Unmanned navigation system

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Abstract. After Lockdown - 2020, the unmanned navigation system began to be more actively developed. In a pandemic, it became clear that the modernization of ships, namely the automation of most operations, would reduce the size of the crew. This will reduce the number of jobs; on the other hand, this will ensure safety, which, today, is a priority. In addition, the introduction of a system of unmanned navigation will require a revision of the professions of seafarers, there will be a demand for highly qualified personnel, which will contribute to the emergence of new specialties in higher educational institutions. The sources for writing the article were the regulatory legal acts regulating the activities of the Maritime Law and the data of companies working in this area, taken from open Internet resources over the past 5 years. The article provides an overview of the unmanned navigation system market as a separate segment of the shipbuilding market that has significant prospects. A SWOT analysis of the implementation of the unmanned navigation system was carried out, the opinions of independent experts were considered. During the study, it can be argued that all economically developed countries are trying to switch to a system of unmanned navigation, but the main limiting factor for all is the issues of legal regulation.

1. Introduction
The maritime industry today is 90% of the volume of all world traffic, 30% of oil production, one of the main reserves in the field of mining and food production.

However, navigation is one of the most conservative areas in the application of IT technologies. If earlier the introduction of unmanned navigation was spoken of as an indefinite future, then after Lockdown – 2020, shipowners had to reconsider their attitude to the unmanned navigation system.

Unmanned navigation opens new horizons for economic development. First, the unmanned navigation system will improve the efficiency and safety of the crew and their operations. According to Allianz Global Corporate & Specialty AG, in 2017, the cost of losses because of crew errors during sea transportation amounted to 1.6 billion [1].

Secondly, it will solve the main task of the shipping companies – optimization of operating costs. To date, more than 50% is allocated for the maintenance of ship crews.

Thirdly, the introduction of the unmanned navigation system will require the training of specialists at a new level. The problems of unmanned navigation are increasingly attracting the attention of the world community. In 2018, Amsterdam hosted the Autonomous Symposium dedicated to this topic.

2. Technical characteristics of the "autonomous vessel"
An "autonomous vessel" means "a sea vessel with sensors, automated navigation, propulsion, and auxiliary systems, with decision-making logic to follow mission plans, set up mission execution and..."
work without human intervention," - presented in a report by the American Bureau of Shipping (ABS) on Autonomous Vessels: ABS 'Classification Perspective for 2016' [2]. The main levels of autonomy according to the ABS report on autonomous ships for 2016 can be seen in the table (Table 1. Main levels of autonomy according to ABS).

| Level | Characteristics                                                                 |
|-------|---------------------------------------------------------------------------------|
| 0     | Human control                                                                   |
| 1     | Some functions automated                                                        |
| 2     | Normal operations are automated; human ready to take over                       |
| 3     | Safety-critical functions automated; human present                              |
| 4     | Full autonomy of safety-critical functions and environmental monitoring for duration of trip |
| 5     | Full autonomy with no human-available control interfaces                        |

According to the Lloyd's Register of Shipping guidelines "Cyber-enabled ships (ShipRight procedure assignment for cyber descriptive notes for autonomous & remote access ships)" from December 2017, six autonomy levels (ALs) are proposed for shipping depending on technology, systems, and operational characteristics of the vessel. These levels range from AL1 for vessels with data collected for on-board decisions to AL6, which denotes a fully autonomous vessel. For vessels classified according to levels AL1 and AL2, all operations will be undertaken by a human operator, but decisions will be supported from shore. On vessels belonging to levels AL3 and AL4, the crew will have only a supervisory role, beyond the operations of the autopilot. Ships of levels AL5 and AL6 will be completely autonomous, and decision-making will be made without human intervention [3].

The first fully autonomous vessel was tested by Rolls-Royce and Finferry on 3 December 2018. They demonstrated the capabilities of the fully autonomous ferry "Falco", which performed all automatic operations without intervention from the crew [4]. Currently, the development in the direction of marine unmanned vehicles is at the stage of experiment and testing. The leading developer of control systems for autonomous ships is the Norwegian company "KONGSBERG". She is involved in several projects focusing on integrated sensor technology and automatic collision avoidance.

