Above and below water drones market

1. Foreword

Sea Drones Systems represent a multifaceted domain encompassing a wide array of applications rooted in unmanned underwater and surface drones. These systems serve diverse purposes, spanning data collection, search and rescue, and engineering operations. This report embarks on an analysis of the global sea drone market, subsequently focusing on the unique dynamics and opportunities within the Italian market.

Diving into the domain of Sea Drones Systems, we encounter a spectrum of applications that include both underwater and surface vehicles. Unmanned vehicles, both remotely and autonomously operated, play pivotal roles in tasks such as ocean mapping, marine research, environmental surveillance, and underwater inspection. Further, the rise of hybrid sea drones, capable of seamlessly transitioning between surface and subsurface operations, and even air operations in maritime environments, highlights their versatility.

However, the growth of the ecosystem faces substantial challenges. Issues like autonomous navigation, infrastructure for docking and maintenance, maritime regulations, and the need to outperform traditional maritime vessels pose hurdles. Over the past decade, the sea drone sector has witnessed noteworthy technological development,

thanks to advancements in autonomous navigation, energy-efficient propulsion systems, and data collection capabilities. As a result, it has gathered the attention of diverse participants, including both established entities and ambitious startups that invest in sea drones equipped to perform complex operations across diverse marine landscapes.

Italy is riding the tide of this sea drone revolution. Driven by industrial and public entities aware of the manifold opportunities presented by these applications, the Italian maritime landscape is undergoing a remarkable transformation. These aspirations come hand in hand with distinct challenges and disruptive potential, necessitating the establishment of a robust national ecosystem. This ecosystem is geared to facilitate the seamless integration of sea drone technology into existing maritime operations, develop innovative regulatory frameworks, and drive advancements in sea drone vehicles, systems, and supporting infrastructures.

To realize these objectives, this report takes a deep dive into key market trends, identifies critical gaps within the sea drones sector, and provides a set of recommendations. These recommendations are aimed at incentivizing the growth and development of Italy's Sea Drones Systems market, fostering innovation and regulatory excellence.

2. Sea Drones Systems Overview

2.1 The concept

Sea Drones Systems represent a diverse family of unmanned vehicles and devices specifically designed for aquatic and maritime operations. These advanced systems are equipped with a wide array of sensors, instruments, and technologies that enable them to perform a variety of tasks both above and below the water's surface.

Categorizing the sea drones ecosystem into three distinct groups, we have Unmanned Surface Vehicles (USV), Unmanned Underwater Vehicles (UUV), and the emerging category of Hybrid Vehicles (HV), representing a nascent branch in the developmental continuum.

Surface vehicles

- Remotely Operated Surface Vehicles (ROSVs): primarily operated on the water surface, come equipped with an array of sensors and instruments. ROSVs allow operators to control their movements and collect data.

- Autonomous Surface Vehicles (ASVs): surface vehicles that can operate without direct human control. These self-guided sea drones navigate water surfaces independently and carry out tasks like data collection, monitoring, and maritime surveillance in full autonomy.

Underwater vehicles

- Remotely Operated Underwater Vehicles (ROUVs): vehicles designed to operate beneath the water's surface without human occupants, are remotely operated, allowing for precise control in underwater environments. They are deployed for several tasks such as underwater mapping, defense and security applications, oceanography, environmental monitoring, archaeological exploration, oil and gas exploration, data collection, search and rescue operations, as well as underwater filming and photography.

- Autonomous Underwater Vehicles (AUVs): AUVs are fully autonomous and can operate independently playing a critical role in a wide range of applications with a specific focus on tasks characterized by high operational risks for humans and manned vehicles, as well as operations requiring long periods underwater.

Hybrid Vehicles

- Sea Hybrid (Undersea/Surface Vehicle): These hybrid sea drones operate on the water surface and beneath it, combining the capabilities of surface and underwater vehicles.

- Aerial-Marine Hybrid: Designed for both aerial and aquatic operations, these sea drones excel in scenarios that demand versatility. They seamlessly transition between aerial and aquatic environments, making them valuable assets for tasks such as reconnaissance, monitoring, and operations that span both air and water.

- Airborne Drones for Marine Environments (Waterproof Drones): These full-air drones are engineered to operate in marine environments with waterproof materials to ensure their resilience in aquatic conditions.
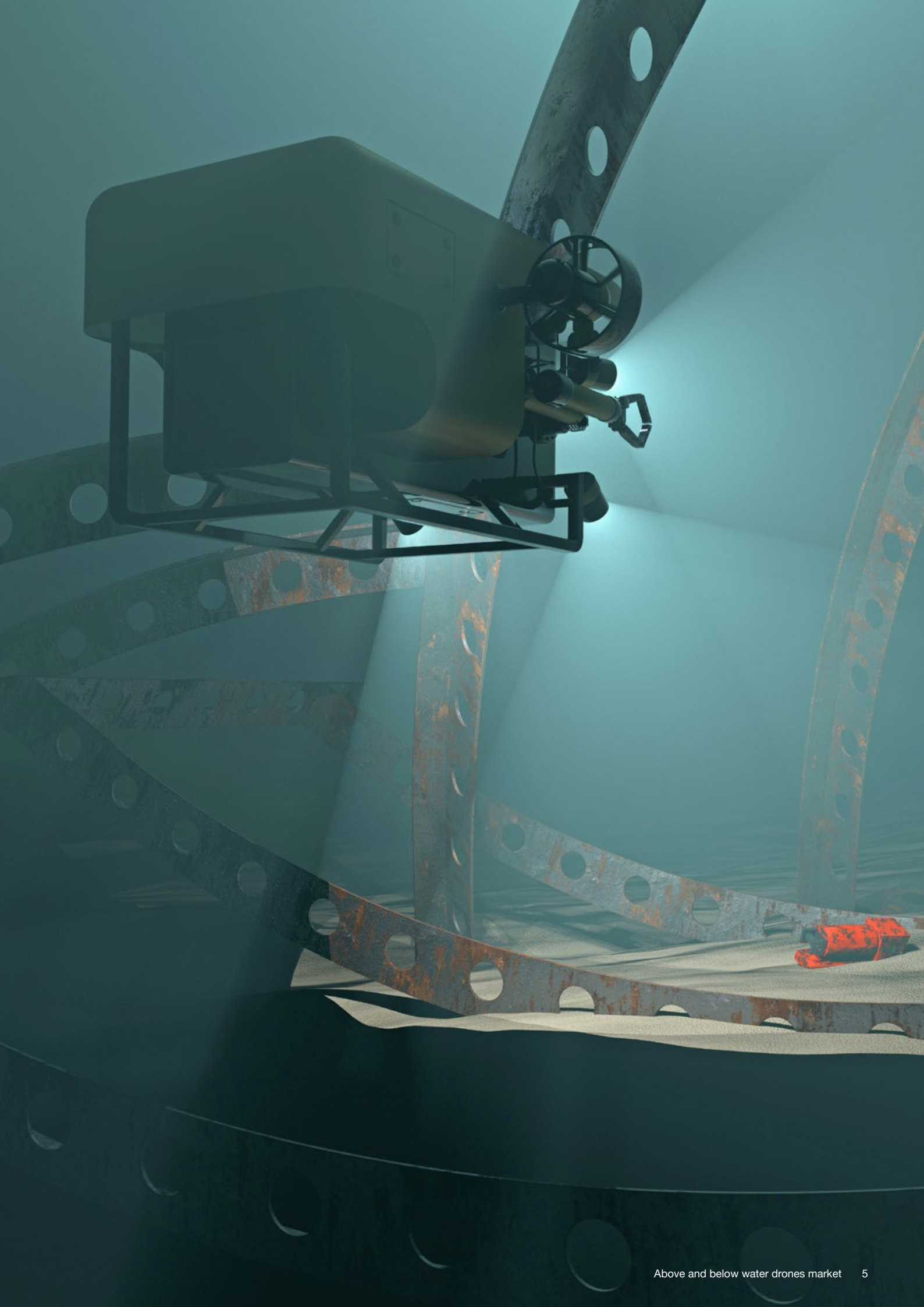
2.2 The Technology

