (UTC)
- Course Over Ground (COG)
- Speed Over Ground (SOG)
- Heading
- Turning Time of Navigational Situation

Navigational Information;

- Draft of Ship
- Dangerous Cargo Information
- Destination and Estimated Time of Arrival (ETA)
- Route Plan (turning points)
- Speed.

Different types of AIS devices are used on ships according to their tonnage and the regions they sail. It would be greatly beneficial to make this device mandatory for all vessels and to make new regulations regarding its operating conditions in order to increase navigation safety [33].

In addition, if the navigation information (route, speed, position, turning information, etc.) received from the surrounding ships in the AIS system is evaluated on a computer and the ship's route/speed is controlled accordingly, "unmanned" driving of ships can be easily achieved.

It is Possible to Graphically Display the Static, Dynamic and Navigation İnformation in AIS Devices on the Figure Below.

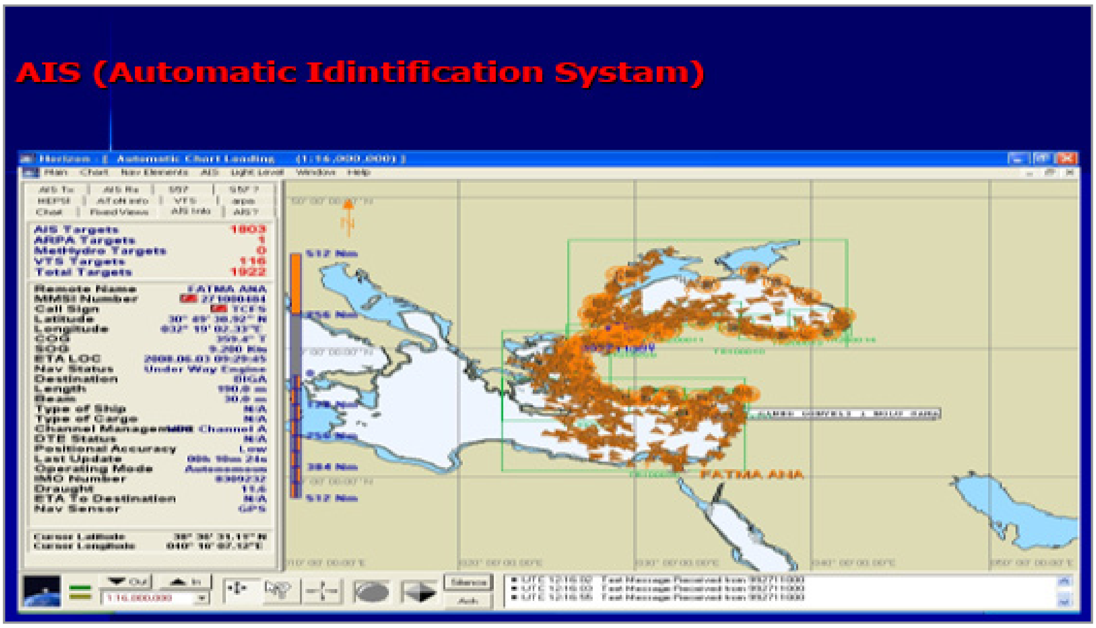


Figure 6: AIS Screen [6].

It is also possible to send navigation information as a broadcast (to the general public) through the broadcasts made via AIS devices at coastal stations. Such broadcasts are currently made especially in Northern European countries. In particular, virtual buoy information and information regarding systems that are not physically present are transmitted as a broadcast to AIS devices on ships.

For this purpose, special codes determined for MMSI (Maritime Mobile Service Identity) numbers related to Virtual AIS (imaginary AIS) have been allocated to all countries by the ITU (International Telecommunication Union).

The table below shows the ship-to-ship and ship-to-land AIS data format.

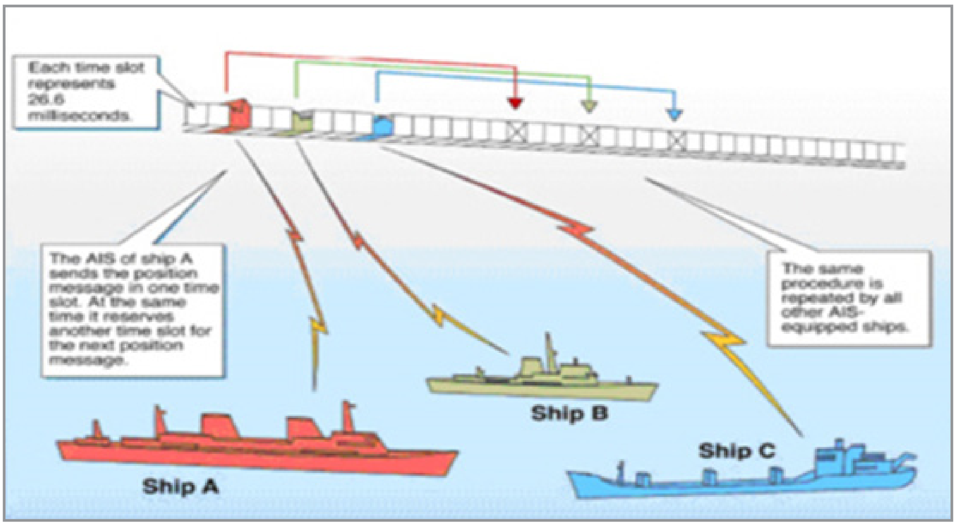


Figure 7: AIS Data Format [6].

