GEOSPAR PROJECT
VALIDATION AND SELECTION METHODS OF GEOINFORMATION ANALYSIS USING GIS FOR RANKING AND FORECASTING OF TERRORIST THREATS AND CRIMINAL EVENTS

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The paper presents the description of work activities which have already been done within the first two stages – WorkPackage 1 and WorkPackage 2 - of the GeoSPAR Project. In such a context the general conceptual design of the GIS system and associate web service was presented and analysed. In addition, the operational and technical requirements for the GeoSPAR system have been specified and discussed; with special emphasis on system applications, including both the detection and monitoring of hazardous events along with their simulation and possible outcomes. In particular, the requirements and specification with reference to various sensors and data sources were formulated, these include: airborne data sources, remote sensing satellite data sources and ground-based data sources.

INTRODUCTION

The main objective of the GeoSPAR project, as was stated in the Project Proposal and Contract was *validation and selection methods of geo-information analysis using GIS for ranking and forecasting of terrorist threats and criminal events* The GeoSPAR project was, in general, scheduled for a three year period, and the scope of the paper covers the first two stages of the project.

The first stage of the project WP1 constitutes *Specification of the project requirements along with the selection of useful geospatial information*, while the second stage WP2 consists of *Analysis of applied geo-information methods to localization and prediction of threats.*

In these two Work Packages, the following main tasks were carried out:

- Conceptual design of the system kernel which constitutes the GIS system and associate web service
- Specification of the system applications, including both the detection and monitoring of hazardous events along with their simulation and possible outcomes.
- Requirements and specification of airborne data sources – both airplanes and AUV.
- Remote sensing requirements, especially the Earth Observation (EO) satellite data sources, using SSE services and a satellite ground station.
- Requirements and specification of ground-based data sources – both from stationary sensors and from mobile agents.

1. WEB GIS SYSTEM

The GeoSPAR project assumes that the system kernel will consist of a web-based GIS system embedded in the network architecture of *web-service* technology. The block diagram of the web-GIS system architecture is presented in Fig. 1.

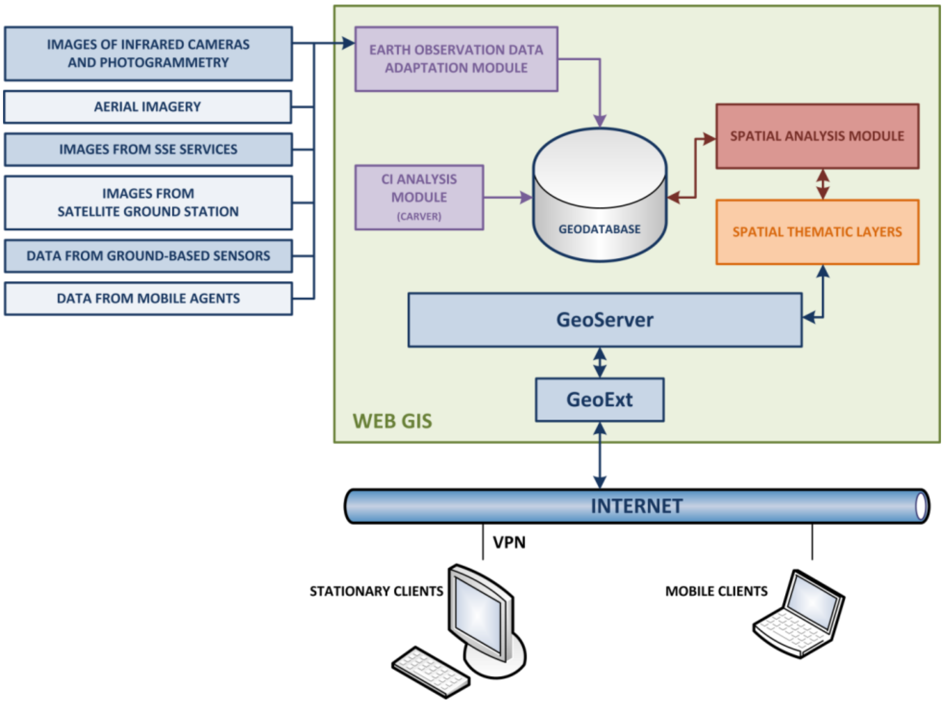

Fig.1. The architecture of the system.