In the realm of Sea Drones Systems, technology plays a pivotal role in defining the capabilities and applications of these aquatic and maritime vessels. Control systems and propulsion technologies are the key drivers that enable these sea drones to perform a wide range of tasks, from precise inspections to expansive surveying missions. There exist three different types of technologies:

Remotely Operated Vehicles (ROVs)

- Control System Type: ROVs are remotely operated vehicles that offer direct human control from the surface. They are often tethered to a surface vessel to facilitate power and communication.

- Propulsion Technology: ROVs commonly employ electric thrusters for propulsion, which are powered through the tether to the surface vessel. This system is particularly suitable for tasks that require precision and control.

- Target Use for ROV: ROVs are well-suited for missions demanding precise maneuverability and detailed inspection and maintenance tasks. Their application spans various sectors, including civil applications like underwater inspections and military applications like mines countermeasures.

Autonomous Vehicles

- Control System Type: Autonomous sea drones are capable of operating without direct human control, thanks to advanced navigation systems.

- Propulsion Technology: Autonomous vehicles often rely on electric propulsion systems powered by onboard batteries, which provide energy for propulsion and other operations.

- Target Use for Autonomous: Autonomous sea drones are designed for missions covering extensive oceanic areas in a short period or for extremely long operations at sea, such as facility maintenance and surveillance. They find applications in oceanographic research, marine surveying, offshore energy exploration, and military reconnaissance.

Semi-Autonomous Vehicles

- Control System Type: Semi-autonomous sea drones strike a balance between full remote control and full autonomy, often requiring some human input or guidance.

- Propulsion Technology: The propulsion systems of semi-autonomous drones can vary, depending on the specific mission requirements and the level of autonomy required.

- Target Use for Semi-Autonomous: Semi-autonomous sea drones are suitable for scenarios that benefit from human oversight or intervention. They are deployed in dynamic conditions where adaptability and flexibility are crucial, such as search and rescue missions, scientific research, and complex data collection tasks.

The technology underpinning Sea Drones Systems is a driving force behind their adaptability and versatility in a wide range of marine and maritime applications. Control systems, whether remotely operated, fully autonomous, or semi-autonomous, dictate the level of human involvement and the range of tasks these sea drones can undertake. Additionally, propulsion technologies, such as electric thrusters, hydraulic systems, and buoyancy control, provide the means for efficient movement and energy utilization.
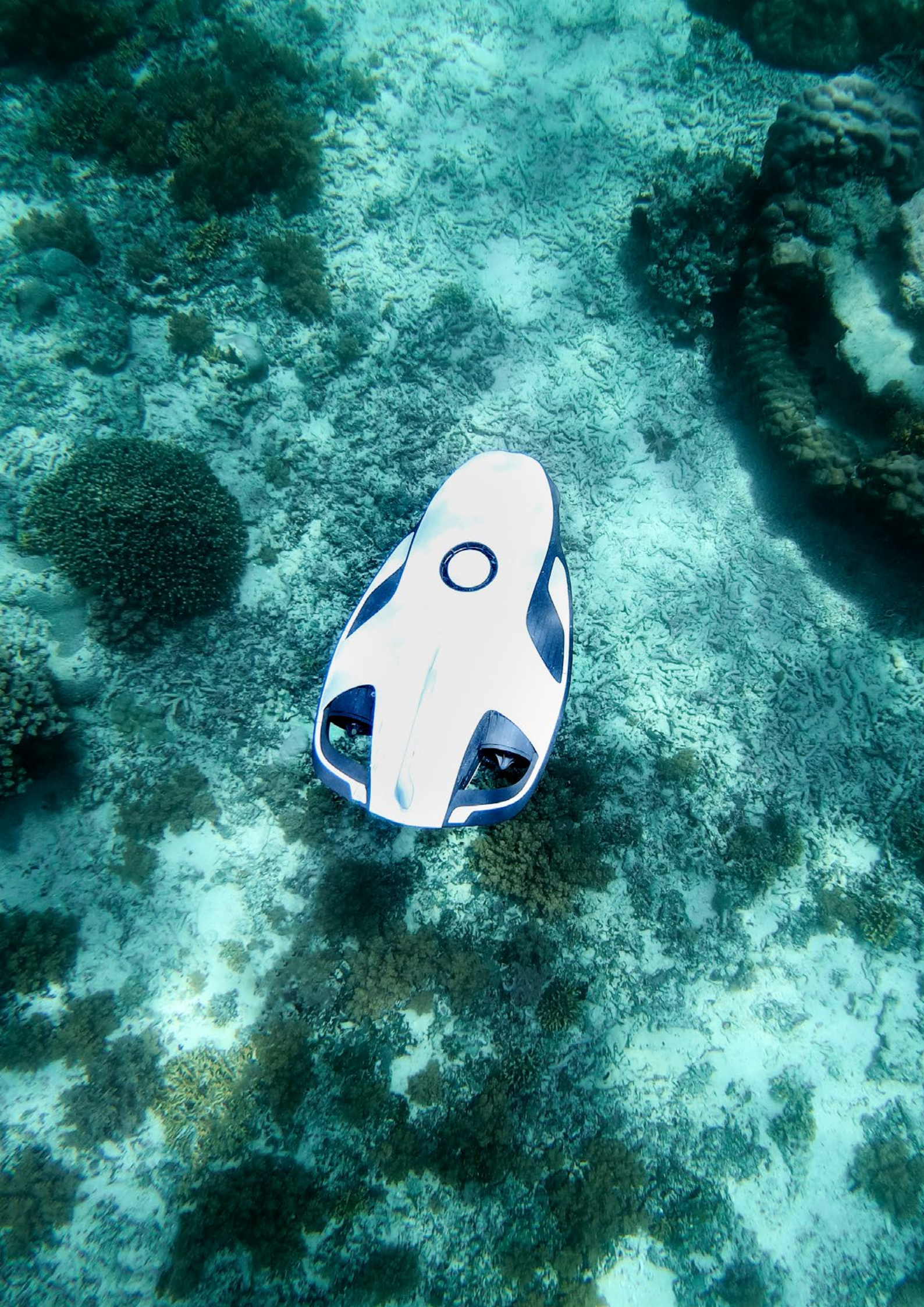
2.3 Perimeter of Sea Drones Systems Applications

Sea Drones Systems offer a diverse range of applications, leveraging advanced technologies to address various maritime and aquatic needs. To better understand the market trends and distinctive characteristics, we have identified and categorized 48 applications into five main missions based on their target objectives.

