The Use of Satellite Technologies for Maritime Surveillance: An Overview of EU Initiatives

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Abstract: *The sea lies at the heart of the EU prosperity and security: the Union and its member states depend on open and secure seas and oceans for their trade, transportation, energy, food, mineral resources, tourism, and a healthy marine environment. Maritime surveillance constitutes a key enabler for safeguarding the EU strategic interests at sea, by providing vital information on developments over, on and under the sea surface and coastal areas. A fundamental role in the process of collecting and communicating relevant information is held by satellite technologies which open paths to cost-effective and innovative alternatives to traditional surveillance techniques. The article proceeds as follows. The first section briefly outlines the key importance of the sea for the economic, military, energy, food, environmental, health, and cultural dimensions of EU security. Then, the concept of "maritime surveillance" is explained within the broader context of maritime security in the following section. In order to explore the use of satellite technologies in the EU maritime surveillance mechanisms, the third section of the paper examines three cases related to: the vessel monitoring system (VMS) and the vessel detection system (VDS); FRONTEX, the EU agency for external borders management, and the related framework of EUROSUR; and finally, the CleanSeaNet oil spill monitoring system developed by the European Maritime Safety Agency (EMSA). Lastly, the concluding section summarizes the main findings of the article.*

Key Words: *The EU, maritime security, maritime surveillance, satellite technologies.*

1. INTRODUCTION: SEA MATTERS

The sea has been at the core of human existence since immemorial times, by providing vital physical, chemical and biological functions for the planet; a medium for transportation, trade, commerce and communication; rich sources of food and medical cures; a plethora of living and non-living resources; and numerous touristic and recreational opportunities.

In the case of Europe, its proximity to the sea has shaped its entire history and has enabled its coastal states to become hubs of growth and innovation, transportation, foreign

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exchange and defence. The same holds true for the EU. With 23 coastal member states and more than 70% of its external borders at sea, the prosperity and growth of the EU and its citizens are intrinsically connected to the security of the maritime domain. In 2013, 90% of the EU`s external trade and over 40% of its internal trade were sea-borne [1], while for the same year the total gross weight of goods handled in the EU ports was estimated at 3.7 billion tones, and the number of passengers passing through EU ports reached almost 400 million [2]. The 'blue' economy accounts for circa 5.4 million jobs and generates a gross added value of approximately €500 billion a year in a wide array of sectors, ranging from coastal tourism, offshore oil and gas, fisheries, monitoring and surveillance, marine mineral mining and ocean renewable energies [3]. Therefore, growth in the blue economy can provide a leverage to boost the EU international economic competitiveness, the efficient use of resources, the creation of jobs, and the marine environment protection. As a catalyst for growth, trade and transportation, the sea is intricately linked to the economic dimension of the EU security. However, it also occupies an important role in connection to other facets of security. One major dimension is related to the protection of the states` core military and economic interests, such as defending the territorial integrity against deliberate attacks from the sea, projecting power at distance, or preventing others from exploiting the economic resources in their internal waters and territorial seas. In this context, the sea is understood as a *milieu* which enables member states to protect their security and to exert power though their navies performing military or more constabulary tasks, as in the case of the EU Naval Force (EU NAVFOR) Somalia - Operation Atalanta, EUCAP Nestor and the EU Training Mission Somalia (EUTM Somalia) which aim to address both the root causes and effects of piracy in the Horn of Africa [4].

