COSMOS CONSULTING S.A.

Cosmos Business Systems S.A. Group

Sea Observer VMS

"A VMS system for Managing and Visualization of Sea Area Surveillance Data in Real Time"

White Paper

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General

This document provides the basic definition for the Sea Observer VMS. System's main aspects of operation are explained, focused on the advantages of innovations introduced in the handling of spatial data.

This document also describes the way Sea Observer handles real time procedures such as collecting, parsing, effectively processing and visualizing very large number of vessel position data, through multiple channels, to create a "Combined Operational Picture".

Finally, it presents the case study of the implementation and operation of Sea Observer for the needs of Fishing Monitoring Center in Greece is presented.

Who should read this Document?

This paper is strongly recommended to be read by any authority mandated with establishing reliable vessel monitoring and tracking as well as surveillance of sea areas and maritime safety:

- Navy
- Coast guards
- Maritime authorities
- Ship owners & vessel fleet operators
- Environmental protection authorities
- Any other authority dealing with maritime environment

Introduction

The term **Vessel Monitoring Systems** (VMS) usually describes systems used in commercial fishing to equip environmental and fisheries regulatory organizations with tools to track and monitor fishing vessels activities. Thus, they are generally considered as a key part for vessels monitoring, control and surveillance within national and international activity. VMS may be used to monitor vessels in a country's territorial waters or a country's subdivision, or in its Exclusive Economic Zone (EEZ).

Sea Observer VMS (from now on indicated as "Observer") satisfies both requirements of the above concepts. Observer can be used to improve management and sustainability of the marine environment, by ensuring proper fishing practices or assist prevention of illegal fishing and thus protect and enhance the livelihoods of fishermen. Additionally, Observer can also be used to monitor any legal or illegal marine traffic activity, ensuring safety and efficiency in ports and busy waterways and thus directly contributing to Maritime Surveillance & Awareness.

Getting a comprehensive overview of activity at sea, is definitely a challenge for most countries. To implement maritime policies effectively, governments and authorities need detailed and reliable knowledge about what is happening at sea, in real time. Observer, provides the flexibility to tailor maritime information according to unique or special operational requirements. Observer also provides accurate services, which directly confront any specific need of diverse maritime users, in any country.

Integrated maritime services offered by Observer, include advanced maritime data processing and combining information from all of the agency's maritime applications, as well as other external sources.

Observer fulfills the requirements of any VMS system of any kind. The most important Observer functions consist of the following:

- Implementation of innovative methods for collecting and parsing a very large number of vessel position data through multiple channels
- Effective processing for a very large number of vessel position data, compared with spatial data in order to identify vessel activities
- Real time visualization for a very large number of vessel position data

All the above are used to create the so called **"Combined Operational Picture"**.

The term **"Combined"** means it applies to all involved data channels, including data coming through any communication technology (such as AIS, Iridium, Inmarsat, Argos, GPRS etc.), to data collected from a variety of sensors. **"Operational"** refers to actual (real-time) parsing and processing vessel position data. Data are being compared with spatial data already stored into system, in order to identify each vessel's activity. **"Picture"** refers to a visual representation of the environment, based on various maps and cartographic layers, enriched with vessels data (current positions or tracking), vessel activities and alarms.

After connecting all the above together, we can state that Observer's Combined Operational Picture is the absolute tool in decision making processes.

Basic Features and Main Functionality of Sea Observer

Observer provides power tools to collect information from various data sources. It also provides tools tomanage, interpret and display information in an extremely efficient way. In a way that assists decision makers to make better decisions, by having immediate and comprehensive awareness of a situation.

Observer also increases the management effectiveness of governmental agencies and authorities, which are responsible for monitoring, protecting and managing marine environments. Using a web based geo mapping dashboard, Observer provides real time information, such as vessels activity indication, message alerts and previous actions taken history.

The main functionality of Observer VMS is described below:

- **Creating a Combined Operational Picture**
  - **Basemap Layers**

    Every available basemap consists of a background of geographical context. Operators can change the basemap of the current map, any time by using the basemap gallery.

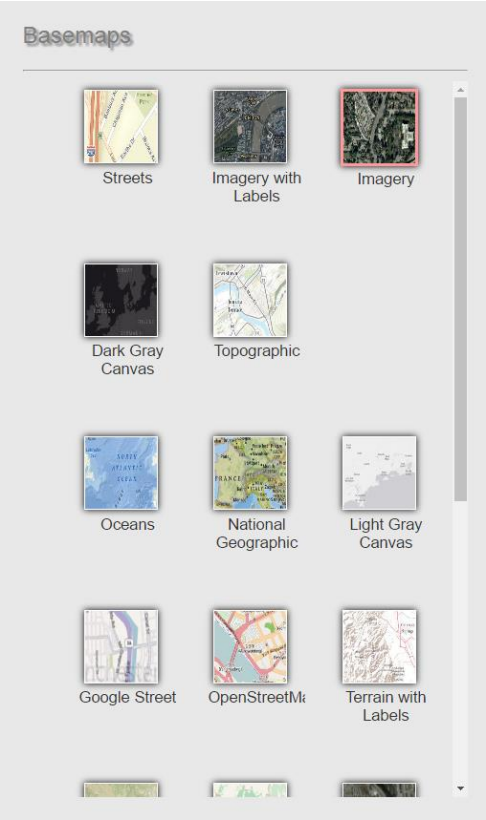

Figure 1: Basemap Gallery

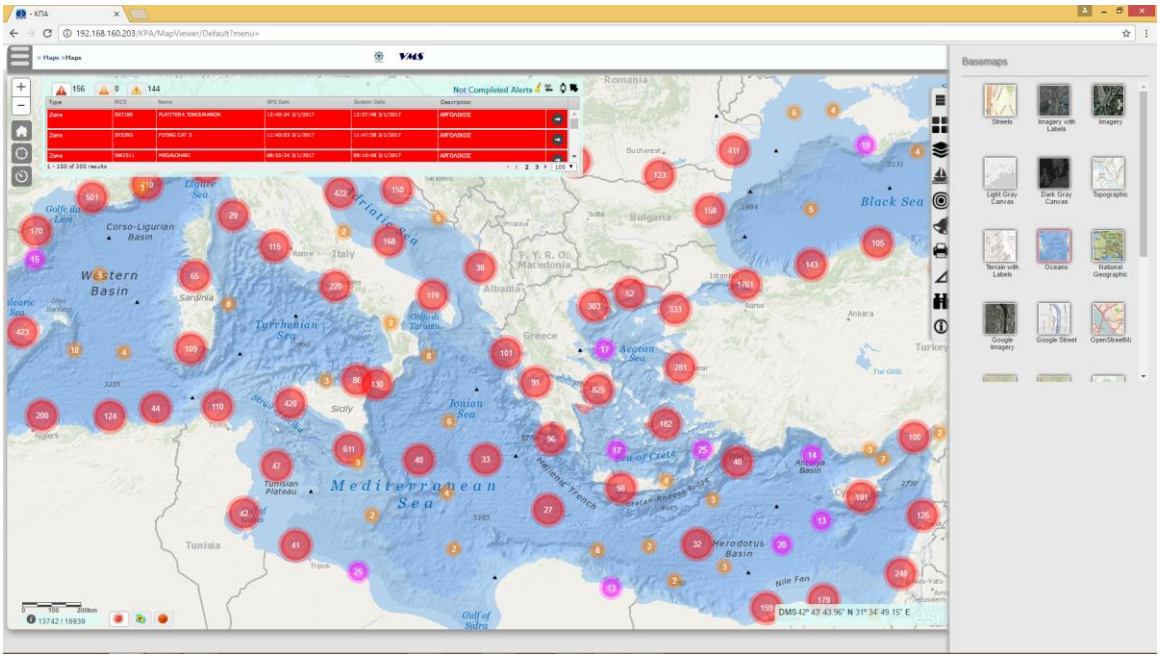

Figure 2: Oceans Basemap View

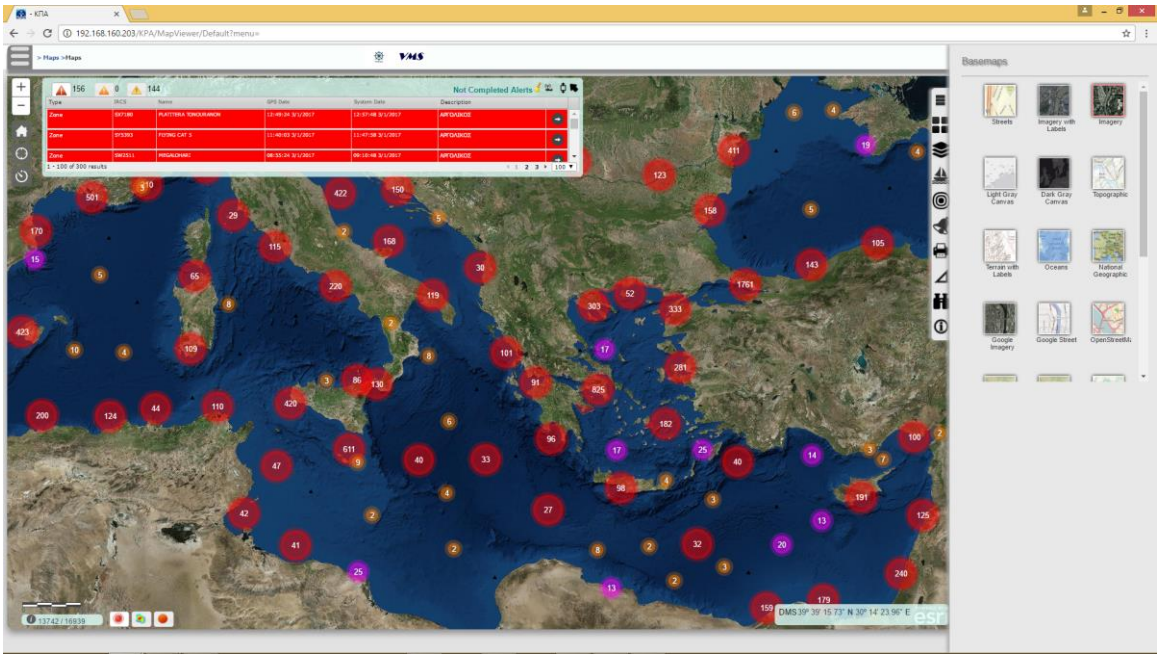

Figure 3: Imagery Basemap View

- **Real Time Vessel Position Tracking**

A major Observer service is the ability to combine information from a range of different data sources and create the “Combined Operational Picture”.