Sea Drone Systems - 5 Missions and main applications

Military & Security		Scientific research		Aquatic engineering		Search & Rescue		Commercial & Recreational	
1 Maritime surveillance	2 Anti-submarine warfare	11 Oceanography and marine biology	12 Seismic activity monitoring	21 Pipeline inspections	22 Infrastructure maintenance and cleaning	31 Vessel in distress search & rescue	32 Individual at sea search & Rescue	41 Underwater filming	42 Underwater photography
3 Mine counter-measures	4 Underwater reconnaissance	13 Environmental monitoring	14 Bathymetry & sea floor mapping	23 Dredging	24 Hydroelectric facilities inspections	33 Drowning victim retrieval	34 Swiftwater rescue	43 Fishing	44 Aquaculture & fish farming
5 Warfare search & rescue	6 Port & harbor security	15 Underwater archeology	16 Remote sensing	25 Offshore infrastructure repair	26 Underwater construction	35 Night / Low visibility search operations	36 Safeguarding and first aid	45 Scuba diving & water sports	46 Shipping & logistics
7 Coastal & boarder surveillance	8 Combat & combat support	17 Scientific surveying	18 Maritime habitat reconstruction	27 Freshwater inspections	28 Oil & Gas explorations	37 Underwater search	38 Asset recovery	47 Wildlife observation	48 Waste collection & cleaning
9 Underwater payload deployment	10 Amphibious assault support	19 Education & Teaching	20 Climate research & water sampling	29 Inland underwater engineering	30 Oil spill response	39 Search pattern optimization	40 Wreckage & debris survey		

Military & Security
Military and security applications of Sea Drones Systems encompass tasks such as surveillance, monitoring, and safeguarding of national borders, harbors, and maritime assets. They also play a crucial role in warfare actions, including mine detection and clearance.

Scientific Research
Sea Drones Systems are instrumental in advancing scientific research, enabling marine data collection, precise ocean mapping, pollution analysis, and habitat restoration efforts. These technologies are indispensable for understanding and preserving the marine environment.

Aquatic Engineering
The use of sea drones is widespread in aquatic engineering, where they contribute to oil and gas explorations, streamline the construction of infrastructures (e.g., oil rigs and wind farms), and support the ongoing maintenance of offshore and inland facilities.

Search & Rescue
Sea Drones Systems excel in search and rescue operations, thanks to their efficiency and speed. These unmanned vessels play a crucial role in saving human lives during emergency situations, recovering wreckage, and safeguarding critical assets.

Commercial & Recreational
The efficiency and speed of sea drones make them invaluable for both commercial and recreational purposes. Emerging technologies in drone development have found their place in various recreational activities, including filming, fishing, and aquaculture. Meanwhile, logistics and shipping applications are under development.

These applications demonstrate the versatile nature of Sea Drones Systems and their ability to address a wide array of challenges and opportunities in the maritime and aquatic domains.
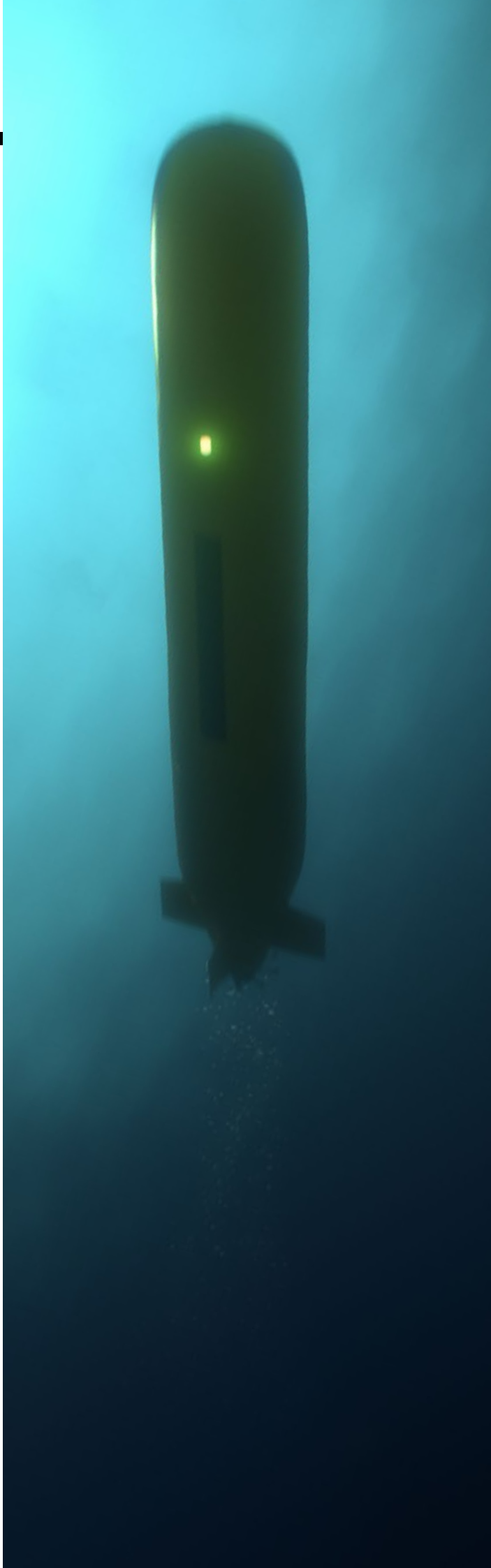
2.4 The End Users

The adoption of Sea Drones Systems spans a diverse range of end users, each harnessing these advanced technologies for specific purposes.

1. Governments

Governments, including military and law enforcement agencies, utilize sea drones for national security, defense, and research purposes. These entities often employ sea drones for surveillance, monitoring, and safeguarding maritime borders.

Example: The US Navy operates multiple sea drone systems, such as the Sea Hunter, to track submarines and enhance its maritime capabilities.

2. Private Companies

Private companies are major stakeholders in the sea drone industry, focusing on commercial applications across various sectors. These companies leverage sea drones for purposes such as exploration, engineering, construction, and monitoring of facilities and infrastructures.

Example: Ocean Infinity is a prime example, providing seabed exploration and mapping services, demonstrating the value of sea drones in commercial ventures.

3. Research Centers

Research centers play a pivotal role in environmental assessments, scientific data collection, and technological innovation enhancement. They utilize sea drones to collect crucial data related to oceanography, marine biology, and environmental assessments.

Example: The Monterey Bay Aquarium Research Institute employs sea drones to collect data on ocean chemistry, biology, and physics, contributing to the advancement of marine research and environmental science.