The system consists of three main components, including the web GIS Server, the web GIS client, and a set of modules for spatial analysis and data management. The latter include an Earth Observation Data Adaptation Module, a CI Analysis Module, which delivers synthetic scores regarding the vulnerability of Critical Infrastructures, Spatial Analysis modules. Data from various airborne and ground-based sensors along with satellite images and SSE services, as well as simulations produced by the system, are stored in the GeoDatabase. The stored data is further processed by the Spatial Analysis Module. The resulting spatial data is disseminated to authorized users of the web GIS client in the form of Spatial Thematic Layers by the Geo Server.

EO Data Adaptation module will serve as a link between the system and ESA SSE platform. The module will enable the system to exchange data with selected SSE services by fulfilling the role of data adapter and request processor. It will receive requests from the Web GIS client, translate them into SSE queries, forward them to appropriate SSE services, receive the service responses and forward them to the web GIS server in an appropriate format.
The module will function in both ways: ensuring that the web GIS users may request data from selected SSE services, as well as send satellite data to be processed by specific services. In both cases the module will ensure appropriate processing of the services' responses.

Another functionality of the module will encompass adaptation and integration of data collected by the HRPT/MetOp satellite ground station. On user demand, the module will fetch newly collected satellite data directly from the ground station. The data will then be adapted to a standard GeoTIFF format, which will enable it to be either registered in the system geodatabase, or included in a request to an SSE service.

GeoDatabase module implementation is based on a relational model extended by spatial data types. It allows the analysis of data already on the database level. Vector data from various sources can be combined together by many queries and view types using spatial operators, i.e. correlating CARVER analysis results with the existing buildings list. Raster data is stored in a file system. This data is delivered by the GeoServer and sent via WMS to the client.

The Spatial Analysis module will perform several spatial processing and analysis functions operating on spatial data; in particular, the one pertaining to Critical Infrastructure information. The sample possible analysis tasks include both basic geoprocessing as well as advanced spatial analysis. The first tools can prove to be a useful aid in analysis of urban areas in relation to spatial distribution of Critical Infrastructures. The second ones operate on both vector and raster data as their input or output. An example may be the creation of a thematic (raster) layer with the value of each point (pixel) defined as the local density of critical infrastructure objects, calculated as the total number of critical objects of a specified type (weighted by its score or not). The result can be presented in the form of a layer overlaid on the source data. Another example could be the interpolation of vector point data, obtained previously as a result of a given spatial processing or analysis.

The CARVER2™ module is a tool for comparing dissimilar types of critical infrastructure using the same standards. CARVER evolves from Criticality, Accessibility, Recoverability, Vulnerability, Espyability and Redundancy. It is designed for quick and easy identification and comparison of potential terrorist targets at the local, state, and national levels in order to assist government officials in the allocation of protective resources.
The synthetic score calculated by the CARVER2™ module reflects the total value of all data inputs, and gives a numerical basis for making infrastructure comparisons. The CARVER2 scores may form a basis for prediction of threat scenarios, planning of response and mitigation as well as minimising the outcomes of a threat. Fig. 2 contains a sample application of the CARVER2 algorithm to a Critical Infrastructure vulnerability assessment.