The seas and oceans are also enormous and predictable sources of clean renewable marine energy from waves, tides, marine currents, salinity and temperature gradient, submarine geothermal resources and marine biomass; although ocean energy research within EU has developed at different speeds and a number of technologies are still in incipient phases, the progressed achieved so far holds promise for an increased exploitation of ocean energy to meet EU demands [5]. Additionally, the seas play a key role in the food and health security of member states. A clear example is the case of coastal communities which rely on the consumption of seafood and which are the most vulnerable group to maritime and coastal pollution, through direct exposure to infectious and toxic organisms, dissemination of human pathogens by sea transportation, or contact with sewage and industrial wastewater. However, linkages expand well beyond the coastline, as fish safety and sea-borne menaces to human health are of concern for the entire population. More broadly, the well-being of the environment worldwide is impacted by the health of the seas and oceans. The hydrologic cycle depends on the oceans` key capacities to store and transport and exchange heat, water and gases with the atmospheric environment. The oceans and seas also act as a sink for the excessive amounts of agricultural nutrients and untreated wastewater washed down by rivers from land-based sources. Further on, the marine environment hosts the widest diversity of living organisms on Earth, which constitute a relatively unexplored source of compounds with applications in numerous sectors. The increasing reliance on the coast and the sea for abundant food resources, habitation, transportation, trade, commerce and communication, coupled with the demographic pressure exerted by coastal populations have raised important concerns related to the marine environmental security. Marine pollution; Illegal, Unreported and Unregulated (IUU) fishing; ocean acidification and climate change; and the irreversible destruction of marine habitats as a result of anthropogenic activities – trigger cumulated adverse effects on humans and environment.

Last but not least, the seas and oceans are an important part of the European (and the EU) culture and identity. Throughout history, the use of watercraft opened new avenues for territorial exploration and expansion, fishing, migration, trade, conduct of warfare, and recreational activities, which resulted in enhanced cultural interactions and diffusion [6]. At the same time, navigating vessels required crews drawn from the population ashore, temporary or permanent housing, transport infrastructure, ports and harbors, maintenance installations, and essential community facilities, which led to the gradual development of coastal communities. The identity of these populations is strongly linked to the maritime and coastal spaces which are characterized by their own environment, resources and natural rhythms. The distinctiveness of the area, coupled with the specific skills and knowledge acquired by the littoral inhabitants to adjust to a coastal life gradually shaped a "distinct subculture" socially shared across the wider maritime community [7]. To protect its maritime identity, the EU has focused on the protection of its tangible (underwater and onshore archaeological sites including ports, shipwrecks, barrows, tombs, etc.) and intangible cultural heritage (oral histories and folklore traditions, seafaring experiences, the craft of building and sailing indigenous boats, or local fishing practices), while at the same time attempting to enhance the visibility of the European maritime heritage through various cultural manifestations for wide audiences, such as the European Maritime Day.

As suggested above, the EU and its member states hold numerous security interests in the maritime domain, including the preservation of the freedom of navigation and maritime trade, the protection of economic interests and critical maritime infrastructure, the prevention and countering of transnational illegal activities, the protection of the marine environment, and the conservation of biodiversity and cultural heritage. In order to safeguard these interests, the EU relies on maritime surveillance which informs any decision and action taken with regard to the sea.

2. MARITIME SURVEILLANCE AS AN INTEGRAL PART OF MARITIME SECURITY

Despite its widespread use in the realm of security and defence, law, policing, shipping industries, governments, international organizations, agencies, NGOs and academic literature, maritime security lacks a univocal definition. We can distinguish at least three major categories of definitions. The first (and arguably the most prominent strand of literature) defines the concept in negative terms, i.e. as the absence of a set of sea-based threats. Although the exact wording differs across actors, the menaces outlined in the scholarly literature generally include deliberate attacks emanating from state and non-state hostile forces; terrorism; trafficking of people, arms or drugs; piracy; irregular migration at sea; energy supply disruptions; sea-based resource depletion; and marine environmental degradation [8], [9], [10], [11]. Similar definitions often feature in key documents in the maritime field, such as the maritime strategies of national states or regional organizations, or the United Nations Secretary General`s (UNSG) annual reports on developments and issues relating to ocean affairs and the law of the sea.

A second framework for understanding maritime security is that of "a good order at sea" which describes maritime security as an ideal end-state characterized by the absence of disruptions in a well-functioning and prosperous global international system [12]. In a similar vein, the EU Maritime Security Strategy (EU MSS) defines maritime security as "a state of affairs of the global maritime domain, in which international law and national law are enforced, freedom of navigation is guaranteed and citizens, infrastructure, transport, the

environment and marine resources are protected" [13].

A third line of inquiry defines maritime security as a comprehensive process which brings together a broad spectrum of tasks requiring coordination and harmonization to attain a desired outcome. According to this view, maritime security includes "all relevant activities that support the early identification, mitigation, management of and recovery from intentional, unlawful acts and hazardous incidents threatening the stability and good order of the maritime domain, thereby limiting or preventing access to, freedom of action within, and use of the maritime domain." [14].