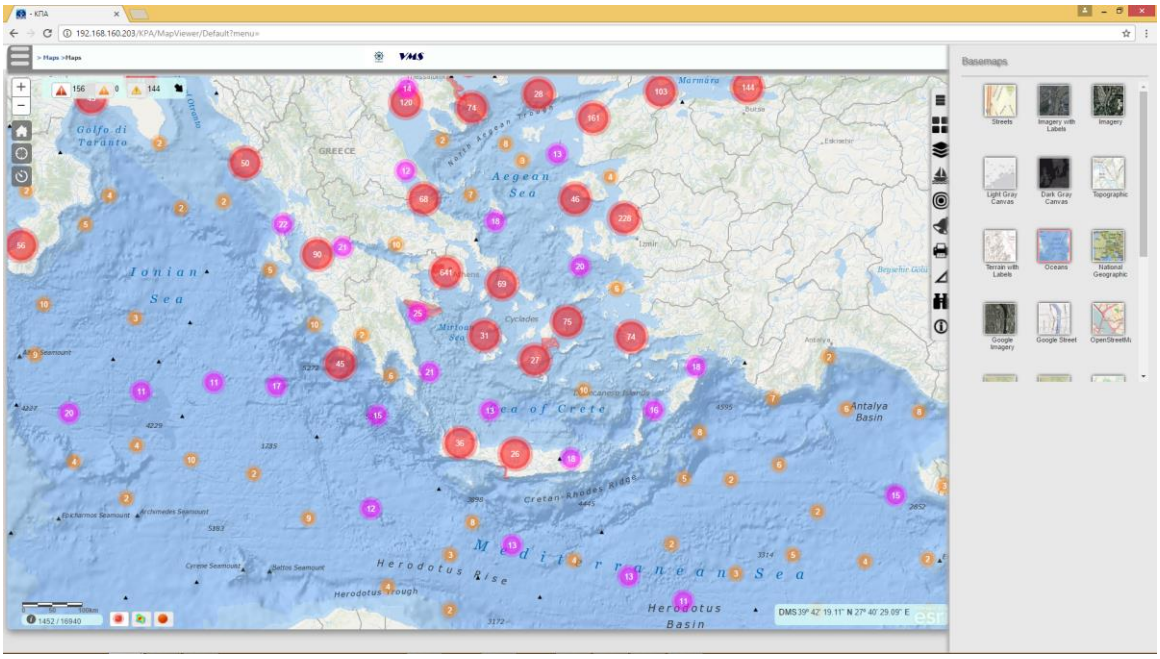

Figure 4: High Levels of Detail View Using Clustering Option

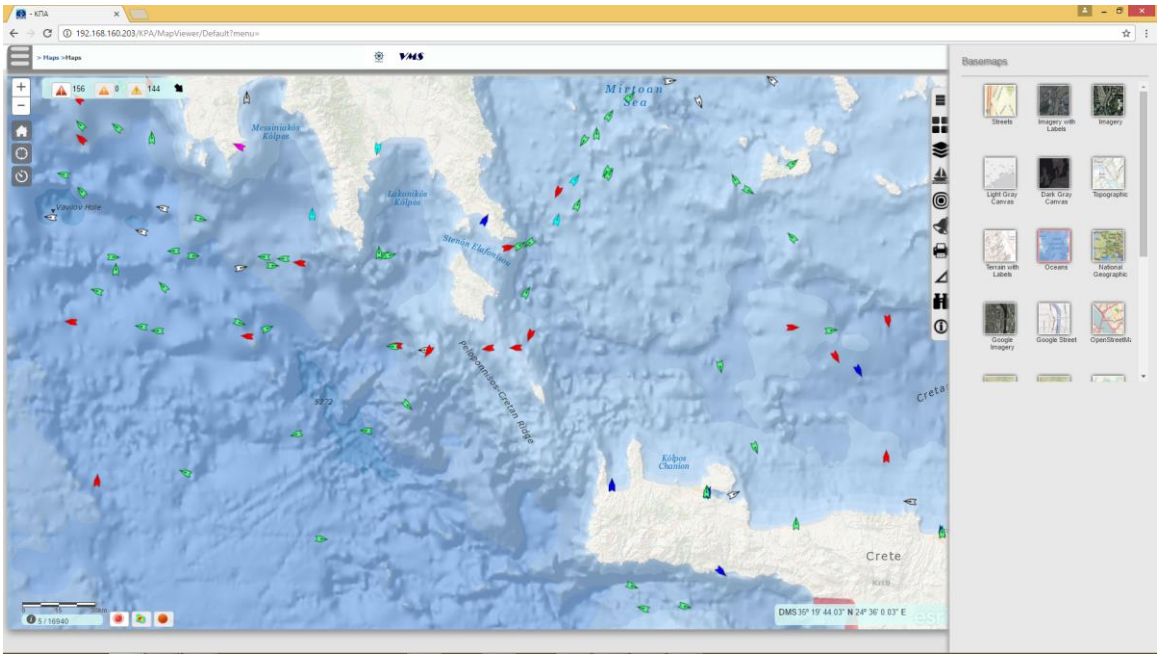

Figure 5: Vessel position tracking

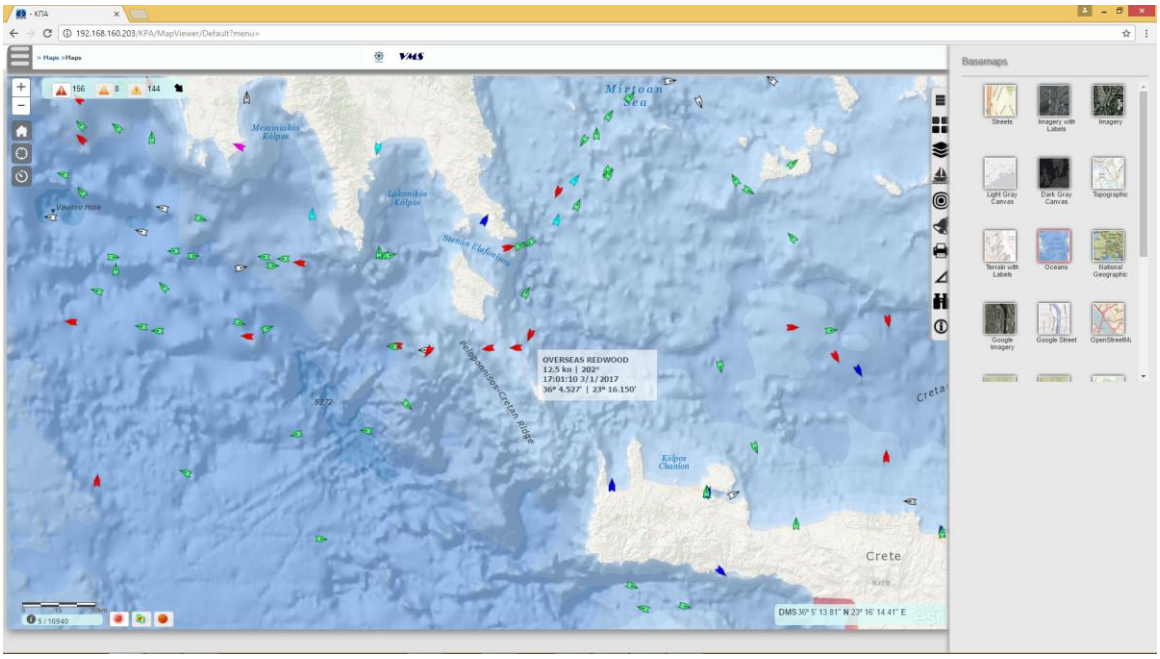

Figure 6: Tooltip Support

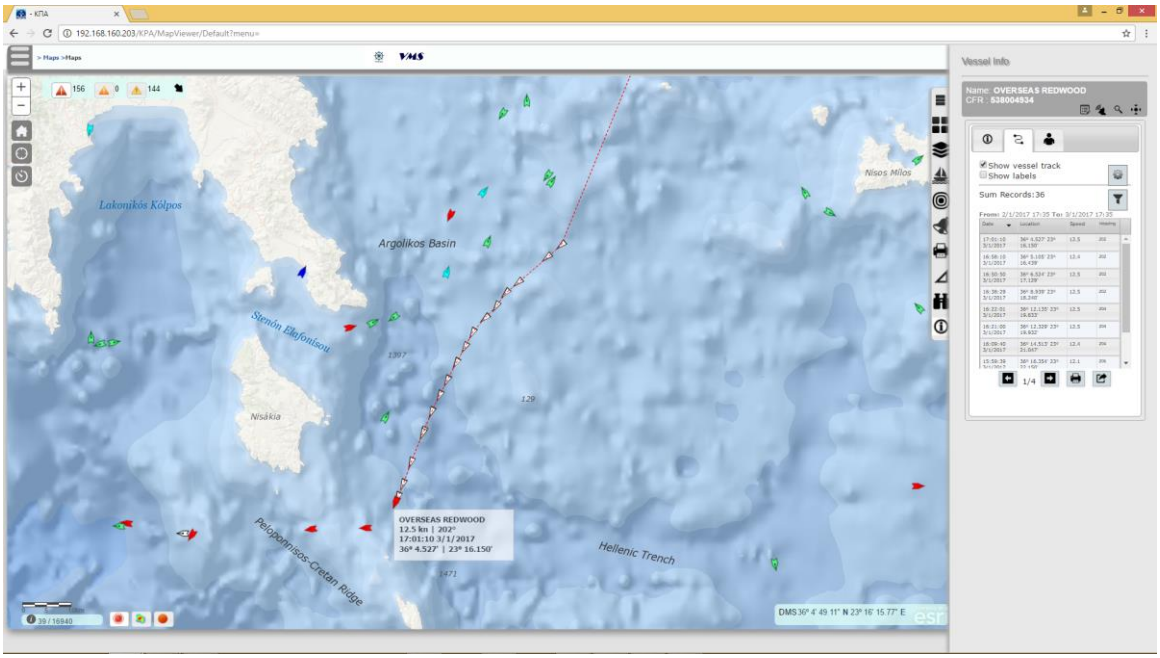

Figure 7: Vessel Trail History

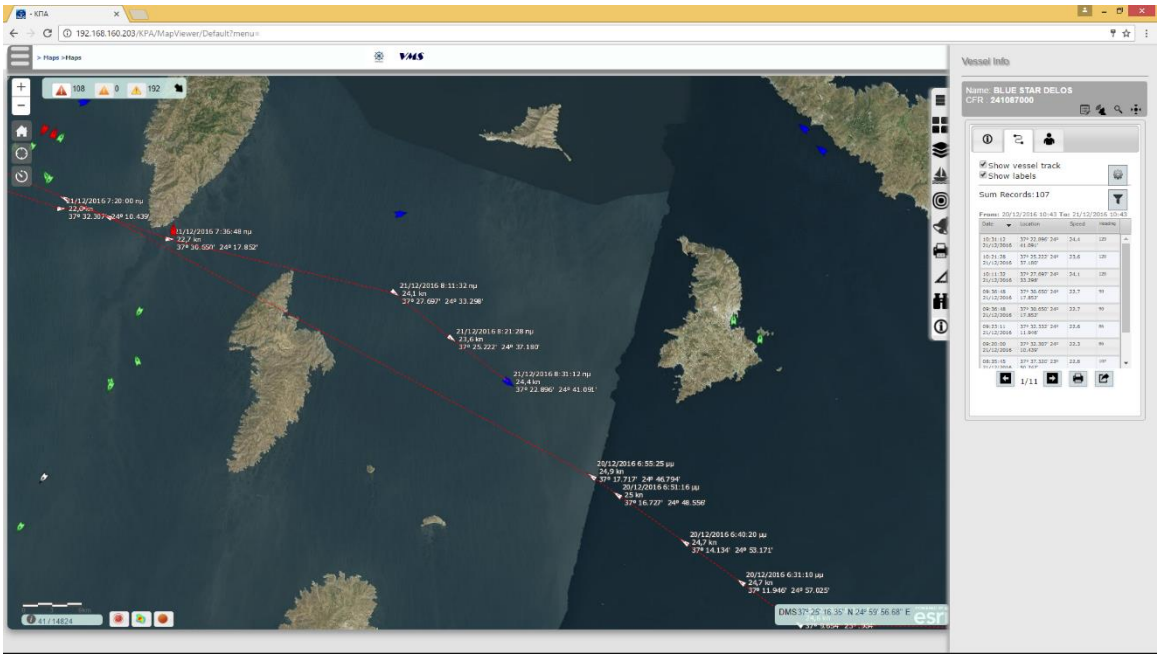

Figure 8: Vessel Trail History with Details of Positioning Data

- **Surveillance Areas Management**

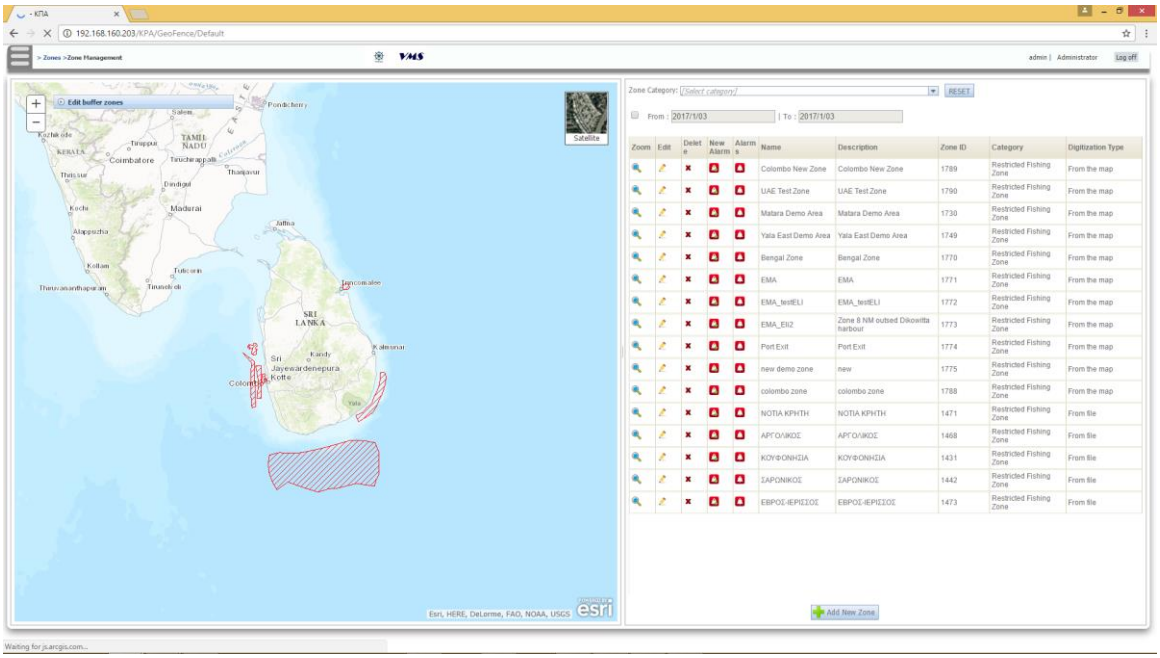

Figure 9: List of Surveillance Areas

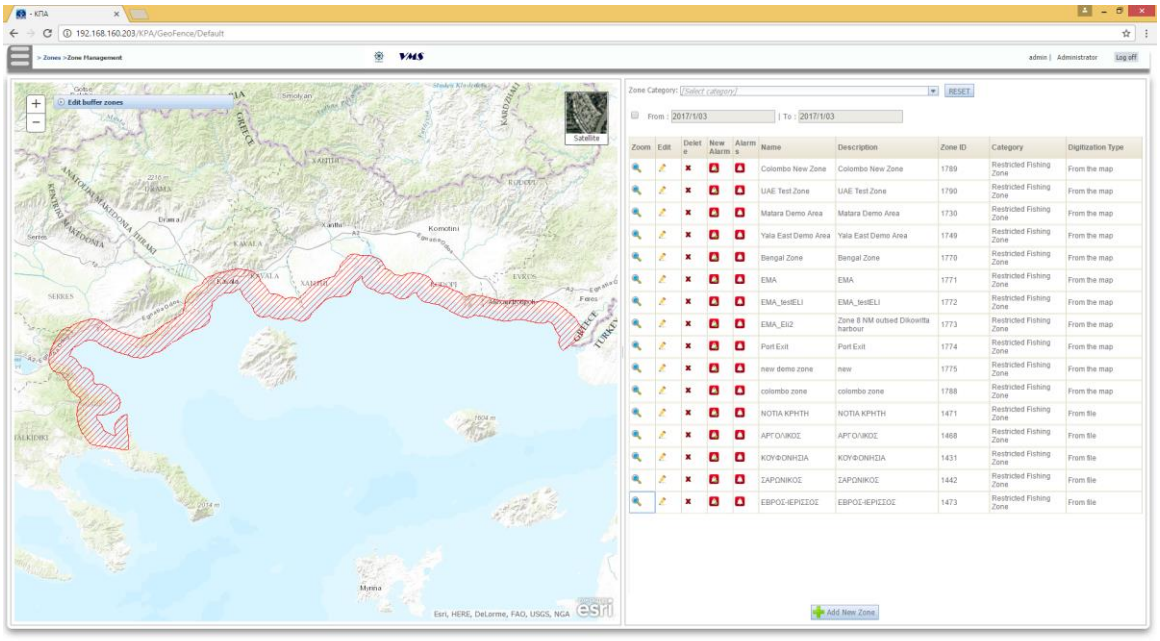