The Hrönn project was first demonstrated on November 1, 2016. The dynamic positioning system (DP), satellite navigation system, maritime communication systems supplied by the Kongsberg company are presented. The world's first autonomous, unmanned zero-emission container ship, the YaraBirkeland (Figure 1. YaraBirkeland).
The length is 80 m, the width is 15 m, and the capacity is 120 TEU. The container ship is involved in the delivery of Yara products from the Porsgrunn plant to the ports of Brevik and Larvik. The company expects that the reorientation of cargo from road transport to sea transportation will reduce the level of noise and emissions. The vessel is equipped with key Kongsberg technologies, which provide remote and autonomous control, as well as electronics, batteries, and power plants developed by Kongsberg [5].

In the future, unmanned navigation systems will use integrated autonomous control systems that can be controlled and/or monitored by an onshore control center operator via satellite or radiofrequency systems.

### 3. Review of foreign projects

| Project Description                                                                 | Operating Principle                                                                 | Country                        |
|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|--------------------------------|
| **Table 2. Foreign projects**                                                      |                                                                                      |                                |
| Argo                                                                               | Robotic displacers measuring a range of environmental indicators                     | Country and manufacturer unknown|
| C-Enduro 'Thomas', ASV Global                                                      | Surface platform for sea data collection                                              | United Kingdom                  |
| Emily (the Emergency Integrated Lifesaving Lanyard)                                | Remote Controlled Water Rescue Robot                                                 | USA                            |
| Hrønn, Kongsberg Maritime Project "YaraBirkeland"                                  | The world's first autonomous ship                                                   | Norway                         |
| Name unknown                                                                       | The world's first autonomous container ship                                         | Norway                         |
| Hupersub Fathom, Reynolds Marion                                                   | Joint project of Kongsberg Maritime and Automated Ships Ltd. (UK) to develop an unmanned vessel for offshore service operations | Norway, Great Britain          |
| DFFAS                                                                              | Hybrid marine vehicle that can be used in autonomous or manned versions              | USA                            |
| MAST (Maritime Autonomy Surface Testbed), MK2 Inspector, ECA Group                 | Coastal shipping using unmanned navigation of surface sea vessels                    | Japan                          |
| Pacific 950, Baesystems Robot                                                      | Unmanned boat                                                                       | United Kingdom                  |
| Sailbuoy Met, Offshore Sensing                                                      | Multipurpose jet-powered roboboat platform                                          | France                         |
| Saildrone, Saildrone WaveGlider, Liquid Robotics SeaFly-01                          | Telecontrolled boat with thermal imager and panoramic view. Can be used for reconnaissance purposes. | France                         |
| Saildrone, Saildrone WaveGlider, Liquid Robotics SeaFly-01                          | Autonomous robot                                                                     | Netherlands                     |
| Saildrone, Saildrone WaveGlider, Liquid Robotics SeaFly-01                          | Autonomous sailing boat weighing 60 kg, orientation by GPS, transmission of the collected information - through the Iridium system. | Norway                         |
| JARI-USV                                                                           | Autonomous boat for collecting data on the oceans                                    | USA                            |
| M80A                                                                               | Above-water platform for sea data collection                                         | USA                            |
| M80A                                                                               | Beijing Sifang Automation, unmanned boat                                            | China                          |
| M80A                                                                               | Unmanned surface ship                                                               | China                          |
| M80A                                                                               | Yunzhou Intelligence Technology. The unmanned navigation system is designed to solve the problems of reconnaissance and hydrography | China                          |
Due to the special automatic control system, the unmanned navigation system is the most complex technical vehicle. Currently, various options for projects of unmanned research vessels are being implemented, as well as a system of unmanned navigation for civil purposes:

- passengerliners;
- searchandrescueoperations;
- firefighting system of unmanned navigation;
- environmentalSafety;
- UAV;
- underwatervehicles;
- research and monitoring sea expeditions.