If maritime security is understood as a process, the key role of its components – including of maritime surveillance – becomes easily observable. Based on the information resulting from maritime surveillance activities, the EU and its member states can – among other - detect, identify, track and intercept IUU fishing, piracy, terrorism, organized crime, human smuggling and illegal migration; prevent accidents at sea; and protect the marine environment. Given its importance as a prerequisite for any action at sea, it is hardly surprising that maritime awareness has been labeled as one of the five main areas of implementation of the EU MSS to strengthen the EU response to maritime challenges.

Maritime surveillance was defined by the European Commission as "the effective understanding of all activities carried out at sea that could impact the security, safety, economy or environment of the European Union and its Member States" [15].

Essentially, the process of surveillance implies collecting information about an object, its properties and behavior within a designated area. For this purpose, it may include one or more subsequent phases: detection (establishing the presence of an object and its location), classification (establishing the type/class of the detected object), identification (individualizing the object among the acknowledged class, generally without relying on prior information), recognition (matching a detected object with a pre-defined particular object), and verification (the confirmation of the presence or geographical position of an object based on prior information on that object) [16].

In the EU, maritime surveillance is conducted for military uses (e.g. in counter-piracy operations) and for non-military tasks (such as border control, search and rescue, or marine environment protection) in the waters under the sovereignty and the jurisdiction of the member states, but also in the international waters where the EU has compelling security interests (e.g. in the Gulf of Aden).

The different purposes imply the deployment of a variety of layered capabilities at multiple levels: satellites are particularly useful for collecting information over wide geographical areas; maritime patrol aircraft and ships are used for smaller surfaces; while unmanned aerial vehicles and helicopters are suitable for specific areas [17].

Within EU, there are approximately 400 authorities dealing with maritime surveillance information across 7 sectors (maritime safety, maritime security and prevention of pollution produced by ships; control of fisheries; marine pollution preparedness and response and marine environment protection; customs; border control; general law enforcement; and defence), collected from multiple types of sensors (radio, radar, underwater sensors, satellite images, etc.) and platforms (ships and aircrafts) [18]. Most of these public authorities are located at the level of EU and EEA member states. However, several EU agencies and bodies have emerged as active participants in maritime surveillance activities. These include but are not limited to the European Maritime Safety Agency (EMSA), the European Fisheries Control Agency (EFCA), the European Agency for the Management of Operational Cooperation at the External Borders of the Member States of the European Union (FRONTEX), the European Environmental Agency (EEA), the European Defence Agency

(EDA), and the European Union Satellite Centre (SatCen). The multitude of diverse national and EU bodies managing vast (and often overlapping) quantities of information through sectorial and uncoordinated policies, coupled with the proliferation of security threats at sea, and the constraints imposed by the economic recession have fueled the urge to facilitate the exchange of maritime surveillance information between different authorities. A flagship initiative in this regard was the development of a Common Information Sharing Environment (CISE) within the framework of an Integrated Maritime Surveillance. In essence, CISE functions as a voluntary collaborative platform which aims to enable member states to coordinate their responses, streamline their resources and share knowledge to avoid fragmentation of information and duplication of efforts and costs.

3. THE USE OF SATELLITE TECHNOLOGIES

Nowadays satellite technologies are increasingly embedded in maritime surveillance instruments and mechanisms as they provide versatile and cost-effective solutions for gathering relevant information. Satellites are suitable both for wide area surveillance, as well as for monitoring targeted locations; they have access to remote areas; they operate independently of air traffic control; and they can be used for a broad range of activities in maritime security and safety, including those related to maritime pollution, maritime border security, fisheries control, search and rescue, or accident and disaster response [19].

Despite their seemingly clear advantages, satellites have not been seen as particularly relevant instruments for maritime security from the outset; instead, space assets have been gradually incorporated into the European maritime context following several initiatives which highlighted their added value [20]. Such projects have been developed both at the national and the European level.