Figure 10: Surveillance Areas Preview and Processing Options

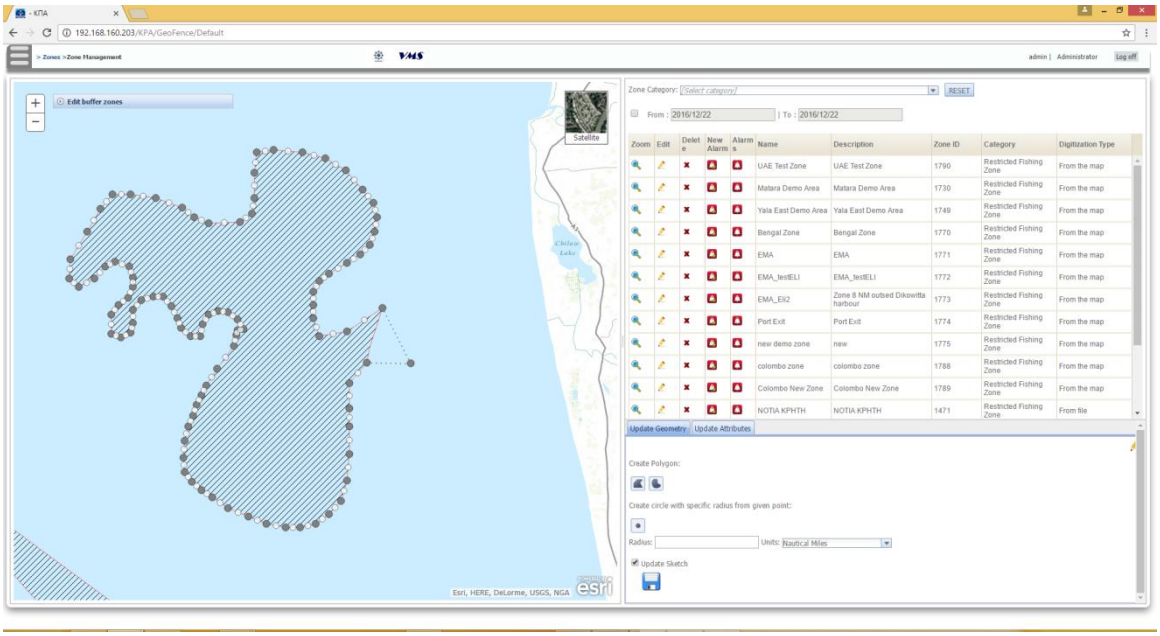

Figure 11: A Surveillance Area in Edit Mode

- **Situational Awareness Alerts**

Situational Awareness refers to the ability of understanding the importance of an event, concerning various factors. Observer produces events, each time a vessel enters, leaves or passes a surveillance area (or a restricted zone). The application can match these events with vessel activity (such as type of vessel, vessel velocity and more) and various factors such as time period, in order to identify if this vessel activity should generate an Alert.