4. Private Individuals

Private individuals, including hobbyists, explorers, and photographers, find immense value in sea drones for recreational purposes. These enthusiasts use sea drones to explore the underwater world, capture imagery, and unique multimedia content.

Example: Open ROV, for instance, manufactures and operates low-cost underwater robots tailored for marine enthusiasts, providing them with the means to explore and discover the mysteries of the deep.
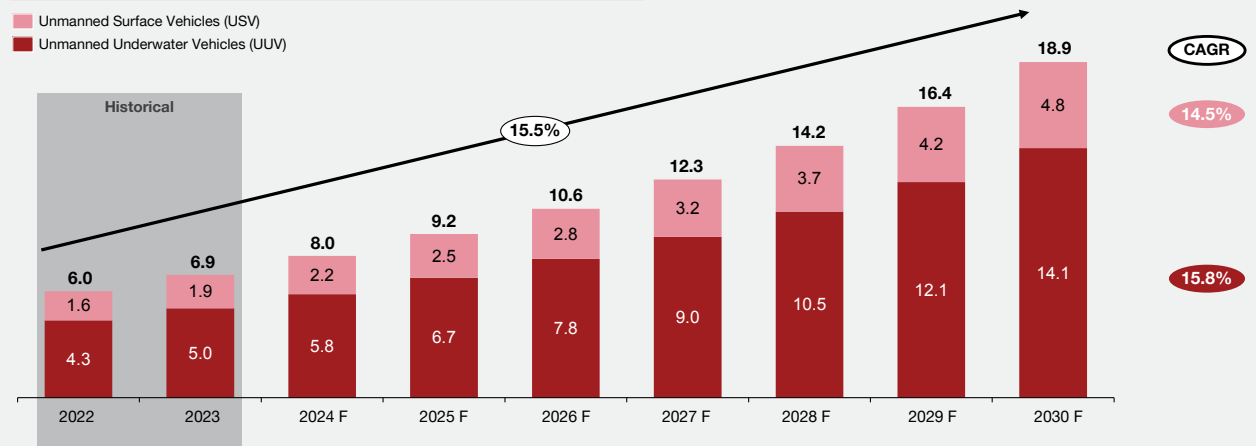
3. The Sea Drones System Market

The Sea Drones Systems market is undergoing a remarkable transformation, with global prospects that promise significant growth. This chapter focuses on the global market landscape, analyzing its key dimenions and main players, to finally investigate the unique positioning of the Italian ecosystem. As sea drones continue to advance in technology and applications, they are poised to reshape maritime operations, making a substantial impact across various sectors. From military and security applications to scientific research, aquatic engineering, and commercial endeavors, the sea drone market is on a trajectory of expansion, driven by innovation and the pursuit of safe and sustainable maritime solutions.

3.1 The Global Market

The Sea Drones Systems market is on a significant growth trajectory, with a global market size expected to reach €18.9 billion by 2030, driven by a compounded annual growth rate (CAGR) of 15.5%. Key factors behind this expansion include technological advancements, increased defense spending, and a growing emphasis on environmental policies.
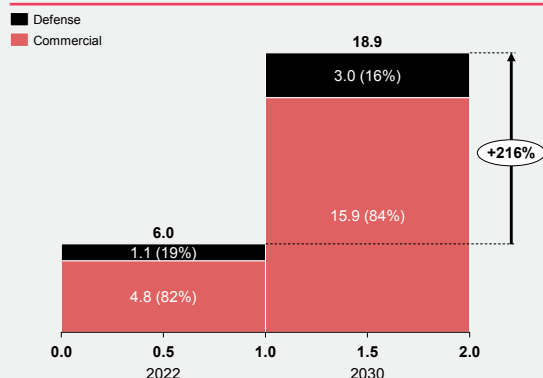
In this burgeoning market, Unmanned Underwater Vehicles (UUVs) are poised to maintain the highest market share, making up approximately 70% of the total value. They are projected to achieve a CAGR of 15.8%, resulting in a market value of €14.1 billion by 2030. Unmanned Surface Vehicles (USVs) are also on the ascent, with a projected CAGR of 14.5% and an anticipated market value of €4.8 billion in 2030.

Global Unmanned Sea System market (€B, 2022-2030)

Legend:
- Unmanned Surface Vehicles (USV)
- Unmanned Underwater Vehicles (UUV)

Historical:
- 2022: Total 6.0 (USV 1.6, UUV 4.3)
- 2023: Total 6.9 (USV 1.9, UUV 5.0)

Forecast:
- 2024 F: Total 8.0 (USV 2.2, UUV 5.8)
- 2025 F: Total 9.2 (USV 2.5, UUV 6.7)
- 2026 F: Total 10.6 (USV 2.8, UUV 7.8)
- 2027 F: Total 12.3 (USV 3.2, UUV 9.0)
- 2028 F: Total 14.2 (USV 3.7, UUV 10.5)
- 2029 F: Total 16.4 (USV 4.2, UUV 12.1)
- 2030 F: Total 18.9 (USV 4.8, UUV 14.1)

CAGR: 15.5% overall; USV 14.5%; UUV 15.8%

Source: Technavio; Mordor; Stats Market Research; Strategy& analysis

Global Unmanned Sea System market

Legend:
- Defense
- Commercial

2022: Total 6.0 (Defense 1.1 (19%), Commercial 4.8 (82%))
2030: Total 18.9 (Defense 3.0 (16%), Commercial 15.9 (84%))
Growth: +216%

Source: Technavio; Mordor; BIS Research; Strategy& analysis

In 2022, military applications represented 19% of the total market, with a value of €1.1 billion.By 2030, the military segment is expected to reach a value of €3.0 billion, with a CAGR (2022-2030) of 13.4%. This growth is underpinned by increased defense spending and higher vessel prices.