The most advanced countries today working in this direction are Norway, France, Great Britain, Japan, the USA, and China (Table 2. Foreign projects)

4. **Russian programs for the development of the unmanned navigation system**

Russia is relatively new to this market, only in 2016 the Finder unmanned speedboat was released (Figure 2. The Finder unmanned speedboat).

The main Russian programs in the field of development of the unmanned navigation system today are:

1. Marinet;
2. LLC "Kronshtadt - Navigation Systems of the Future" (Kronshtadt Technologies);
3. Pioneer - M (Morinformsystem).

Marinet is a working group of the National Technology Initiative (NTI) that supports the development of high technologies for the maritime industry (Figure 3. AreasofMarinetdevelopment).

Priorityareas:
- Digitalnavigation (e-Navigation)
- Technologies for the development of ocean resources
- Innovativeshipbuilding
- Developmentofhumancapital
- Improvingtheregulatoryframework

![Figure 2. The Finder unmanned speedboat](image-url)
Programs implemented by Marinet:
1. A pilot project of autonomous navigation on ships of the commercial fleet. The participants of the pilot project on automatic and remote navigation "BES-KF" started testing the complex of technical means in real conditions.
2. The tests are carried out as part of the regular operation of the vessels of Rosmorport, Sovcomflot, and Pola Group. The tests are being carried out on four vessels: the tanker Mikhail Ulyanov of Sovcomflot in the Arctic, the dry cargo ship PolaAnfisa of the Pola Group company in the Black Sea and the Rosmorport dredging caravan - barge Rabochaya and the Redut dredger in the Black and Azov seas
3. Creation of a pilot zone of e-Navigation and technical means of e-Navigation. The objectives of the project include the creation of technical means for the practical implementation of the concept of e-Navigation by key participants in the maritime industry, as well as the creation of commercial products in the field of e-Navigation, based on the technical means developed within the framework of this project.
4. Protection and Energy. The technology of active coastal protection and power generation LLC Gidroenergospetsstroy has developed a wave power plant, which is designed to convert the energy of sea waves into electricity. A feature of the wave power plant is that, along with generating electricity, it protects the coast and coastal structures from the negative effects of storms.
5. Development of a new generation high-speed transport platform. One of the most important priorities of Russia's maritime transport policy is the formation and development of a modern transport infrastructure capable of ensuring the prompt transportation of goods and passengers, reducing transport costs, as well as developing an industrial and mineral resource base ("Strategy for the development of the shipbuilding industry for the period up to 2030", FTP "Development of the transport system of Russia for 2010-2020" in terms of the subprograms "Sea transport" and "Transport strategy of the Russian Federation for the period until 2030"
6. Marine multifunctional unmanned platform. The platform is a composite autonomous vessel designed to collect and transmit information. It is set in motion due to the force of the wind by installing a rigid sail-wing, as well as for precise positioning it will be equipped with azipod systems with brushless electric motors. It is planned to install solar panels and wind generators.
to charge batteries and power the "azipod" system to stabilize and position the drone on the water surface.

7. Intelligently dynamic map of renewable energy sources of the world ocean. The idea of the project is to create a service that directly connects suppliers and consumers of renewable energy in the World Ocean. To implement this service, a system will be created that will allow combining information about different types of energy in the oceans, technologies, and devices for its production, as well as accompanying supporting documentation regarding the legal, technological, economic aspects of creating projects for obtaining renewable energy in the oceans.

5. Marinet roadmap for 2020–2035
According to the decree of the government of the Russian Federation of January 21, 2020, No. 40-r, the action plan of "Marinet" provides for the creation of conditions for the launch of new products and subjects of new types of entrepreneurial activity on the market.