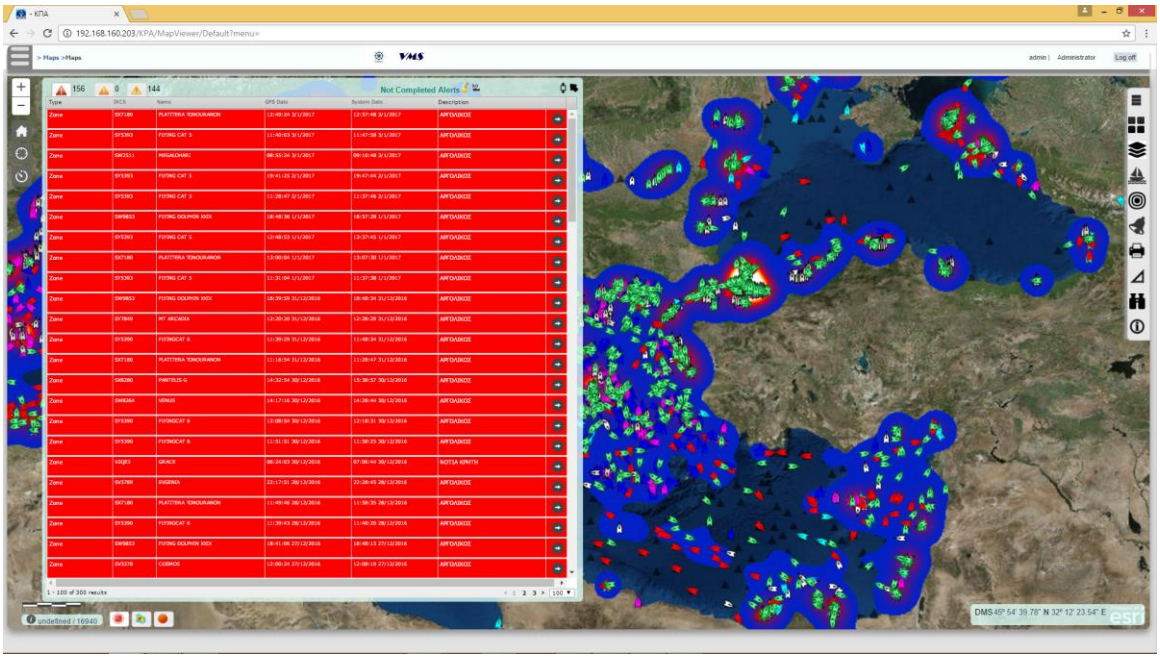

Figure 12: A List of Alerts

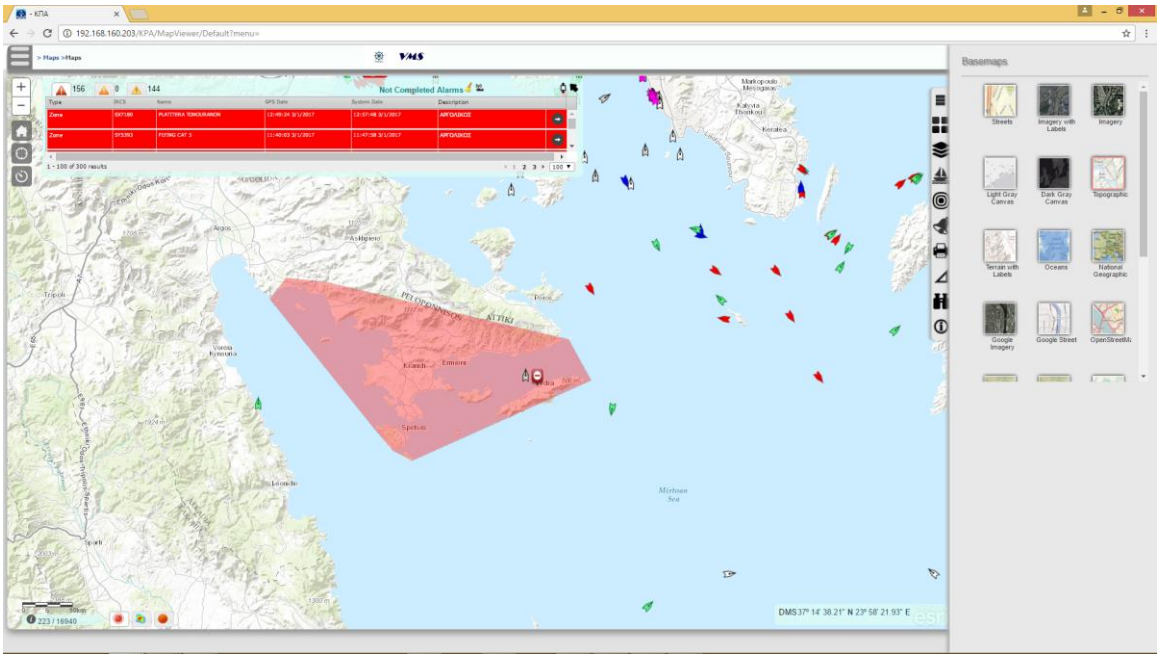

Figure 13: Identify an Alert on Basemap

- **Vessels Registry**

Observer collects all received and calculated data for every vessel and stores them in vessels registry. Vessels Registry consists of the following sections:

○ Vessel Information Data

Vessel Information Data section provides detailed information about every vessel.

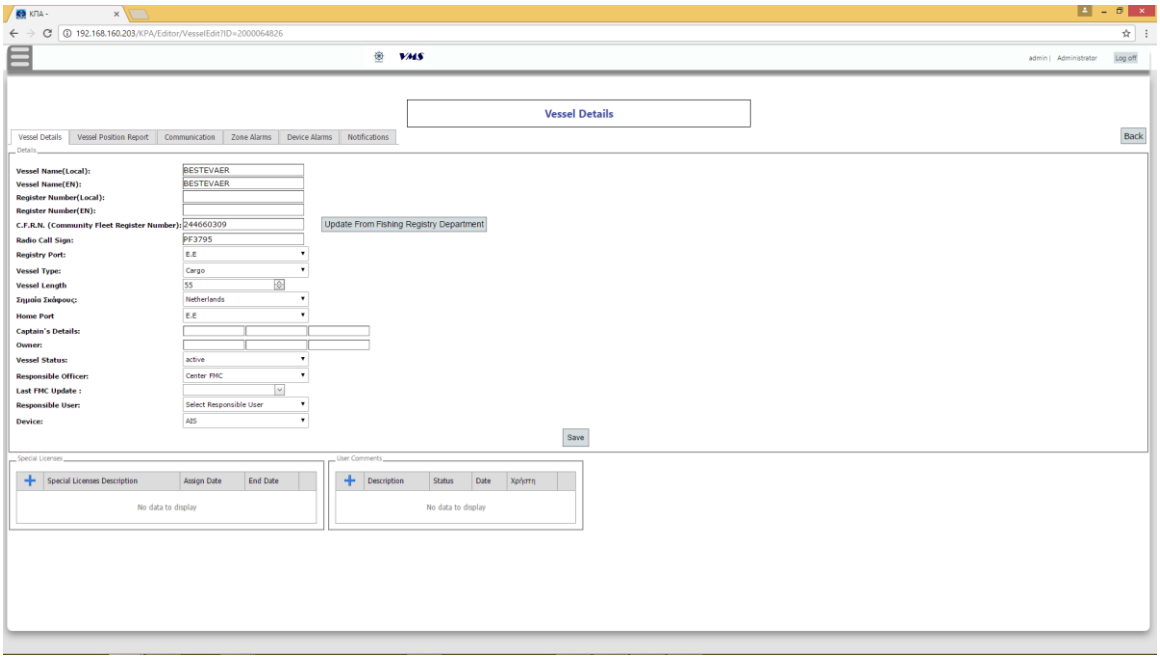

Figure 14: Detailed Information about a Vessel

○ Monitoring Services

Monitoring Services section provides vessels the tools to schedule positions to gateway, based on the desired frequency. Polling service included, offers the functionality of proactive status tracking for any vessel, in any time.

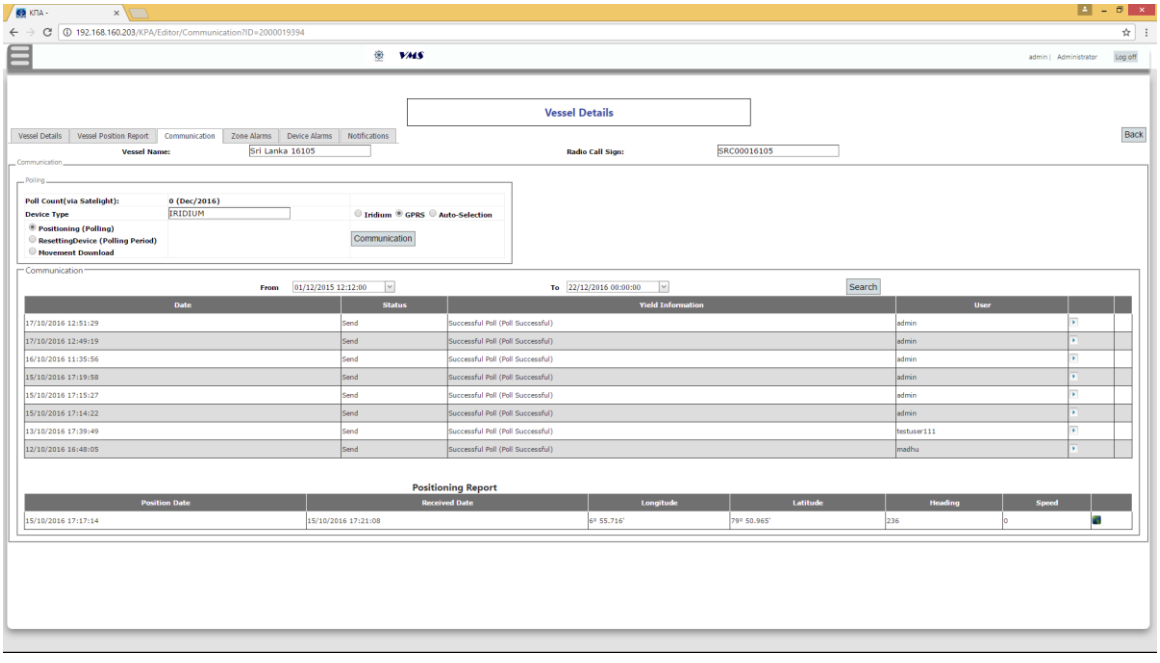

Figure 15: Monitoring Services

- ## Position Report

Position Report section lists all vessels' available positions, ordered by position date. User can locate any position on basemap, following the provided link for a selected position in the list.

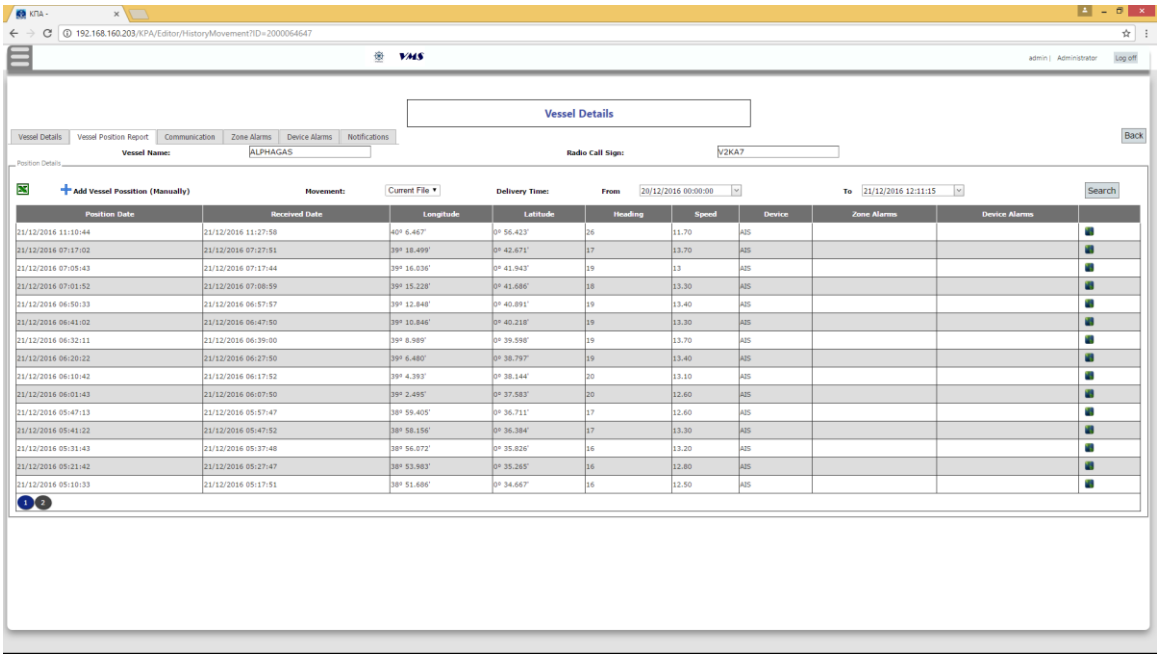

Figure 16: Position Report

- ## Zone Alerts

Zone Alerts section presents a vessel's Zone Alerts.