Civilian applications, spanning scientific research, commercial and recreational uses, engineering applications, and search and rescue, are set to grow at a faster pace. They are projected to increase to a value of €15.9 billion in 2030, capturing 84% of the total market share. The civilian segment's growth is propelled by diversification.
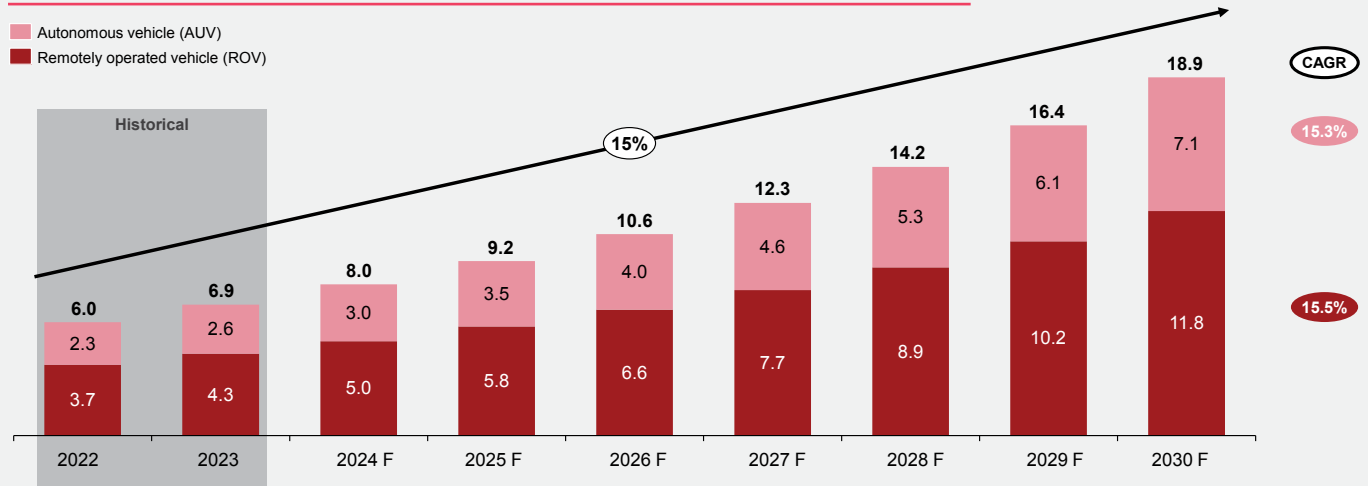
The Sea Drones Systems market is witnessing remarkable growth, with various segments carving out their own niche. Autonomous Unmanned Vehicles (AUVs) are expected to soar to €7.1 billion by 2030, reflecting a robust compound annual growth rate (CAGR) of 15.3%. AUVs operate autonomously, harnessing the power of advanced sensors and navigation systems, and find applications in both the commercial and military sectors.

Maritime systems manufacturers are engaging in strategic partnerships with technology and software companies to integrate cutting-edge artificial intelligence (AI) technologies onboard UUVs and USVs. One illustrative example is Probotek, which actively deploys AI and robotics technologies on unmanned maritime vessels, exemplified by the Flying Ship project.

On the other hand, Remotely Operated Vehicles (ROVs) are expected to reach a market value of €11.8 billion by 2023, displaying a robust CAGR of 15.5%. ROVs are controlled from a base station laptop connected to a surface vessel and find extensive applications in maritime industries. These applications span from oil and gas exploration to research and underwater mining. ROVs can operate autonomously through preprogrammed instructions or AI, enhancing operational safety and offering extended operational time.

Global Unmanned Sea Systems Global Market market by technology (€B, 2022-2030)

Autonomous vehicle (AUV)
Remotely operated vehicle (ROV)

	Historical		2024 F	2025 F	2026 F	2027 F	2028 F	2029 F	2030 F
	2022	2023							
Total	6.0	6.9	8.0	9.2	10.6	12.3	14.2	16.4	18.9
AUV	2.3	2.6	3.0	3.5	4.0	4.6	5.3	6.1	7.1
ROV	3.7	4.3	5.0	5.8	6.6	7.7	8.9	10.2	11.8

15%

CAGR
15.3%
15.5%

Source: Technavio; Mordor; Stats Market Research; Strategy& analysis
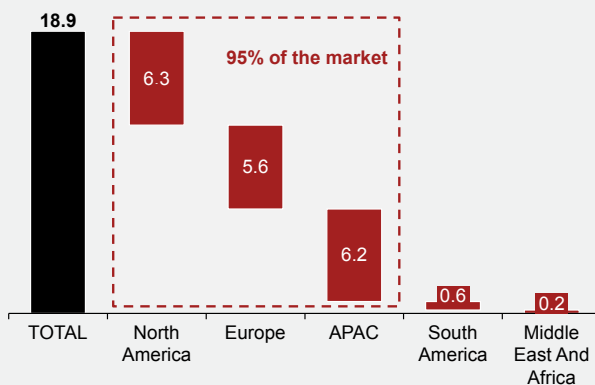
Looking ahead to 2030, the global Sea Drones Systems market is projected to witness significant growth, with major markets emerging in countries like the United States, China, and Germany. These nations are expected to play pivotal roles in shaping the future of sea drones.

The growth of the sea drone market will be fueled by dynamic partnerships between the military and civil industries. These collaborations will open new horizons for the application of sea drones, ushering in a wave of innovation and expanding their presence across various sectors.

Furthermore, the convergence of the private and public sectors will be instrumental in driving market expansion. Public sector initiatives are set to facilitate the integration of sea drones into everyday maritime operations, while private sector investments and innovations will unlock a plethora of opportunities in both the civil and military domains.

Global USS market by geography ($B, 2030)

95% of the market

	Value
TOTAL	18.9
North America	6.3
Europe	5.6
APAC	6.2
South America	0.6
Middle East And Africa	0.2

Source: Mordor Intelligence; Technavio; Strategy& analysis

Major country markets in 2030

3.2 Value Chain and Target Offering

We delved deep into the market assessing over 300 different vehicles and vessels, spanning the product portfolio of UUVs and USVs from more than 100 players globally. Moreover, our research included an in-depth evaluation of 680+ payloads and onboard systems, a critical aspect for understanding the dynamics of this evolving field.

Target Missions	Current split
Scientific Research	30%
Aquatic Engineering	24%
Military & Security	19%
Search & Rescue	15%
Commercial & Recreational	12%

Our research has pinpointed the most targeted applications within the Sea Drones Systems market. Notably, Scientific Research and Aquatic Engineering emerge as the prime focus areas for manufacturers and operators with 30% and 24% of the applications respectively, followed my Military & Security (c.19%). As such, Scientific Research and Aquatic Engineering missions have considerable influence over the pace of innovation and the growth potential of the entire sector. Numerous technologies related to sea systems are developed to meet the specific requirements of these missions. Notably, a significant number of manufacturers offer customization options for payloads. For instance, inspection and monitoring technologies can be tailored to the specific needs of individual customers. Consequently, despite their civil nature, several vehicles and vessels manufactured for Scientific or Engineering purposes may hold substantial interest for actors such as the Navy or for warfare applications in general.

However, what really sets the Sea Drones Systems ecosystem apart is the diverse array of players engaged in its development and deployment. Both traditional industry international companies and innovative start-ups actively participate along the Sea Drones ecosystem, highlighting the market's versatility along the entire Value Chain, from raw material suppliers, up to port infrastructure providers and system integrators for maritime connectivity.

Taking on a holistic approach that enables us to understand the interconnected dynamics driving the sea drone market, the key players contributing to the Value Chain include:

1. Tier 1 and Tier 2 Suppliers

- These suppliers play a pivotal role in providing essential components and subsystems that constitute the building blocks of sea drone systems and robotics.

2. Original Equipment Manufacturers (OEM)

- OEMs are central entities responsible for designing and assembling sea drones. Their innovative capabilities, engineering expertise, and manufacturing prowess shape the technological landscape, influencing the functionality and features of sea drone systems.

3. Maintenance, Repair, and Overhaul (MRO)

- MRO businesses ensure the continuous operational readiness of sea drones. Their role in servicing, repairing, and maintaining these complex systems is crucial for sustaining the longevity and effectiveness of the sea drones deployed in various applications.

4. Service Operators

- Service operators represent the frontline users of sea drones, employing them in diverse applications.