For instance, radar imagery has been used for maritime surveillance by the German TerraSAR X project and the Italian Cosmo-Sky Med, while SPOT IMAGE, a French initiative, has relied on a mix of optical and radar capabilities for vessel detection and classification and maritime surveillance for border security. Various national research and development projects have been concerned with maritime security and space, including - to name but a few - the French GALILEOCEAN (improving border security by optimizing the use of Galileo for maritime positioning), Germany`s projects ShipDetec (countering piracy, smuggling, illegal migration and IUU fishing) and DeMarine (focused on improving the security of ship routes), or Italy`s Safety in Sea Traffic (specialized in the development of advanced satellite navigation technologies).

At the EU level, satellite technology has found numerous applications in various law enforcement and compliance systems supporting surveillance operations across a wide range of maritime policies such as fisheries control, irregular migration and border control, marine environmental protection, anti-piracy, drug or weapon smuggling, human trafficking, and many other. For instance, in order to ensure compliance with the rules of the common fisheries policy, member states and the EU rely on modern satellite-based technologies, such as the vessel monitoring system (VMS) and the vessel detection system (VDS) which facilitate effective monitoring, automatic cross-checks across different control instruments and timely analyses of data. The EU was the first to use mandatory VMS satellite-tracking for its larger vessels, which later became a key tool for monitoring and controlling fisheries worldwide. The VMS on board fishing vessels provides real-time data on the identity, location, date, time, course and speed of vessels, which are transmitted to the Fisheries Monitoring Centers (FMC) of the vessel`s flag state; in turn, the FMC forwards the data to

the coastal state or to the fisheries body in whose waters the vessel is present. If the monitoring activities are carried within a broader international context, information is transmitted to the Commission`s DG MARE; additionally, the European Commission may request VMS data from member states for the purpose of specific investigations [21]. The data received by VMS or by automatic identification system (AIS) are corroborated with the data resulting from remotely sensed images sent by satellites through a vessel detection system (VDS). VDS technology is based on satellites carrying Synthetic Aperture Radar (SAR) sensors able to cover wider or more targeted areas to detect vessels at sea during day and night time and through cloud. Data derived from VDS may be used to determine the number and geographical position of fishing vessels within a certain area, to match the positions of vessels detected by VDS with those reported by VMS/AIS, and to assess the presence of fishing vessels for which position reports from VMS are not available. VDS was developed as a complementary control tool for monitoring vessels whose VMS is switched off, malfunctioning or lacking altogether. The purpose of VDS is not to replace traditional control methods, such as onboard or on shore inspections, but rather to contribute to a more targeted response of the fisheries authorities, while also serving as a deterrent [22].

Satellite technologies have also been integrated into numerous maritime border surveillance initiatives. Perhaps the most compelling example is provided by the case of the European Agency for the Management of Operational Cooperation at the External Borders of the Member States of the European Union (FRONTEX) and the European Border Surveillance System (EUROSUR). FRONTEX was established in 2004 as an agency of the EU with the purpose of consolidating and streamlining national cooperation efforts in the management of external borders.

With a broad mandate, FRONTEX is responsible *inter alia* for producing and disseminating a "European situational picture" (ESP) and a "common pre-Frontier intelligence picture" (CPIP) containing information about developments on and outside the EU borders, to help member states prevent illegal migration and cross-border crime.

The information is gathered from a variety of sources and using multiple surveillance tools, including satellites, drones, ground sensors, or ship reporting systems. In addition to the "pictures", the Agency makes available satellite collected data for improving the situational awareness of member states [23].

Under the so-called "EUROSUR Fusion Services", FRONTEX provides access to various cutting edge technologies, including optical and radar satellites for detecting and locating vessels in distress or suspected of being involved in criminal activities at sea [24].

EUROSUR represents a mechanism designed to enhance operational information-sharing and improve cooperation among the EU member states` authorities responsible for border surveillance (border and coast guards, police, customs, navies), FRONTEX, and third neighboring states. Its main focus is to increase the member states` situational awareness and reaction capability at the external borders to detect, prevent and fight illegal immigration and cross-border crime, and prevent the loss of life of migrants [25]. For these purposes, EUROSUR acts as a technical framework promoting the integration of leading-edge tools in maritime surveillance, including satellite technologies.