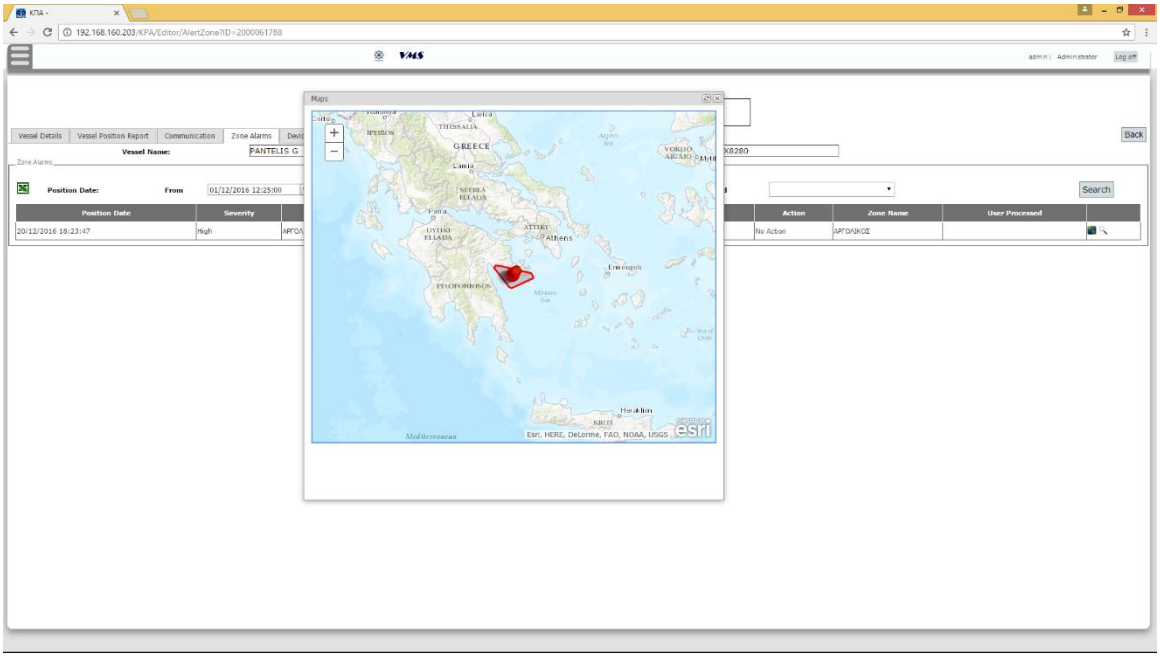

Figure 17: A Vessel's Zone Alerts

- ### Device Alarms

Device Alarms section presents a vessel's Device Alarms.

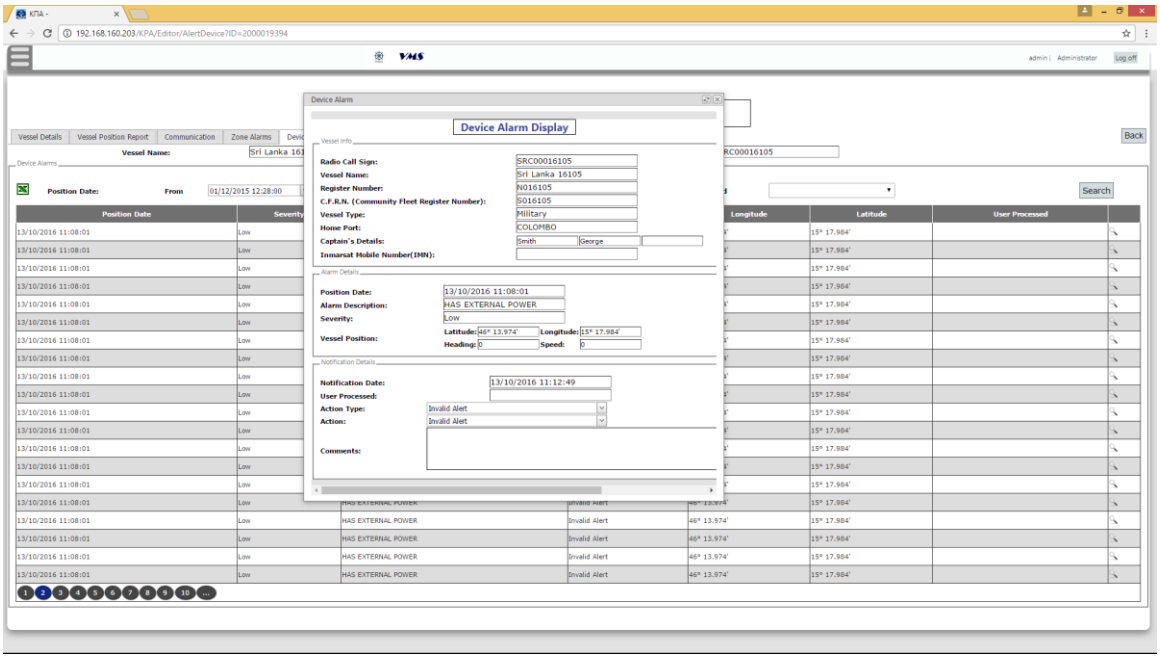

Figure 18: A Vessel's Device Alarms

- ### Device Alarm Management

In conjunction with a vessel transporter, application can provide the appropriate alert configuration.

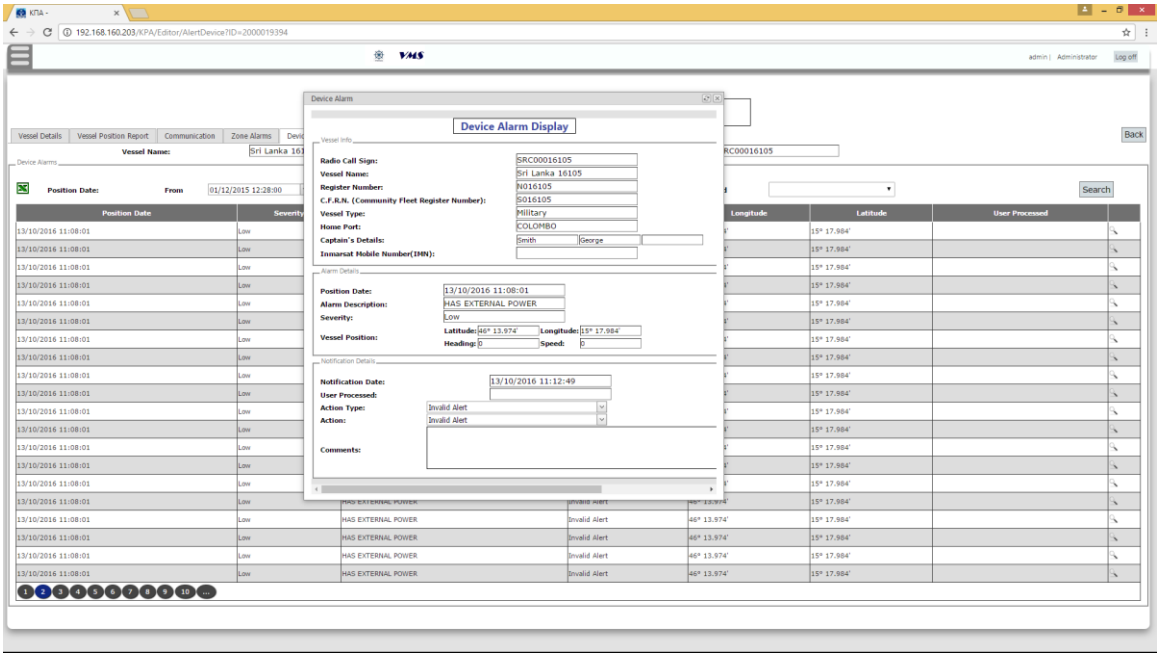

Figure 19: Device Alarm Management

- **Alerts Processing**

Observer supports device alarms and zone alerts processing, providing all the necessary user actions for an alert status to be “Completed”.

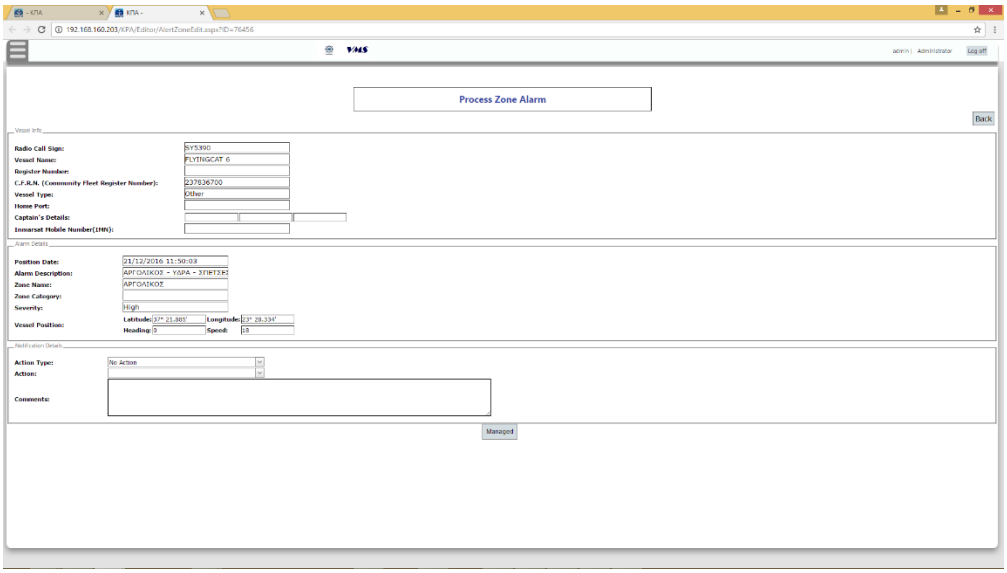

Figure 20: Device Alarm Management

- **Reporting**

The system provides a variety of reports and logs, including a large amount of statistical information, to help users optimize their work and effectively organize organization’s processes. A few examples of reports and logs are “Stay time in Zone” (the time that a vessel stayed inside a zone, calculated in minutes), “Vessel position report” (all vessels positions’ history), “Alarm Zones for Vessels” (zone alarms per vessel), “Managed Alarms” (alarms processed), “Users Time Connection” and many more. All reports include various filters, which users can apply, to limit the data accordingly. All reports (filtered or unfiltered) can be exported to Excel files.