Achievement of these goals will be carried out by solving the following tasks:

- preparation of amendments to the legislation of the Russian Federation necessary for the use of new technologies and promotion of solutions on the international market;
- ensuring the stimulation of the development of the maritime industry of the Russian Federation as a key source for financing the development and implementation of innovative solutions at the first stages of the implementation of the MARINET action plan, including the removal of administrative barriers and stimulation of the introduction of new technologies;
- improvement of the certification procedure for products of the Marinet market in the Russian Federation.

The implementation of the activities of this action plan will be carried out in stages from 2020 to 2035.

**Phase 1 (2020–2021):**
1. Development of electronic services and open data;
2. Increasing the competitiveness of Russian marine technology;
3. Improvement of technical regulation, standardization, certification;
4. Monitoring the implementation of the action plan ("road map").

**Phase 2 (2022–2026):**
1. Monitoring the implementation of the activities of the II stage of the action plan ("road map") and preparation of changes related to the III stage (2027 – 2035) of the action plan ("road map").

**Phase 3 (2027–2035):**
1. Monitoring the implementation of the action plan ("road map") report to the Government of the Russian Federation.

Projects "Kronstadt Technologies"
From 2016 to 2020 The Kronstadt Technologies company has fulfilled an important state contract of the Ministry of Transport of Russia within the framework of the GLONASS federal target program, having completed the e-Sea development project. The purpose of which was to improve the safety of navigation and navigation on the waterways of the Russian Federation and to increase the efficiency of maritime transport. The technological complex "BES-KF", developed by "Kronstadt Technologies", is approved by the RS.

In 2016, the Kronstadt company became the executor of the largest project to create a test water area for e-Navigation [7]. The Hermitage project includes a part of the Gulf of Finland, the Neva, Svir, and Lake Ladoga.

The Kronstadt company has become the only partner of the world's largest European test area for e-Navigation Sea Traffic Management (STM). The first steps have been taken in the joint work of the Hermitage and STM water areas, which is quite logical for various reasons. The port of St. Petersburg
is annually visited by about 50 ships out of 300 participating in STM (20 of them are Russian). These vessels are commercial, as they are subject to the standard work of e-Navigation. Colleagues from STM are interested in the involvement of the Baltic states in the implementation of e-Navigation technologies.

**Projects of the united shipbuilding corporation "Pioneer-M"**

R / V "Pioneer-M" project 25700 – small-size research vessel of the catamaran type with a hull made of composite materials. Designed for integrated research of the coastal water area. In its creation, a new design methodology is applied, including a product lifecycle management system. The vessel is being built to perform a wide range of complex scientific research works in the coastal regions of the Black Sea, including oceanographic, hydrobiological, hydrochemical, geomorphological, hydroacoustic, and diving works. Multifunctionality is realized due to the modular system of container-type scientific laboratories, which are used alternately. The project assumes year-round operation of the vessel in the waters of the Black and Azov Seas up to 20 nautical miles from the place of refuge. The project number, 25700, corresponds to the length of the vessel – 25.7 m; width – 9.1 m, depth amidships – 3.1 m, draft with screws – 1.5 m, displacement – 82 tons. Power plant power – 2 * 246 kW. The area of solar panels is 35 square meters. Speed - 10 knots (maximum) / 8 knots (operational), autonomy – 6 days, cruising range in terms of fuel reserve – 500 miles, seaworthiness – 3.5 points. Crew – 4 people, scientific personnel – 8 people (Figure 4. R / V "Pioneer-M" project 25700). All unmanned navigation systems are based on the use of GIS, discussed in more detail in the article by P. I Smirnov "Methodological support for the formation of the geoinformation system of a sea vessel" [6].

![Figure 4. R / V "Pioneer-M" project 25700](image)

**Expert opinions on the effectiveness of the unmanned navigation system**

An independent expert in the transport industry, Sergey Tuguzov, believes that the introduction of IT technologies will allow efficient data transfer between the ship and the shore and contributes to the creation of a single information network that unites all its participants.
According to the general director of the MariNet industry center Alexander Pinsky, the introduction of the unmanned navigation system can occur in the next decade, will not only reduce operating costs by 30%, but also solve the personnel shortage of qualified seafarers, and establish routes for the movement of ships.