5. Communication and Connectivity Service Providers

- Ensuring seamless communication and connectivity is paramount in the functionality of sea drones. Providers in this category furnish the necessary infrastructure and technologies to establish robust communication links, facilitating real-time data transmission and control.
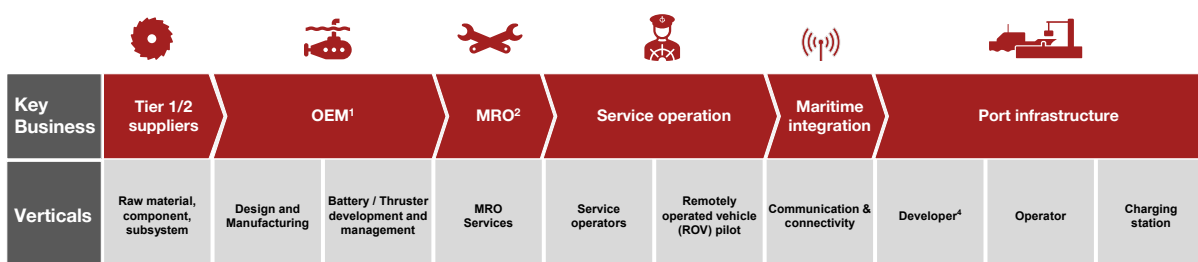
6. Port Infrastructure Developers

- As sea drones become integral to maritime activities, the development of port infrastructure is crucial. Developers in this domain contribute to creating docking facilities, maintenance hubs, charging stations, and operational centres.

Focusing on a manufacturing and operational standpoint, the underwater segment stands out as the most developed within the market. Major international players have established a strong presence here, particularly among Aerospace and Defense (A&D) leaders. This segment is not only where these companies operate but also where they have a significant influence on shaping the industry's trajectory.

Hybrid vehicles, while currently a niche market, are gaining prominence as the technology matures. Innovative ventures, such as research institutes, universities, and high-tech start-ups, are leading the way in this segment. This indicates a surge in forward-thinking ventures seeking to harness the potential of hybrid sea drones.

As a result, Italy hosted over 40 initiatives between currently active and past projects, aimed at fostering the growth of the ecosystem spanning industrial and commercial projects to university research activities and international collaborations.

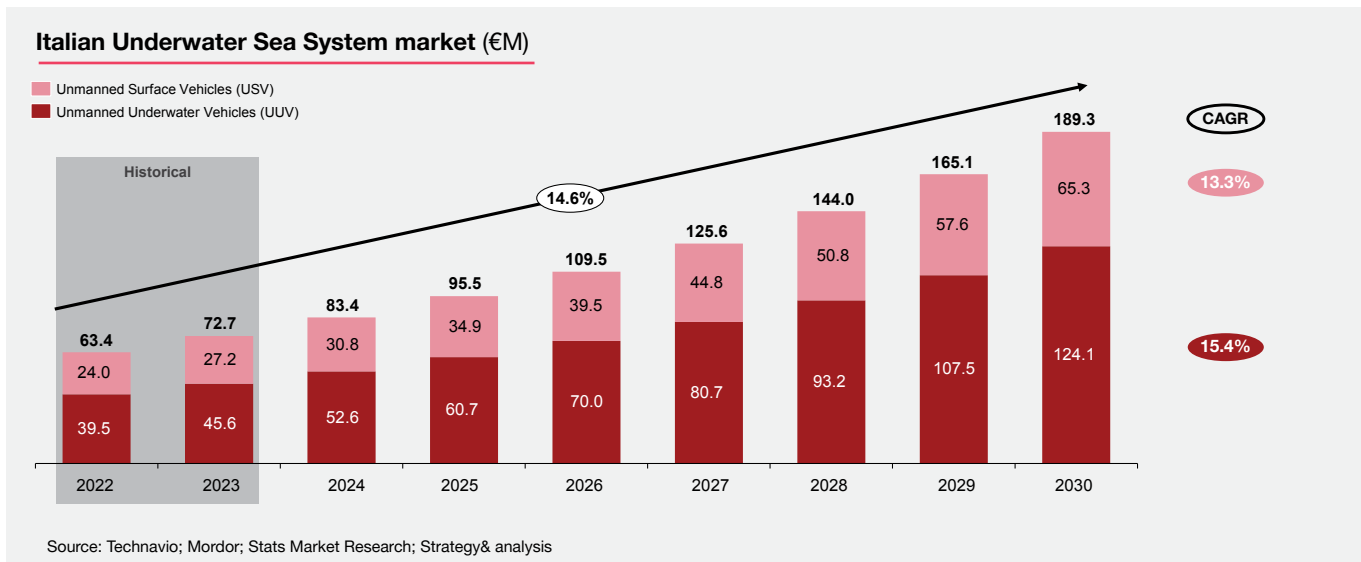| Key Business	Tier 1/2 suppliers	OEM[1]		MRO[2]	Service operation		Maritime integration	Port infrastructure		
Verticals	Raw material, component, subsystem	Design and Manufacturing	Battery / Thruster development and management	MRO Services	Service operators	Remotely operated vehicle (ROV) pilot	Communication & connectivity	Developer[4]	Operator	Charging station

3.3 The Italian Ecosystem

The Italian Unmanned Sea Systems market is experiencing a wave of growth, expected to reach a market value of €189 million by the year 2030. This projected expansion is underpinned by a robust compound annual growth rate (CAGR) of 14.6%, indicative of the market's vibrant dynamics.

Within the Italian market, industry leaders like Leonardo, Saipem and Fincantieri are expected to make a substantial impact. These key players bring experience and expertise to the table, helping to shape and define the market's direction.

However, the Italian Unmanned Sea Systems market accommodates not only large players but also medium-sized and smaller companies, all contributing to the market's development. However, what truly sets the Italian market apart is the consistent influx of startups and university spinoffs. This influx is emblematic of the market's dynamic and innovative nature, with a continuous stream of new technologies driving its evolution.

Even within the Italian market, the UUV segment maintains its lead. This dominance underscores the significance of undersea operations and the role of UUVs in advancing various applications. This segment's sustained growth is expected to have a transformative impact on the Italian Unmanned Sea Systems landscape, offering new opportunities and advancements.

Italian Underwater Sea System market (€M)

Legend:
- Unmanned Surface Vehicles (USV)
- Unmanned Underwater Vehicles (UUV)

Historical

Year	USV	UUV	Total
2022	24.0	39.5	63.4
2023	27.2	45.6	72.7
2024	30.8	52.6	83.4
2025	34.9	60.7	95.5
2026	39.5	70.0	109.5
2027	44.8	80.7	125.6
2028	50.8	93.2	144.0
2029	57.6	107.5	165.1
2030	65.3	124.1	189.3

CAGR: 14.6%; USV 13.3%; UUV 15.4%

Source: Technavio; Mordor; Stats Market Research; Strategy& analysis

As a result, Italy hosted over 40 initiatives between currently active and past projects, aimed at fostering the growth of the ecosystem spanning industrial and commercial projects to university research activities and international collaborations.