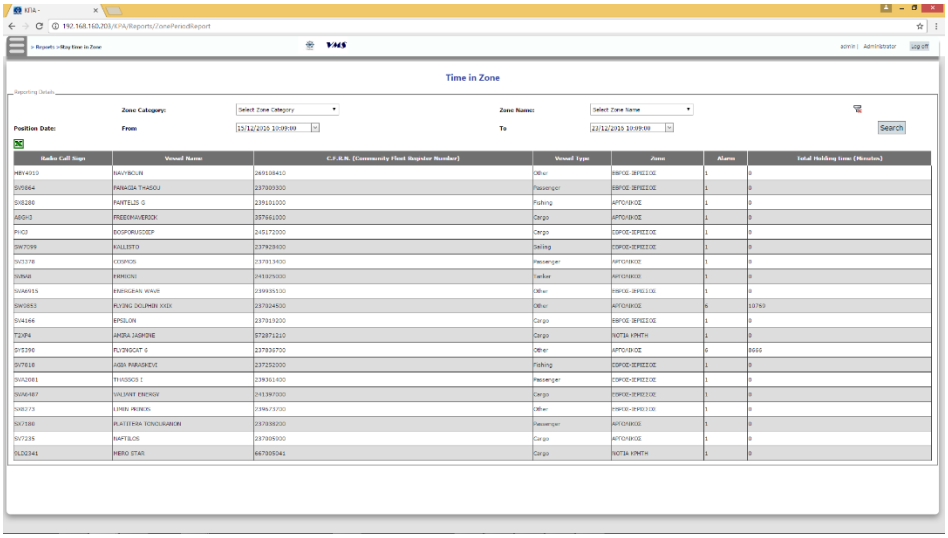

Figure 21: Example of Report

All the main features of Observer are summarized below:

- Provides the ability to combine information from a range of different data sources (vessel devices, sensors, AIS, e.tc.)
- Manages all vessels' data
- Executes POLLs on demand, directed to a specific vessel or to Group of Vessels
- Executes POLLs Commands, if Poll Settings are automated in timely fashion
- Creates and edits custom Geofence restricted zones
- Creates and manages custom alerts per restricted zone, depending on time period, vessel type, vessel speed
- Sets and manages Device Alarms
- Provides design capabilities and geographic information management
- Provides GIS tools to perform spatial analysis, such as determining shortest distance from vessel to coastline, select vessel with spatial conditions (buffer, area e.tc.).
- Allows acquiring coordinates location on map, using different coordinate systems
- Allows interfacing with other authorities/agencies/organizations
- Provides the ability to create the "Combined Operational Picture" which consists of:
    - Basemaps and cartographic layers
    - Each vessel's last available position
    - Monitored vessels' archive positions, during certain time periods
    - Restricted areas
    - Alarms and alerts
- Provides rich reporting functionality, regarding vessels' current and historical positions, alarms triggered for each vessel, poll communication to various vessels and many more
- Provides central management
- Supports multiple users, assigned with different roles

System Architecture and Components

Observer's architecture is based on the principles of N-tier software architecture, allowing the creation of separate logical levels. It consists of four distinct tiers, each of which performs a certain role. Specifically, architecture consists of the following tiers:

Communication Tier

All processes that concern collecting, parsing and effectively processing vessel information data, are supported by Gateway module. Providing services have been implemented, for interoperation with various external sources of data, using various communication methods.

Gateway acts interactively. It acts as a receiver, parsing and assorting incoming data, depending on their data source. It also acts as a dispatcher for the outgoing data, which may need to be sent to another data source.

In conclusion, Gateway services grants the Observer VMS with the ability to combine information from a range of different data sources, and as such significantly enrich the **"Combined Operational Picture"**.

Observer VMS supports integration (via Gateway) with the following data sources:

- **Vessel Tracking Devices:** Tracking devices provide telematic data, through satellite networks (either Iridium or Inmarsat) and GSM/GPRS networks as well.
- **Automatic Identification System:** AIS transmitter broadcasts information about the vessels.
- **Radar (land or sea-based) and sea-based Sonar systems:** These sensors are useful to detect vessels at sea. They do not require a cooperative signal from the vessel and can penetrate clouds. When used in combination with AIS data streams, it is possible to identify vessels which should have been broadcasting an AIS signal, as is required by law, but for some reason, they haven't.

The integration between Gateway and sensors like Radars or Sonars, grants Observer with additional surveillance methods described as below:

- Determine the number of vessels and their positions in a given area
- Cross-check vessels' positions detected by VDS, with position reports from VMS
- Signal possible presence of vessels, from which no position reports have been received through VMS

Sensors may detect vessels, but they cannot identify them. For this reason, Observer VMS supports surveillance methods, to match detection data (data coming through sensors) with VMS position data, using proximity methods.

Data Tier

All data, spatial and non-spatial are organized into the implemented geodatabase, in data tier. Geodatabase uses Oracle RDBMS and acts as the physical store for geographic information. It also provides common application logic, used throughout application tier, for accessing all geographic data and work with them in a variety of files and formats.
Observer's geodatabase has a comprehensive data model for representing and managing geographic information. This inclusive data model consists of a series of tables, holding feature classes, raster datasets, and attributes. In addition, advanced GIS data objects add GIS behavior rules for managing spatial integrity and tools for working with numerous spatial relationships of the core features, rasters, and attributes.

Application Tier

Application tier implements and provides all the features, which compose the business layer of Observer VMS.

- **Map Server Module:** ArcGIS for Server (ESRI) and ArcGIS GeoEvent Extension carry out the enhanced management of spatial data. ArcGIS for Server manages geographic information, allows sharing of geographic information collections and also displays maps or other geographic information within the web application. In addition ArcGIS for server not only provides access to particular GIS resources, but also grants access to GIS functionality, such as managing basemaps, displaying map layers, creating and managing areas, measuring distances and areas and many other operations.
- **Web Application:** Web Application combines spatial and non-spatial functionality, which is described in details in chapter "Basic Features and Main Functionality of Observer". Microsoft .net Framework, ArcGIS API, HTML and Javascript are technologies that have been used to implement web application's functionality.

Presentation Tier

Presentation Tier offers end users access to the web application, from anywhere in the world, using a web browser. Web Servers, which are presentation tier's main components, act as proxy servers, to increase the security of the internal network.

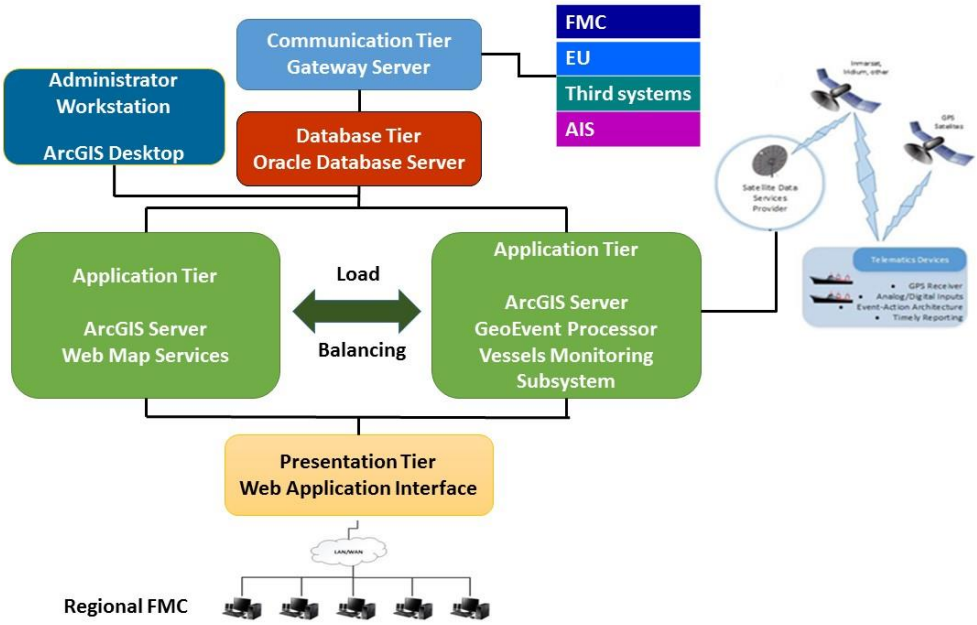

Figure 22: Cosmos's VMS architecture

System Installation

Observer is built over cutting-edge technologies which ensure high availability, scalability, reliability and robust performance of the system.

The system takes full advantage of virtualization software capabilities, to ensure virtual servers, provided by a number of implemented physical servers still keep the same architecture. Virtual servers also have shared infrastructure capabilities in terms of storage, to ensure the availability of stored data.

Additionally, failover configuration can be implemented by placing two or more virtual servers on each architecture level, ensuring high availability, as well as load balancing capabilities.

The VMS solution can be hosted either on authority or organization premises, or in a data center, thus providing the implemented functionality under the model Software-as-a Service (SaaS).

Data management and visualization

As already mentioned, Gateway module implements providing services, in order to interoperate with different external sources of data, using various communications methods.

Gateway executes all procedures concerning vessels information data' collecting, parsing and processing. A generic communication module has been implemented, for reading incoming data and identifying their source, at the same time.

Initially, Gateway parses incoming data and then assorts them depending on the data source. Then Gateway saves data as "Primary Data", into the appropriate structure of geodatabase.

Position elements is the most important information regarding vessels' incoming data. Gateway can identify vessel activity and apply rules depending on vessel position, velocity and sea areas (geozones), marked as "Restricted Zones", at the same time. To be more specific, Gateway runs spatial queries, comparing the boundaries of every geozone with a vessel position, to decide whether the vessel is inside or outside a particular restricted zone. By applying the velocity rule, Gateway can automatically determine the activity of each vessel.

The above procedure also produces "Secondary Data" such as alarms when a vessel enters, leaves or passes a restricted area. Gateway also stores the generated secondary data into the database and fires appropriate events in order to visualize this information into user's screen.

The final step includes all procedures which are involved within data visualization. Web application handles all the necessary events and actions to create the Observer's **"Combined Operational Picture"**.

Figure 23, shows the process for collecting, parsing and processing vessels information data.

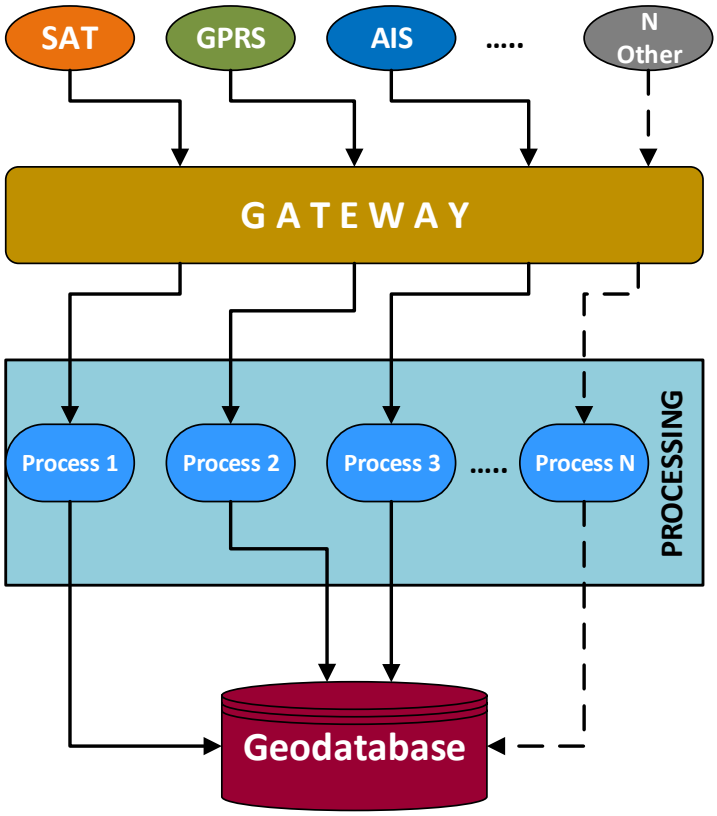

Figure 23: Collecting, parsing and processing vessel information data

Methodologies for real-time management and visualization of data

Observer parses all the necessary information data, using every available communication channel, stores the data into the geodatabase schema, then processes them to determine vessel activity and finally visualizes current data and implemented functionality to create the “Combined Operational Picture”.