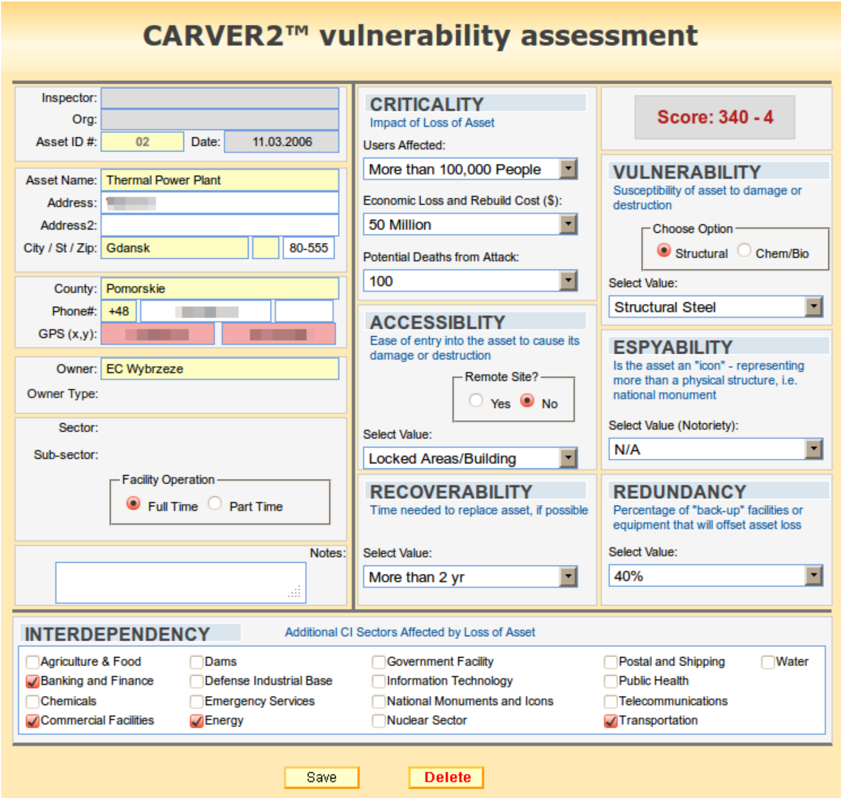

Fig.2. Sample application of the CARVER2 algorithm to a vulnerability assessment.

<u>A Web GIS Server</u> will be responsible for providing the authorized web GIS client users with layers of Critical Infrastructure spatial data, background data, analysis results and other contents of the GeoDatabase. It will be implemented with the use of GeoServer, a dynamically developing Open Source JEE servlet-based GIS server. GeoServer fully supports OGC standards of geographic data exchange; such as Web Map Service, Web Coverage Service, Web Feature Service and Web Feature Service Transactional (WFS-T) protocols.

Service oriented architecture of GeoSPAR system

Network architecture of GeoSPAR system is presented in Fig. 3. It implements the well-known concept of *Service Oriented Architecture* (SOA) with the usage of *web-service* technology. In the context of GIS systems, two service classes are extracted, namely: area-oriented services and event-oriented services.

The first of these categories – area-oriented services - are associated with the delivering of thematic layers to a user. It uses a classical WMS (Web Map Service) protocol and it will include background data, such as various types of maps, and often-updated data such as aerial and satellite imagery.

The second category includes event-driven services, and will provide the data flowing into the system on a continuous basis that is derived from mobile agents (humans equipped with mobile devices and moving vehicles) and stationary ground sensors. Due to the nature of the streaming of such data to the system, they will be cached and made available as a service through a special module acting as a broker, as shown in the schematic in Fig. X. This broker will make available data in the WFS (Web Feature Service) standard.

A web-based spatial information system Web-GIS, which – as already mentioned – represents the kernel of the GeoSPAR system will act as a high-level user interface for these services.

The physical layer of the prototype implementation is the Internet supported by a GSM network. Confidential components of the system will be protected by software and hardware mechanisms, such as compression and encryption offered by the virtual private network VPN.