Industrial
- **SAND** project – Fincantieri Next Tech
- **V-Fides; REPMUS** – Leonardo
- **Hydrone; FlatFish** – Saipem Sonsub
- **Sea Drones** - Graal Tech
- **CK-14** – Codevintec
- **VR Buoy** – Laser Navigation
- **Hugin 4500** – Krongberg Srl
- **Sea Drone** – Gabri Elettroinformatica
- **Defea**– Marconi Industrial
- **SI-USV** – EngCoSys
- **PLUTO** – Gaymarine
- **Observation ROV** – Sea Opportunities
- **U-Safe** – Versilia Marine Service
- **SplashDrone** – SwellPro/ Aeromnia
- **Zattera-ROV** – Greentech Solutions
- **Droni Acquatici** – Orion Srl
- **Sara** – TopView
- **Components** – Novacavi
- **ArcheRov** – WitLab
- **THE Keelcrab** – Keelcrab
- **DEVSS** – 3D Research Srl
- **Umapper, Utracker, etc.**– Edge Lab
- **MAR** - SETEL
    … and more

Research & University
- **Ipnamena project** – OGS
- **ROBUST** – Università di Genova
- **THESAURUS, WAVE, Folaga project** – Centro E. Piaggio, Università di Pisa
- **THESAURUS, ARROWS, PASSport, SUONO** – Università di Firenze
- **DAMPS, PACMAN** – ISME
- **Zeno AUV CrossLab** – Università di Pisa
- **Marin project** – Università delSalento; Seastama
- **SWAMP ASV** – CNR-INM.
- **DEVSS** – ISPRA, Università della Calabria
- **SeaLab** – Università La Sapienza
- **WiMust** – Università di Genova, Università del Salento
- **SeaExplorer** – Università Parthenope
- **Drone Subacqueo** - Regione Sicilia
- **ROV Sea Dragon** – Stazione Zoologica di Napoli
    … and more

International collaboration
- **FeelHyppo** – ISME, EU, Università di Firenze
- **Tarmen** – ISME, QNRF, Mellon University of Qatar
- **OCEAN2020** – EU
- **CORDIS** – EU
    … and more

Legend:
- International collaboration
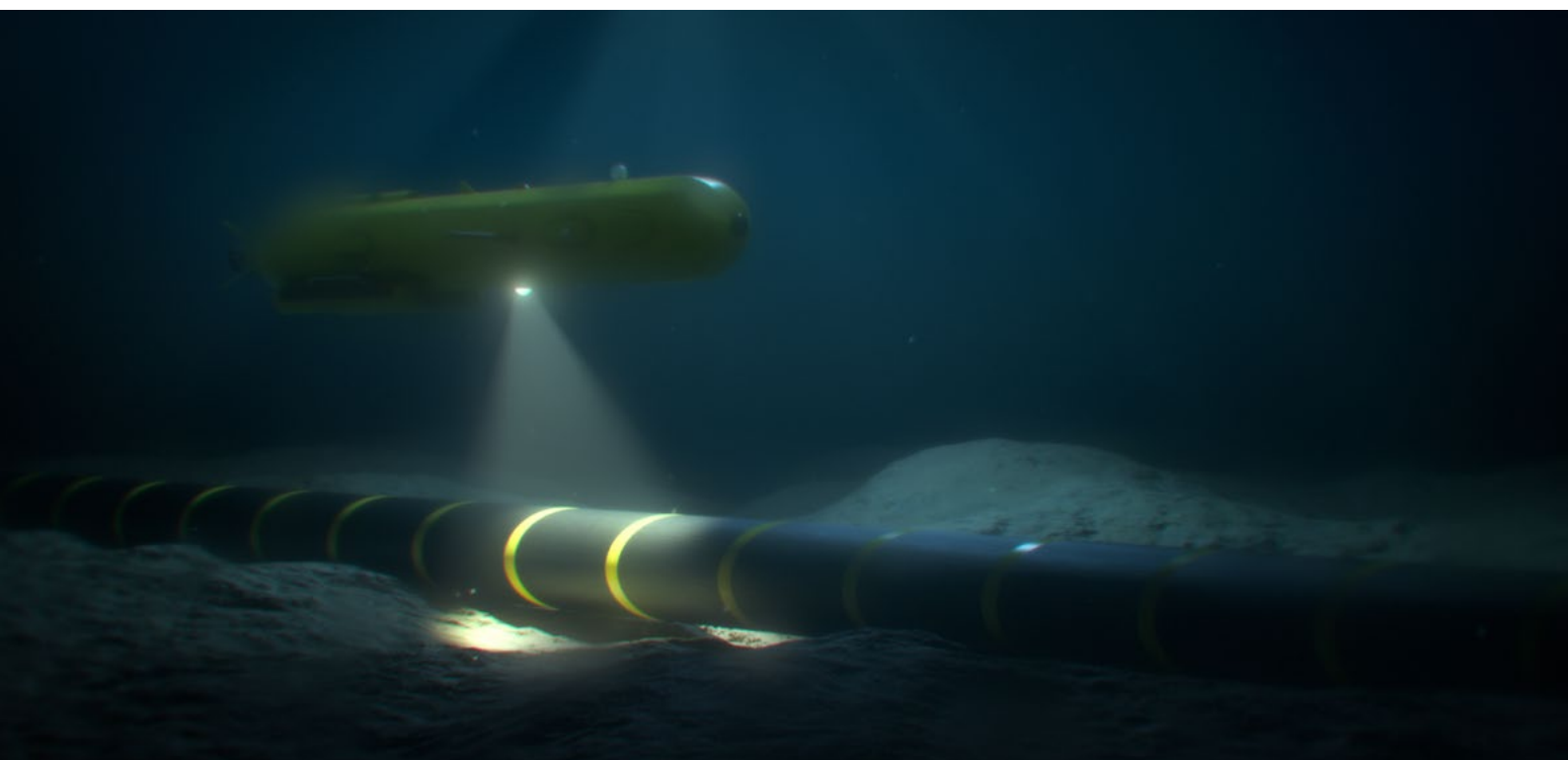- Industry
- Research and university

Nevertheless, the country lags behind compared to other international players, such as the United States and North European nations. This lag can be partially attributed to historical factors and the Mediterranean's unique characteristics. Unlike the turbulent waters of the North Sea, the Mediterranean is known for its calmer and warmer conditions. Consequently, the Italian maritime industry has long favored traditional high-level scuba diving for certain activities. This preference for conventional approaches has somewhat hindered the rapid development and integration of sea drone systems in Italy.

Nevertheless, the Italian market is on a trajectory of expansion and growth. Numerous funding sources are available, fostering innovation and bolstering this sector. National universities, for instance, have access to a diverse array of channels, including regional funding, participation in EU projects (e.g., Horizon Europe) and initiatives, and collaboration in projects funded by European agencies (e.g., European Space Agency). Additionally, the National Recovery and Resilience Plan (PNRR) directs projects toward regions with a strong emphasis on maritime activities (e.g., Liguria and Calabria have active marine robotics projects), and Ministerial funds are also available. As such, various channels and opportunities for financial support are accessible to entities with solid activities in the sea drone industry.