The production of “Combined Operational Picture” in real time, is the top priority for Observer VMS.

Since the above functionality must be provided in real time, cutting-edge technologies have been used to satisfy this requirement.

Data Parsing & Data Processing Procedures

Advanced technologies such as “In-memory computing” and “Parallel Programming” have been used in data parsing and data processing procedures, to accomplish real time functionality, provided by Gateway.

To take advantage of the hardware, Observer parallelizes application code to distribute work across multiple processors. Using .NET framework’s parallel programming model, the data parsing and data processing execution flow is distributed in multiple asynchronous processes. This is executed at the same time (concurrently) by multiple cores or processors. Thus, Observer reduces the overall time needed to complete the above work, earning a remarkably better performance.

Due to the fact that stored data are accessed much more quickly, when placed in RAM rather than in complicated relational databases located in comparatively slow disk drives, “In-memory computing” technology has been adopted to accelerate the performance of data processing procedures.

Using “In-memory computing” and “Parallel Programming” philosophies, Gateway module succeeds in real-time manipulation of huge data sets.

Data Visualization

Monitoring vessels’ real-time positions and moving around the globe with ease and efficiency to track them down, is one of the most important views provided by Observer’s functionality.

As the total functionality of Observer application is provided through a web browser, we considered the inherent restrictions that all browsers have regarding their capacity to present thousands of graphics on a geographic basemap. Thus, a special ArcGIS Server functionality has been adopted, to overcome these restrictions and any browser can be able to display in real time a huge number of incoming positioning data.

Cluster Map, Heat Map and Simple Point Map options (available as ArcGIS Server features) are spatial analysis views, which offer different graphical representation of vessel positioning data, depending either on basemap scale or on user’s selection.

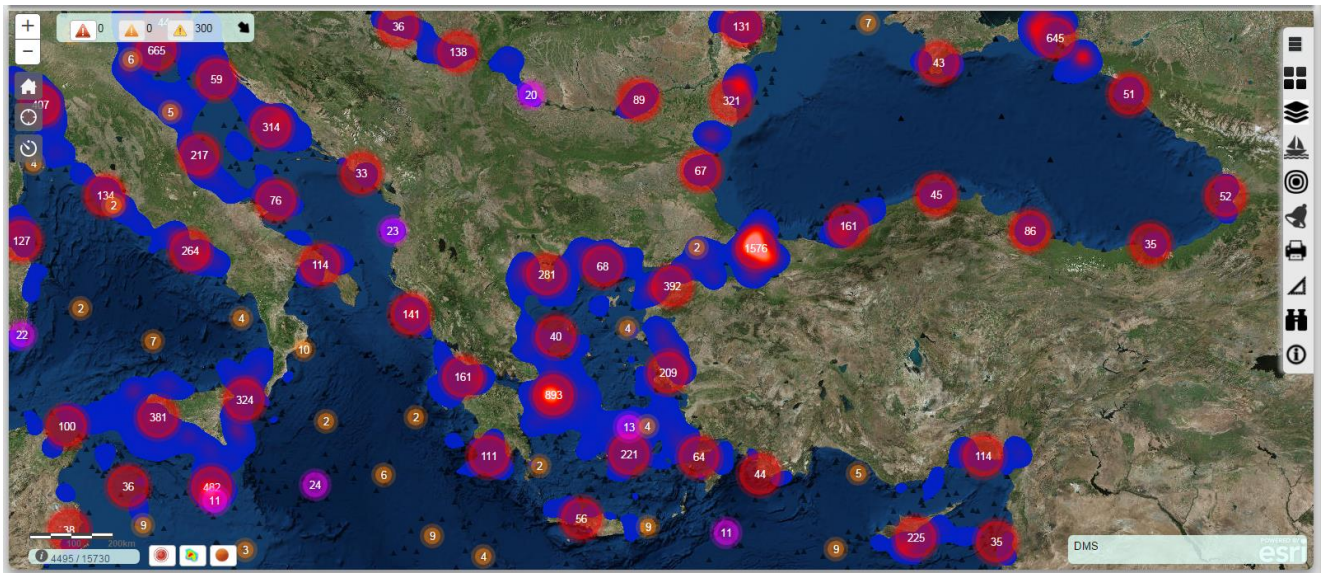

Figure 24: Indication of number of vessels and Cluster Map, Heat Map and Simple Point Map options

Cluster Map View

Cluster Map View is the most effective way to visualize large datasets, especially in cases that a significant amount of points are overlapped. Observer's Cluster Map View option, presents vessel positions in clusters, differentiated with color grading and size, depending on the number of vessels gathered under each cluster.

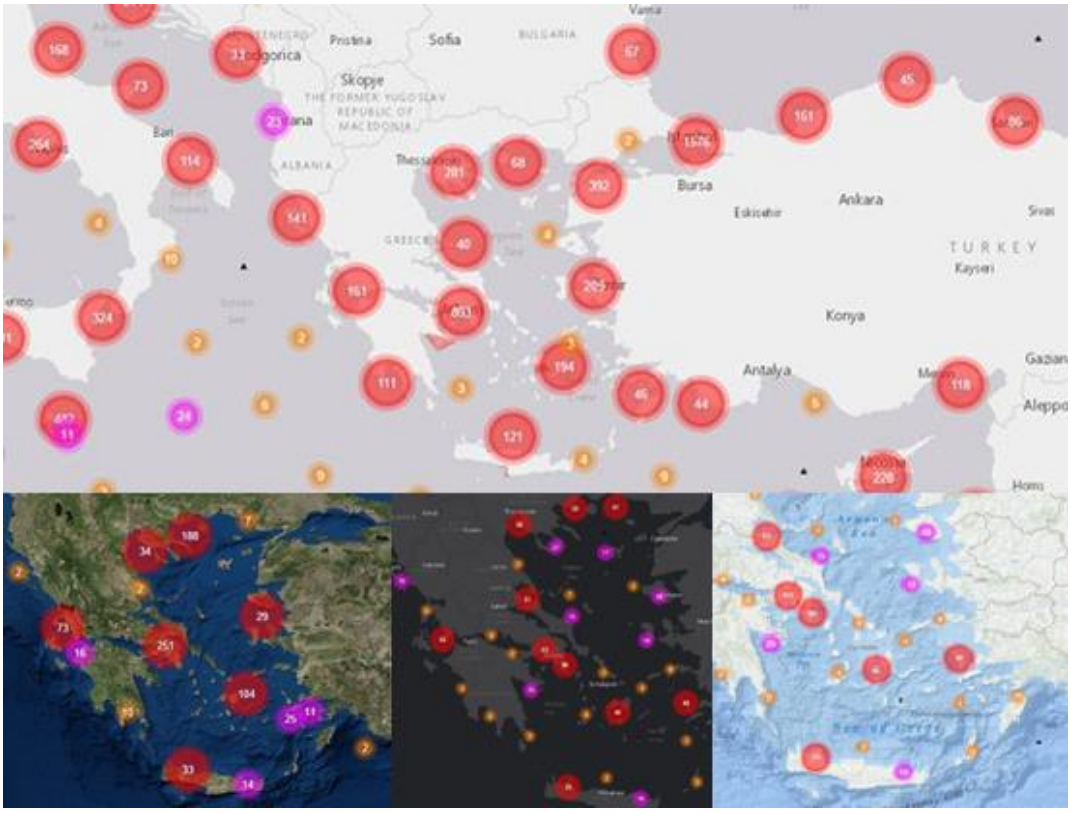

Figure 25: Cluster Map View in different Scales and Basemaps

Heat Map View

The heat map view, shows the geographic density of vessels, using gradient colors to represent a high concentration of vessel positions within a map extent.

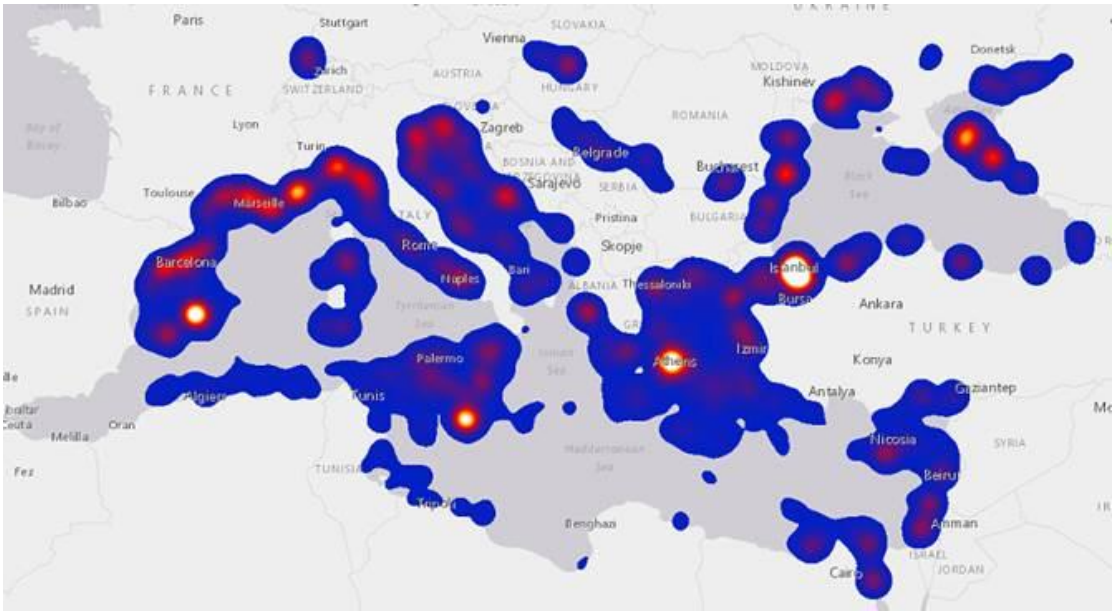

Figure 26: Heat Map View provides an immediate visual summary of information

Simple Point Map

"Simple Point Map" View presents vessel positioning, using a simple point symbol. This option enables the presentation of all points as a dynamic image map, providing fast view of all available points.