"Virtual AIS" information, which will provide the data required for the production of safe navigation information and remote control management of ships in narrow water channels and areas with heavy ship traffic, can be compared to the "Smart Way" management in land transportation. While "Smart Road data" in land transportation is provided by "Sensors" to be installed for these road routes, it is possible to provide the warning information in question (sharp turns, shallows, heels, rocky areas, etc.) in sea transportation with Virtual AIS.

Methodology

In this study, developments in the industry are presented in different areas and their reflections on different sectors are discussed. In this direction, attention is drawn to the effects of the final stage of the industrial revolution, also known as End. 4.0, on the maritime sector. In particular, the contribution of developments in the information technology sector and the opportunities provided in this regard to the development of "Autonomous Ships" is revealed.

For this purpose, the capabilities of navigation and communication devices that can be used in the remote management of autonomous ships, which are expected to lead to great savings in costs by maritime companies, are explained in detail. In addition, the technical structures of the systems in question and the devices related to these systems are examined in detail, and attention is drawn to which ones can be used in the autonomous system.

While determining the methodology in this regard, it is aimed that the devices to be used are the equipment that is currently required by IMO to be mandatory on ships and to present the necessary model without the need for additional systems. In this way, it is aimed to enable maritime companies to use their ships autonomously and remotely by using only advanced computer systems and software for this purpose without the need for an additional investment.

In addition, this study explains which navigation, navigation aid and communication devices on ships, as required by international legislation, can be used in the operation of autonomous ships. In this way, attention is drawn to knowing and preferring the most accurate communication systems for remote control purposes and establishing contact with ships from different distances. In this way, the necessary methodology for the successful and trouble-free operation of autonomous ships has been presented.

Discussion

Today, it has become possible to obtain sufficient data for the ships' own control and management as a result of the evaluation of both the navigation information to be received from the surrounding ships via AIS devices and the navigational assistance information to be sent via Virtual AISs on the ship's computer. It is possible to evaluate this structure as a very advanced "Smart Autopilot" system.

Especially in the open sea, it is possible to reach sufficient data sources for the safe autonomous navigation of the ship with these data. For this reason, it is necessary to make maximum use of the possibilities and capabilities of AIS systems in "Unmanned Ship Management 4.0".

Another important component in "Unmanned Ship Management 4.0" is "M2M". This system, also defined as communication between machines, has become one of the most important elements of the Information Technology Sector today.

Another component of "Unmanned Ship Management 4.0" is "IoT" (Internet of Things). This system, also defined as the Internet of Things, is still one of the most popular topics in the IT sector [10].

Another component of "Unmanned Ship Management 4.0" that will become increasingly important in the future will be "Artifical Intelligence", which is still defined as the "Technology that Will Guide the Future". This technology, also defined as "Artificial

Intelligence”, will constitute the basic element of “Unmanned Ship Management” together with Machine Learning. Because the data collected from different systems with AIS equipment, sensors, M2M applications and IoT (it is also possible to define it as big data) can be evaluated in “Machine Learning”. As a result of processing this data together with artificial intelligence in the computer system to be located in the management unit, a serious automation element will be provided for “Unmanned Ship Management 4.0”.

The experience that the big data to be produced in ship systems during the process will inevitably lead to a serious accumulation of knowledge in analysis systems. When this information is combined with the “artificial intelligence” component, it will also be a very important resource in terms of the computer systems to be located in Ship Management.

It is inevitable that the information to be collected in the data pool will depend on the systems on the ship and the amount of data to be received from these systems with M2M and IoT applications. In other words, the more data is collected in the information pool, the more data can be processed and evaluated with artificial intelligence and the development of "autonomous ship" systems will be easily possible. One of the most important components of "Unmanned Ships 4.0" will undoubtedly be "Communication Systems". Communication systems related to ships; In the data transmission that will be sent to the computers to be used in ship management regarding the information related to the Machinery and Navigation Systems located in different areas within the ship, In the access to the information to be collected in the computer on the ship from the complementary systems on land and In the remote controlled operation of the Ship Management systems.