Another critical aspect of the sea drone industry at a global level is the regulatory and legislative landscape. As of today, such areas are relatively underdeveloped compared to the airspace domain. While this presents challenges, it also serves as a significant driver for innovation. In fact, innovations in manufacturing are facilitated by the absence of strict regulations, encouraging experimentation, and new approaches to technology. Nevertheless, this regulatory landscape is a grey area, with no standardized certifications and licenses for sea drones as temporary permits are granted for operations (*Saildrone became the first company to obtain Approval of Principle for its vessels in November 2023*).

This has implications for the integration of autonomous systems within the maritime ecosystem, particularly in coexistence with manned vessels, and raises questions related to the safe operation of autonomous vehicles, including concerns about insurance and liability.

The lack of clear regulations necessitates the development of a comprehensive framework to address these emerging challenges in the maritime domain, ensuring the responsible and efficient operation of sea drone systems.

4. Lessons Learnt and Recommendations

4.1 Market trends

Unmanned sea systems offer a range of key benefits, making them highly attractive to a variety of industries.

- First and foremost there is **safety**. These systems are instrumental in performing hazardous tasks without putting human lives at risk, excelling in operations that take place in challenging situations such as extreme weather conditions.

- Another significant advantage of unmanned sea systems is their **cost-effectiveness**. These systems offer financial benefit by reducing the operational costs related to manpower and equipment, especially in relation to long-lasting activities such as environmental monitoring and data collection, or maintenance of offshore facilities.

- **Rapidity** is another key advantage of unmanned sea systems. These systems can rapidly cover large distances and reach dangerous or remote locations. This quick response time is critical in delicate situations and search and rescue efforts, where time can be a determining success factor.

- Lastly, unmanned sea systems offer exceptional **efficiency**. The technology embedded in these systems allows for high-quality visual images, videos, and large data collection capabilities. This ensures accuracy in assessing and maintaining equipment and streamlining execution of various tasks.

Looking at the future, several drivers are steering the growth of the sea drone industry, shaping its trajectory in the coming years.

- A first significant driver is the **widespread adoption of disruptive technologies**. Technologies such as 3D printing and advanced sensors are rapidly changing the landscape of sea drones enhancing the industry's capabilities both in terms of manufacturing and operations. Deep learning and AI are also being employed to improve the autonomy and reliability of autonomous vessels, contributing to the sector's development, and enabling their use for additional applications.

- The **increasing focus on sustainability** is another driving force. Sea drones may play a crucial role in reducing the carbon footprint of maritime operations. This has sparked a surge in environmental monitoring, conservation efforts, and pollution detection, ensuring a timely response. This emphasis on sustainability not only benefits the environment but also fosters innovation and knowledge about marine ecosystems.

- Lastly, **increased investments in maritime warfare**, motivated by evolving maritime threats, the need to safeguard critical commercial routes, and defend national boarders, are presenting a surge in funding, compelling the sea drones industry to develop advanced systems for defense applications.

The future of the sea drone industry holds significant promise with innovative applications on the horizon.

- **Autonomous shipping**, involving unmanned cargo ships and submarine vessels, aims to reduce GHG emissions and automate port infrastructures. Advancements in collision avoidance technology are vital for the safe implementation of this application.

- **Waste collection**, facilitated by sea drones equipped with nets and sensors, supports large-scale ocean cleanup efforts, contributing to environmental sustainability and pollution control. International regulation compliance and effective coordination with maritime traffic are essential for the responsible operation of this application.

- Lastly, **underwater farming** for sustainable food, fuel, and pharmaceutical production is emerging as a promising application. Development efforts should focus on materials with resistance to prolonged navigation and technologies for precision tasks, to help address global challenges related to food security and environmental sustainability.

4.2 Main challenges

As the unmanned sea systems sector progresses and expands, it encounters several significant challenges. These challenges, encompassing technological complexities, financial sustainability, emerging regulations, and social and security implications, form the focal points of this discussion, each demanding dedicated attention for the continued growth and advancement of the industry.

1. Technological Complexity and Readiness:
Operating in demanding marine environments requires resilient designs and materials capable of withstanding extreme conditions. Unmanned sea systems must continually evolve, employing technological enhancements to optimize navigation, communication, endurance, payload capacity, and seamless integration with other platforms.

2. Financial Sustainability and Accessibility:
Ensuring affordability and upholding high standards of reliability and quality presents a formidable challenge, particularly for startups and smaller organizations entering the sea drone market. Developing streamlined technologies is imperative to broaden the accessibility of sea drone systems across diverse industries and users.

3. Emerging Regulations and Legal Frameworks:
Maritime settings are characterized by a complex legal landscape, subject to compliance requirements dictated by national and international laws. However, there are substantial normative gaps. To advance the sea drone industry, addressing significant regulatory gaps and establishing requirements and standardization are vital. Collaboratively tackling gaps in accountability and liability is equally essential.

4. Social and Security Implications:
Ethical and social concerns encompass aspects like privacy, security, and transparency. There is a tangible risk of accidents, malfunctions, and collisions, particularly concerning manned vessels, due to adverse weather conditions. For autonomous sea drones, these challenges necessitate a deeper exploration of ethical considerations. Additionally, the real-time transmission of data introduces concerns about the accidental disclosure of sensitive information. Addressing these issues and integrating them into the evolving framework of the sea drone industry is imperative to ensure its growth and success.

4.2 Recommendations and Final Remarks

As the unmanned sea systems industry continues its journey of growth and transformation, a set of strategic recommendations emerges to pave the path toward success. These recommendations are tailored to the diverse range of stakeholders involved in the sea drone ecosystem.

1. Enable Access to Funding

- Explore diversified funding sources spanning various industries that stand to gain from investments in sea drones.

- Cultivate partnerships with financial institutions, venture capital firms, and funding agencies to provide essential financial backing.

- Promote the establishment of startup incubators and grant programs for research institutions, fostering innovation and the development of cutting-edge sea drone technologies.

- Prioritize investment attractiveness by identifying lucrative segments within the sea drones market, offering high growth potential and investment returns.

2. Establish a Supportive Regulatory Framework

- Identify regulatory gaps and opportunities for innovation, particularly in the context of non-standardized programs, permits, and production requirements.

- Stay at the forefront of emerging regulatory trends, anticipating future challenges, and proactively addressing potential roadblocks.

- Focus on critical aspects such as safety standards, environmental regulations, and data privacy as essential components of a forward-thinking regulatory framework.

- Foster close collaboration between regulatory bodies and industry stakeholders to define common standards and operational requirements. This collaborative approach will contribute to the growth of the sea drone market while ensuring safety and reliability.

3. Promote Public-Private Collaboration

- Support joint demonstration projects aimed at showcasing the tangible benefits and capabilities of the sea drone sector. Such projects serve to raise awareness among potential stakeholders, investors, and end-users.

- Cultivate knowledge-sharing consortia, facilitating collaborative relationships between academia, startups, established companies, and research institutions. This collaboration will result in the efficient exchange of expertise, experience, and capabilities, driving innovation and the evolution of the sea drone ecosystem.

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