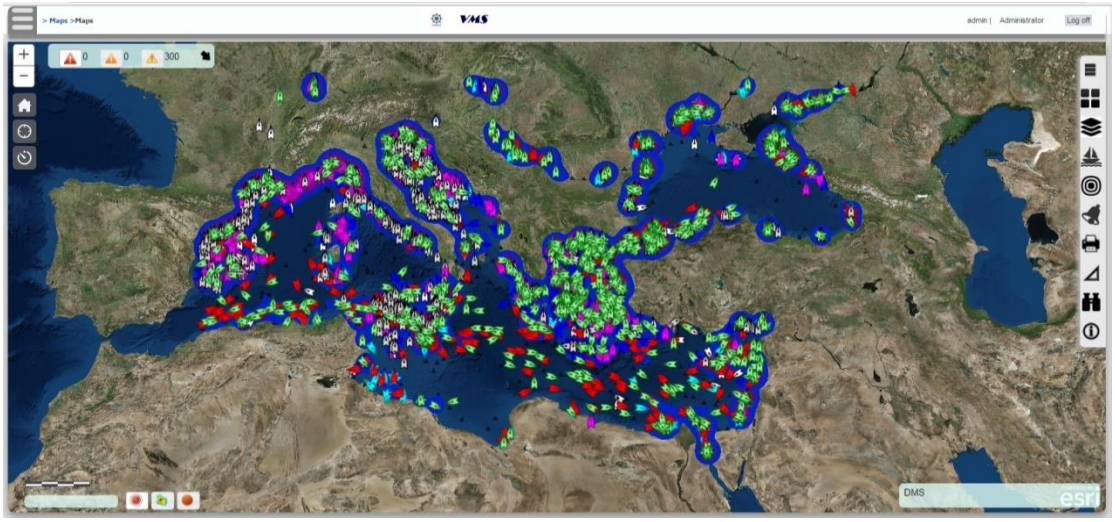

Figure 27: Heat Map View presents the information in simple point symbol

Combining Cluster Map, Heat Map and Simple Point Map options

Observer allows simultaneous combination of all three options (Cluster Map, Heat Map and Simple Point Map) which provides the user with the capability of acquiring combined information in one single view.

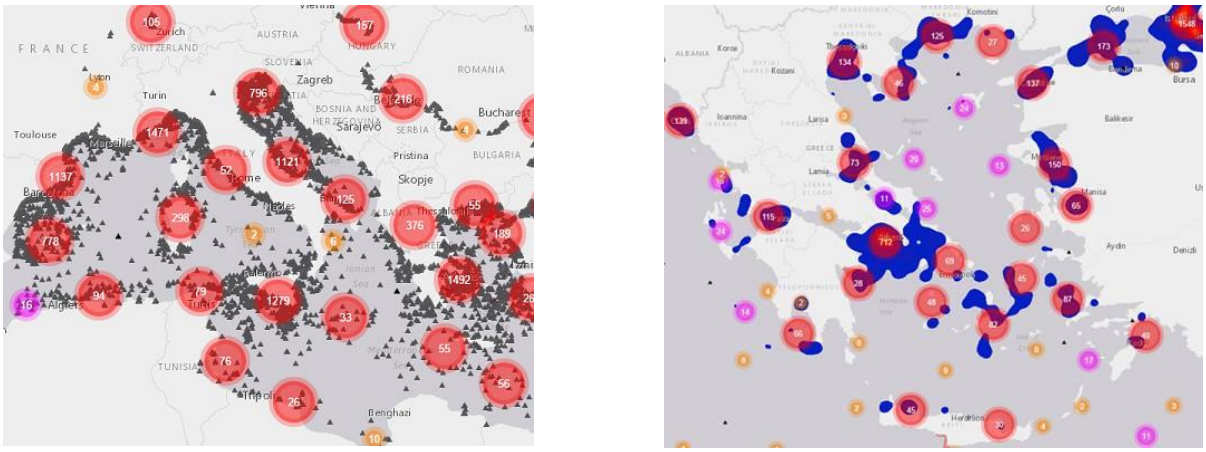

Figure 28: Combination of Cluster Map, Heat Map, Simple Point Map options

Main Advantages of Sea Observer over the competition

Sea Observer is one of the latest systems in EU level. It offers particular advantages over other similar solutions, with the most important of them presented in the following paragraphs:

- The whole solution can be implemented either on authority or organization premises, or to be provided as a service following the wide spread Software-As-A-Service (SaaS) model.
- Provides the ability to combine information from a range of various data sources such as vessel devices, sensors, AIS, services etc.).
- Thanks to its structure and architecture, supports the capability to monitor and manage thousands of vessels, in real time.
- The whole solution is implemented with open architecture standards and policies, allowing any customization according to the Client's Business Requirements.
- The system is enhanced with ESRI technology (ArcGIS) providing an integrated GIS platform for smarter decision making and uses ArcGIS technology in any level in order to expand the system with GIS functionality.
- The system can use any basemap including ESRI basemaps, Nautical Charts, Online Community and other GIS resources and also Organization's specific GIS data.
- Rich GIS tools functionality including:
  - Spatial criteria for Vessel search
  - Tools for Printing Maps through Web GIS environment
  - Generation of history reports with spatial criteria
  - Use of measure tools on the map (length, area, measure with circle)
  - Find closest position from vessel to coastline or to other geometry
  - Show and find position in DMS, DM, DD format
- Provides strong alerting mechanism with advanced spatial conditions.
- Restricted areas can be defined from the end user, using Web GIS interface or using ArcGIS for Desktop. New alerts, having other spatial conditions (e.g. vessel is 40 miles away from Home port) can be created and enabled.
- Complies with all open interoperability standards, both in the GIS field and in the wider field of information technology.
- Sea Observer is designed to exchange data with other systems, using well defined standards.

Case Study

Sea Observer implementation for the needs of Fishing Monitoring Center in Greece

Introduction

The Common Fisheries Policy (CFP) establishes a Union system for the conservation and sustainable exploitation of fisheries resources. The CFP is guided by principles of good governance, including decision-making, based on the best scientific advice available [1]. Scientific advice depends on the availability of having relevant, accurate and up-to-date data.

Scientific fisheries data are currently collected under the Data Collection Framework (DCF)[2], whereby they are collected by the competent national bodies. Then data are processed and stored in national databases and transmitted to the Commission and other Member States if needed, as well as to other bodies which have research or management interest, in the scientific analysis of data in the fisheries sector.

In this context, Greek Ministry of Maritime and Islands Policy for the needs of Greek National Fishing Monitoring Center carried out an open, international bidding procedure, aiming at the implementation of a Vessel Monitoring System (VMS) in line with European Union (EU) regulations.

Cosmos Business Systems awarded the contract among five Consortiums which participated in the bidding procedure and implemented its VMS solution- Sea Observer- in Greek Ministry of Maritime and Islands Policy, for the needs of Greek National Fishing Monitoring Center, so as the Ministry to comply with European Commission's Common Fisheries Policy (CFP) and obligations arising from it.

Sea Observer implementation

Sea Observer implementation for the needs of Hellenic National Fishing Monitoring Center is an integrated Information System, designed and developed to monitor Greek vessels' fishing activity, as well as fishing activity of vessels, while operating within Greek National Waters.

The whole solution in terms of monitoring the fishing activities, fully complies with EU regulations and its amendments (European Council regulation # 1234/2009, Commission implementation regulation (EU) # 404/2011), ensuring the effective communication and data exchange with all the EU member states which apply the above regulations, as well as all international organizations which exchange data with EU member states.

[1] Council Regulation n° 1380/2013 of the European Parliament and of the Council on the Common Fisheries Policy, amending Regulations (EC) n° 1954/2003 and (EC) n° 1224/2009 and repealing Council Regulation (EC) n° 2371/2002 and (EC) n° 639/2004 and Council Decision 2004/585/EC.

[2] Council Regulation 199/2008 concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy and Commission Regulation 665/2008 laying down detailed rules for the application of Council Regulation 199/2008.

The total budget of the project raised approximately to 800,000 € excluding VAT.

Currently, the system is in full operational mode under the administration of the Hellenic Coastguard and supports monitoring of fishing activities of more than one thousand (1000) vessels.

Implemented Architecture

The whole solution is hosted on premises of Greek Ministry of Maritime and Islands Policy and consists of:

- Hardware and System Software Infrastructure
- GIS Infrastructure
- Web GIS Solution

The following figure describes the implemented architecture for the needs of Greek FMC:

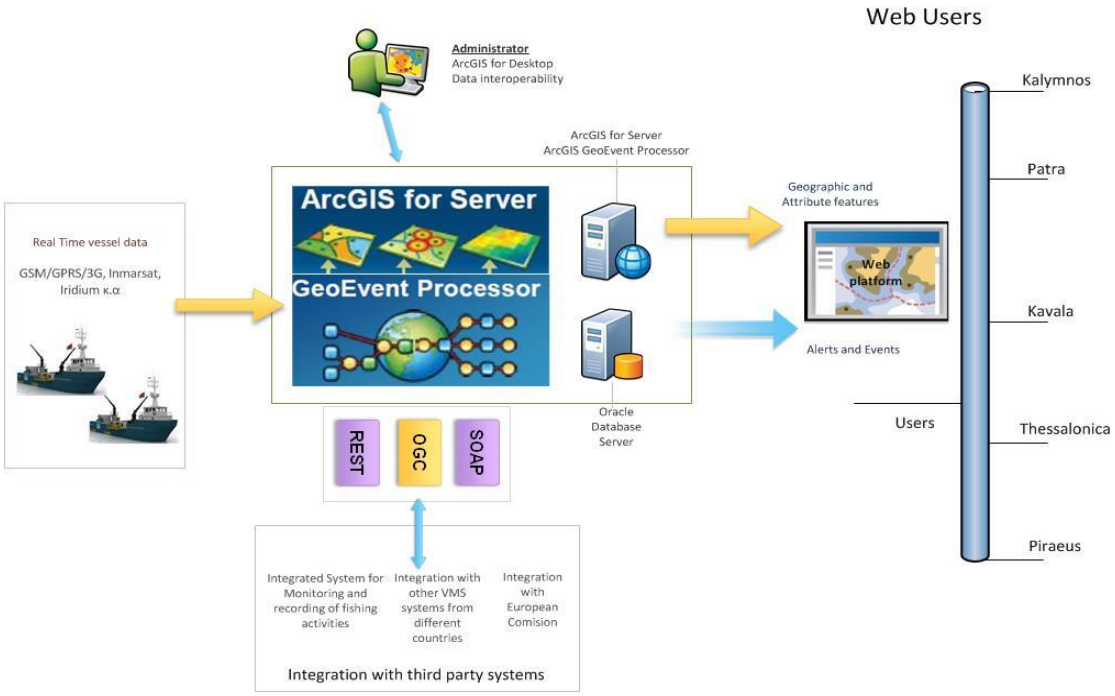

Figure 29: Description of Sea Observer Solution for the needs of Greek FMC

Communication Support

Sea Observer VMS receives vessel position data through both satellite (Iridium as well as Inmarsat C constellations) and GPRS communication, supporting already four (04) different hybrid VMS devices.

In addition, the system receives data originated from AIS stations, in order to support identification process.

Interoperability with other systems

Sea Observer is designed to exchange data, using well defined standards.

Sea Observer is one of the latest and few systems that exchange data with European Commission using FLUX Transport software. The FLUX Transport software consists of a set of components implementing the FLUX

Transport protocol, designed by European Commission and its Partners. This protocol implements business-independent transport of business messages, over simple SOAP Web Services. It operates over FLUX Nodes, which act as store and it forwards relays to transmit any business messages along over multiple-hop routes.

Additionally, Sea Observer supports interoperability between Greek and other EU FMCs, like Italy, Malta and Cyprus through HTTPS Post method for exchanging vessel position data of common interest.

Finally, Sea Observer transfers vessel position data to Hellenic Ministry of Rural Development and Food's information system (ERS), responsible for electronic monitoring and recording of fishing activities.

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