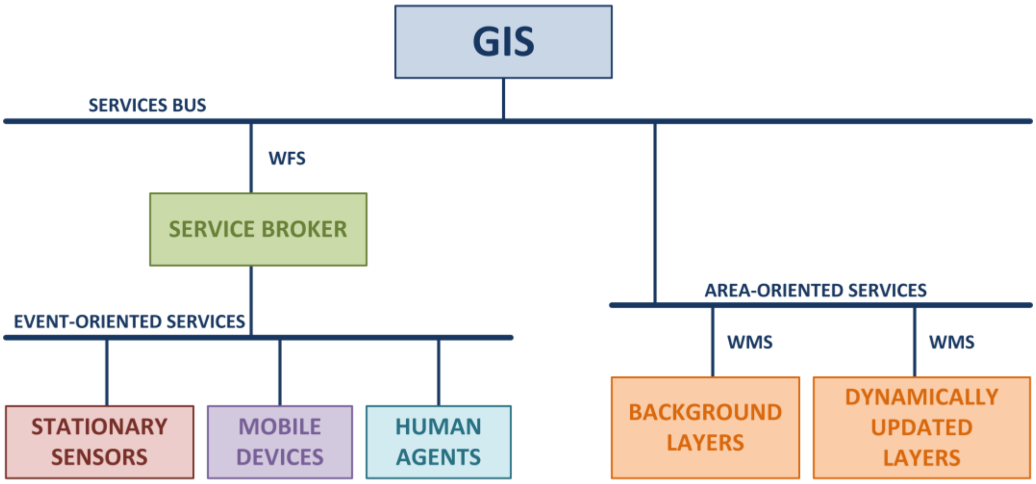

Fig.3. Network architecture of GeoSPAR system.

Remarks for the design of cloud computing environment

It is assumed that the system will be suitable for installation in a public cloud infrastructure (available in external processing centers) or a private cloud (ie, the beneficiary's own infrastructure).

The project co-partner OPEGIEKA owns modern research infrastructure in the form of a DataCenter equipped with ICT infrastructure, and the latest technological solutions that ensure the security of the storage and maintenance of digital data. The property is connected by edge routers, network security and fiber optic with telecommunications operators GTS, Netia, Dialog, TP, Pioneer and the municipal broadband network. At the moment, the OPEGIEKA DataCenter potential is more than 300 virtual servers that can achieve the power of 1 MVA. An adequate part of this infrastructure will be available for the GeoSPAR project, mainly in the form of a private cloud computing platform based on virtualization and server clusters.

The security of the cloud computing environment will be ensured by:

- Implementing safeguards for controlling access to data,
- Defining the requirements for protection against attacks,
- Development of plans for regular audits of system security,
- Securing the physical safety of the operation of computer equipment and data.

2. AIRBORNE DATA SENSORS AND SOURCES

Airborne images (images from photogrammetric cameras)

High-resolution images obtained by high and low ceiling airborne platforms, equipped with photogrammetric cameras, shown in Fig. 1, will be the main sources of data to plan and coordinate emergency response actions.

High-resolution photos in the compositions of RGB and CIR channels, allows for event detection, determination of losses, and planning activities at a macro scale. Images derived from using photogrammetric cameras have the following parameters:

a. 230 megapixel image resolution,

b. Different levels of detail, depending on the flight altitude:
   - Single pixel ground resolution = 2cm (GSD ground sampling distance) derived from a height of 300m, the coverage of a single photograph - 311 mx 282 m,
   - Single pixel GSD = 25cm, derived from a height of 4100 m, the coverage of a single photograph - 3888 mx 3536 m

Unmanned aerial vehicle platforms UAV’s flying at a low ceiling obtain images with a very small pixel GSD (order of mm) and have the following features:

a. 24-megapixel resolution,
b. Possibility of using telephoto lenses to obtain a very high magnification from a large distance,
c. Opportunity to take a series of pictures from one location thanks to the hovering mode,
d. Preview of images in real time
e. Real-time GPS localization
f. The opportunity to take pictures at any angle.

Fig.4. Photogrammetric camera (a) and Airborne thermal camera (b).

Thermal camera images

High and low ceiling airborne platforms use thermal sensors to detect heat sources, events, and to search for wanted persons.

A high ceiling aerial platform equipped with a medium format camera (resolution of images obtained at 60 megapixels) and a thermal camera IGI DIGITHERM – shown in Fig.4 - (sensitivity of 0.06°C) is dedicated to obtain images showing a thermal phenomenon.

A low ceiling platform has the ability to record thermal video-images, which allows the monitoring of events in real time. Images are obtained at 320x256 resolution and can be obtained at different angles.

Data obtained with the use of an airborne laser scanner

Colored point clouds obtained with the use of an airborne laser scanner, will be used to generate digital terrain models (DTM) and terrain surface models (DSM) containing buildings, infrastructure and terrain obstacles, as shown in Fig. 5. The sensors set is formed by: a medium format digital camera (60 megapixels resolution) and an airborne laser scanner. The scanner registers up to 266 000 measurements per second, in the form of infrared nanosecond pulses reflected from the ground surface. A point cloud with the density of 20 points per square meter, is used to quickly generate 3D models of the environment. With the ability to generate a 3D environment of the area, the development of emergency situations can be simulated and losses already incurred evaluated.