For example, FRONTEX cooperates with other EU agencies, such as the European Maritime Safety Agency (EMSA) and the European Union Satellite Centre (SatCen), as well as with key non-EU bodies, such as the European Space Agency (ESA) within the framework of the Copernicus program.

Formerly known as GMES (Global Monitoring for Environment and Security), Copernicus represents the flagship European Earth Observation (EO) Program which uses a

combination of satellite imagery and *in situ* data from non-space sources (e.g. ground stations, sensors installed on floats, research vessels, balloons and aircraft) to generate integrated geospatial information.

The program covers six main sectors: land monitoring, marine monitoring, atmosphere monitoring, emergency response, climate change, and services for security applications, which in turn focuses on three key areas: border surveillance, maritime surveillance, and support to EU External Action. The border surveillance component has been placed under the responsibility of FRONTEX in order to support EUROSUR, by making available real time data on developments at sea/on land affecting the EU borders.

The maritime surveillance area functions under the aegis of EMSA which relies on data collected by Copernicus Sentinel 1 satellites to monitor maritime surfaces within and outside the borders of the EU. Lastly, SatCen enables the EU external actions in third countries (most often related to crisis prevention or crisis management) by providing up-to-date satellite imagery [26].

Marine environmental surveillance is another field where satellites are increasingly used. An illustrative example is CleanSeaNet, a satellite-based oil spill and vessel detection system covering all European maritime areas. The system became operational in 2007, following the adoption of the Directive 2005/35/EC on ship-source pollution which called for the implementation of technical solutions and assistance for tracing discharges using satellite monitoring and surveillance. The system performs three core categories of tasks: it carries out routine monitoring activities to identify illegal discharges, detect vessels and track polluters; it supports the enforcement actions undertaken by coastal states, such as on site controls, follow-up, and inspection of suspected vessels; and at last, it contributes to response operations in case of accidental pollution [27]. Initially CleanSeaNet was based on three SAR satellites (ENVISAT, RADARSAT-1 and RADARSAT-2), to which ESA`s satellite SENTINEL-1 was recently added. SAR imagery is able to capture unusual textures of the sea surface which may indicate a possible oil spill, while at the same time it can be used for vessel detection; it has been estimated that the satellites produce service more than 2000 satellite radar images per year for over 400 users in near real time. After the reception of data, the images are analyzed in conjunction with relevant auxiliary information to detect potential oil spills. The detection results are almost immediately transmitted to the affected coastal states in order to prompt a rapid reaction on behalf of the national authorities. Without replacing the surveillance systems in place at the national and regional level, CleanSeaNet complements their activity and constitutes an integral part of the existing oil spill response chains. Without doubt, an effective common response requires improved communication and coordination with the user community; for this, EMSA has created a CleanSeaNet Data Center (CSN-DC) to share data and knowledge, has organized regular CleanSeaNet User Group meetings and has provided trainings on how to use the system [27].

4. CONCLUSIONS

Space assets have become an essential tool for strengthening the capacity of the EU to safeguard its maritime security interests, including with regard to maritime surveillance. Building on the member states` experience, multiple EU agencies and bodies have integrated satellite technologies into their maritime surveillance activities.

In order to gain a preliminary understanding of the role of satellites in the maritime surveillance mechanisms developed at the EU level, this article has explored three cases: the vessel monitoring system (VMS) and the vessel detection system (VDS); FRONTEX and

EUROSUR; and finally, the CleanSeaNet operated by EMSA. Far from being all-encompassing, the analysis enables us to derive several observations.

First, satellite-based technologies have multiple uses across a wide range of maritime surveillance fields such as monitoring and controlling fisheries, detecting vessels, patrolling borders, protecting the marine environment, preventing crises, responding to emergencies, and numerous other. Second, the added-value of using satellites is deemed to reside in an increased effectiveness coupled with lower costs of action; traditional methods of surveillance (e.g. on board inspections) are not dismissed, but rather streamlined and focused through the introduction of new technologies. Third, the satellite-based surveillance systems emerging at the EU level supplement the existing mechanisms at the national and regional level, serving as integrative frameworks and information sharing platforms. Finally, within this intricate network of actors, effective communication is a *sine qua non* condition for the success of joint efforts.

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