Conclusion

It is inevitable that “Ship Management 4.0” will develop rapidly in the near future. Considering the technological developments currently taking place in the information sector, there is no technical problem in this regard. In addition, developments in this sector are further accelerating the development process of unmanned ships. Especially in recent years, the great opportunities provided in ship systems, data transfer and communication systems have reached the features that will easily allow “Unmanned Ship Management” and monitoring them from long distances and intervening when necessary.

Meanwhile, the rapid spread of machine-to-machine communication today, the Internet of Things, and developments in Sensor Technology also provide very serious technological opportunities for “Unmanned Ships”. The experience that will be provided by the big data to be produced in on-board systems in the process will also lead to a serious accumulation of knowledge in analysis systems.

It is inevitable that this information to be collected in the data pool will depend on the systems on the ship and the amount of data to be received from these systems with M2M and IoT applications. In other words, the more data is collected in the information pool, the easier and faster it will be to process and evaluate with artificial intelligence and develop "Autonomous Ships". It is possible to evaluate the ship movement controlled by the computer system supported by artificial intelligence as an advanced form of the ship navigation system managed by the Smart Auto Pilot. This application currently produces very successful results for "Unmanned Ships" in the open seas.

Considering the point reached in technology today, it is easily possible to develop the "Unmanned Ship Management" system, especially in the open seas, and to monitor and control ships with remote access. On the other hand, in narrow water channels and sea areas with heavy ship traffic, it is beneficial to first reduce the number of seamen and make a gradual transition to Unmanned Ship Management.

Currently, both wired and wireless systems are used in communication between the systems on the ship. However, if only wired systems are used to transmit increasingly developing and diversified data from different systems to the central control system, it is inevitable to establish a very long wired network inside the ship. This is not a suitable infrastructure architecture due to both cost and high probability of technical maintenance and failure.

In addition, since there are many different systems on the ship, they have to be installed in different and distant locations inside the ship, and the ship has many floors and closed areas, it is technically more accurate to establish a "wireless intranet" network that will also allow data transmission between these units.

In this way, it will be possible to establish a “Ship Management System” that will operate as “Unmanned and Remote Controlled” and controlled by a computer within the ship through an onboard access system that will be established as a combination of wired/wireless communication. In order for this system to be monitored by units on land, to remotely control ships and to intervene when necessary, it is necessary to utilize short-range and long-range communication systems. There is currently no technical infrastructure problem in this regard.

For this purpose, it is a more appropriate approach to establish a hybrid structure that will ensure the joint use of mobile communication technologies such as 2G, 3G, 4G and/or VHF systems in short-range communication between ship and land. In other words, a mixed structure that will ensure the use of these in places where mobile communication coverage is available and the use of the VHF system in places where this coverage is not available is seen as the most suitable solution for short-range radio communication between ship and land.

In long-range communication, satellite systems such as Inmarsat, etc. can be utilized, as well as the use of an HF system that works on the principle of reflection of electromagnetic waves from the ionosphere. However, while the HF system's communication is free, its use is dependent on interference and atmospheric factors, it has different coverage distances during the day/night, and in short, it is more difficult to use than the Inmarsat system. For this reason, it is inevitable to encounter interruptions and disruptions from time to time in ship/land communication via HF Systems.

The evaluations on this subject have been made in the relevant articles, and it is seen that the most suitable structure for this purpose among the existing systems is the “LRIT system” operating via Inmarsat satellites. This system, which is also defined as the long-distance form of the AIS system, provides many dynamic information such as instant position, route, speed, etc. in addition to the static information of the ships. In this way, it is easily possible to produce an autonomous ship system by evaluating the data received from the surrounding ships and the ship itself on an advanced computer. In addition, it is technically possible to monitor the ship's movement via different satellite devices, primarily Inmarsat C, and to intervene in the autonomous ship from land when necessary.

For this purpose, the most urgent and necessary issue that still needs to be done is the regulations regarding "Autonomous Ships". For this purpose, with the studies to be carried out under the coordination of IMO, the long-distance communication standards to be used in Autonomous Ships should be determined universally. It is possible to prepare the necessary regulations in a very short time with the participation of satellite organizations such as Inmarsat, ship navigation and machinery equipment manufacturers, companies producing marine communication devices and all relevant stakeholders in this study.

As a result of these evaluations, it is possible to say that the LRIT system, which must be available on large-tonnage and long-distance ships due to legislation and operates via Inmarsat satellites, is the most suitable infrastructure for this communication. There is no technical problem in using this system, which is currently used intensively, especially via the Inmarsat C device, effectively in the remote controlled operation of Unmanned Ships.

In this regard, in a working group to be established under the coordination of IMO, modifications to the technical standards of LRIT for this purpose and research on infrastructures that will ensure the transfer of data produced in this system via satellite systems other than Inmarsat will pave the way for the rapid spread of Autonomous Ships in a short time.

Researchers' Contribution Rate Statement

The authors' contribution rates to the study are equal.

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There is no conflict of interest with any institution or person within the scope of the study.

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