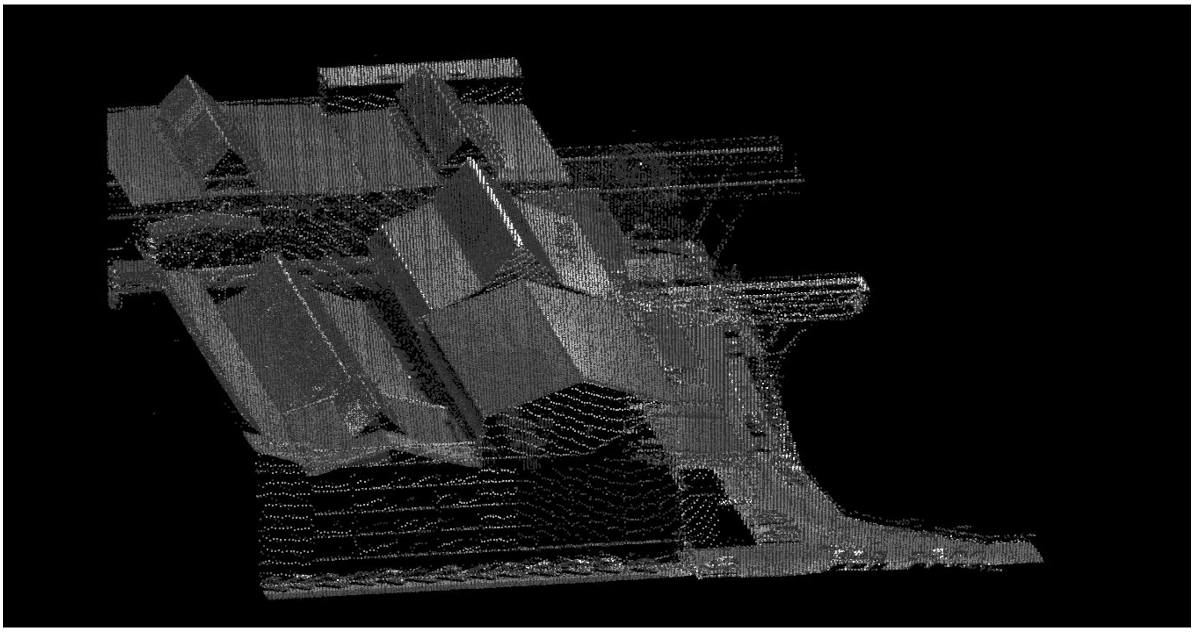

Fig.5. Laser scanner point cloud DTM of industrial area.

3. SATELLITE DATA SENSORS AND SOURCES

The second of the main tasks completed within the first stage of the project was also the selection of EO satellite data sources. For the hazardous phenomena detection and monitoring, the following types of satellite data sources have been selected:

- 1.5 metre HRPT/MetOp Satellite ground station possessed by the Contractor (see description below),
- ESA services built using the SSE (Service Support Environment) platform
  - utilising the implemented dedicated algorithms processing the EO data, like SOMAFID,
  - disseminating the original, calibrated and pre-processed, satellite data, like MODIS Data Catalogue,
- data provided by the GMES SAFER Emergency Response Service.

HRTP-MetOp Satellite Station

The 1.5 metre HRPT/MetOp-A/B satellite ground station has been operated by the Department of Geoinformatics, Gdańsk University of Technology since 2009. The station is capable of obtaining data (High Resolution Picture Transmission (HRPT)) from a set of atmosphere and land monitoring sensors available in NOAA-N and MetOp-A/B satellites. Within the course of the GeoSPAR project implementation, the station has been upgraded lately to enable the MetOp-B (launched on 17 September 2012) data receiving, besides the NOAA and MetOp-A data. What is more, the further upgrading of the station, to allow receiving of imagery from the Chinese FY-3 satellite, has been also scheduled to be considered.

As shown in Fig. 6, the station consists of the antenna, localized on the roof of the WETI Faculty Building and the indoor part consisting of the receiver and acquisition-storage-control computer unit.