Dmitry Sukhoversha, head of multimodal transportation at FMLogistic, believes that now the operation of the unmanned navigation system is hampered by technical and legal aspects. In addition, the economic situation is now going through hard times and does not contribute to the massive introduction of the unmanned navigation system. Now it is not a new fleet that is being operated, which is gradually becoming obsolete. Modernization is slow because costs a lot of money. Paying for the services of a crew capable of solving all arising problems is now much more profitable.

The main concern is the fact that, like any mechanism, the machine can malfunction. In this case, Alexander Pinsky suggests thinking about creating an analog of "naval special forces", which, in the event of a force majeure situation, will land on the unmanned navigation system and fix the problems.

During Lockdown – 2020, air traffic between the countries was cut off, which in turn slowed down the change in ship crew. The solution to this problem also arouses interest in the unmanned navigation system.

**SWOT – analysis of the implementation of the unmanned navigation system**

As with any project, the implementation of a crewless navigation system is accompanied by certain opportunities and risks. Based on the analysis of publications and regulations over the past 5 years, a SWOT analysis was carried out.

**Strengths:**
- savinghumanresources;
- reducing the cost of transportation;
- crewsafety.

**Weaknesses:**
- undevelopedinternationallegislation;
- expensive maintenance of the unmanned navigation system;

**Opportunities:**
- reducing the costs of shipowners;
- reductionofinsurancecosts;

**Threats:**
- hardwarefailure;
- jobcuts;
- hackerattacks.

**The need for highly qualified personnel**

With a massive transition to a system of unmanned navigation, the size of the crew will be reduced. But this will only apply to those specialties, the work of which can be automated, it is not worth talking about deserted ships. It will not be possible to completely do without seafarers, the need for highly qualified engineers will sharply increase, the profession is transforming, it will become more qualified and safer.

Since 2021, the Maritime State University named after Admiral G. I. Nevelskoy, Sakhalin State University, and the shipping company Morspetsservice signed an agreement for the training of autonomous navigation (a-Navigation) specialists. The agreement provides for the development of training programs and training of specialists in a-Navigation, including practical exercises on the autonomous vessels of Morspetsservice.

The latest five-year BIMCO / ICS ManpowerReport predicts that an additional 147,500 officers will be required by 2025 to service the world's merchant fleet. An acute shortage of engineers at the level of management and officers is experienced by specialized vessels: chemical carriers, tankers for
transporting LNG and LPG. This opinion is shared by Vitaly Klyuev, Director of the Department of State Policy in the Field of Sea and River Transport of the Ministry of Transport of Russia.

6. Conclusion
Navigation is a well-regulated industry in which all ship roles are spelled out. The captain is the representative of the shipowner and the state. When introducing a crewless navigation system, will the state or the shipowner be able to transfer their powers to artificial intelligence? These questions are being asked more and more after 2020. There is no need to talk about the complete automation of the vessel yet since this entails several problems that cannot be solved within a short period of time. Many ships were built in the 20th century, and their service life is 18-30 years, but in fact, the service life is much longer, therefore, it is not immediately possible to completely replace the ships. In addition, it is necessary to finalize and update the regulations of maritime law. The unmanned navigation system requires consistent implementation - from allowing the crew to be temporarily absent from watch in uncomplicated navigation conditions to full automation of the navigation process in any conditions.

The Government of the Russian Federation has adopted draft federal laws and government decrees on autonomous vessels, which will allow, after the completion of the tests, to begin mass operation of autonomous vessels under the Russian flag as part of a national experiment from 2021 to 2025. Thus, ships may become the first type of autonomous transport allowed for commercial operation in Russia.

It is too early to talk about deserted crews, but it is no longer possible to ignore this trend. Lockdown – 2020 is a confirmation of this. All technologically developed countries that own a significant marine fleet assess the prospects for the transition to a system of unmanned navigation.

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