Fig.6. Antenna of the 1.5m HRPT/MetOp Satellite Ground Station and its control-desk.

The ground station is capable of obtaining data from the Advanced Very High Resolution Radiometer (AVHRR) which is a major sensor onboard the aforementioned NOAA-15 – NOAA-19, MetOp-A and MetOp-B meteorological satellites.
Due to the localization of the ground station (N54° 22' 15.60", E18° 36' 45.48") and the sensor geometry constraints, the geographical areas addressed with the service will mostly cover Poland, the Southern Baltic (including the Gulf of Gdansk) and some adjacent regions.

Application of Service Support Environment (SSE) Platform

Service Support Environment is a platform which is designed to ease sharing satellite data among the scientific community. This platform also allows you to provide and combine data processing services. Application or adaptation of the SSE Environment in the GeoSPAR system will be twofold. In the first mode of operation, services which are developed for the GeoSPAR may be also deployed in the SSE Environment. Alternatively, in the second mode, the GeoSPAR system may exploit services from the SSE Environment including own services, third party services, and even chain different services (Single Service Definition SSD) together to form complex services.

<u>GeoSPAR services deployed in the SSE</u>

The first assumes that GeoSPAR provides services through the SSE environment. In general, the services deployed in the SSE range from data dissemination to data processing types. The deployed services will be available to the SSE user as shown in Fig. 7.

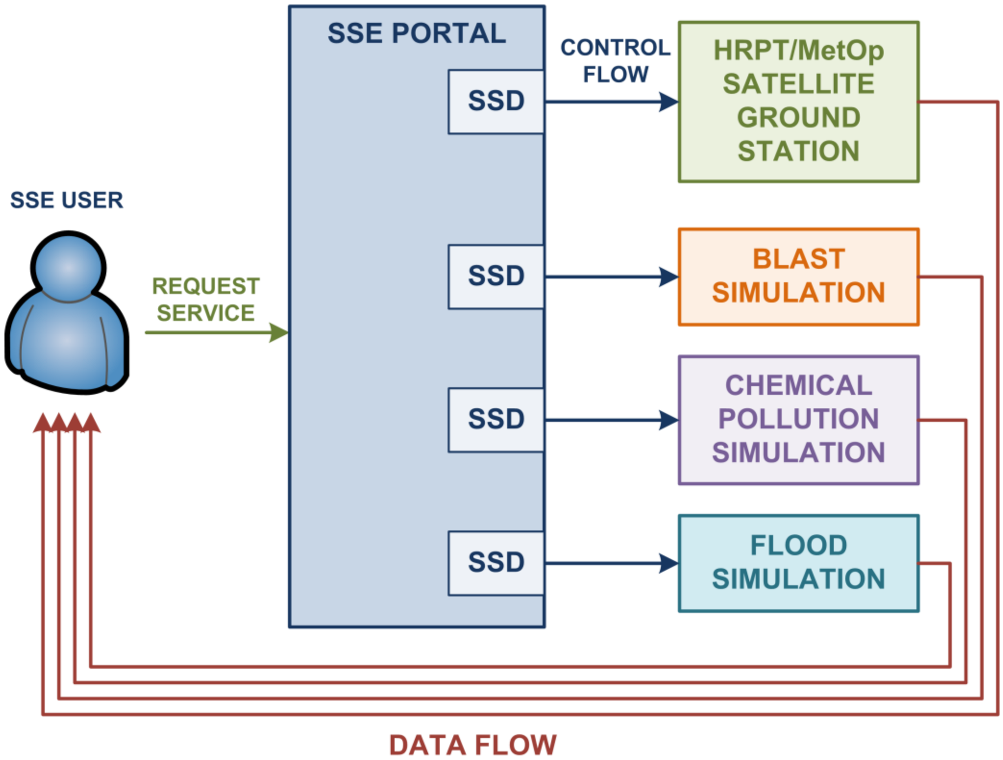

Fig.7. Using of the services deployed in the SSE.

<u>Data processing services</u>

The examples of data processing services which will be deployed in the SSE environment are: explosion, chemical pollution and flood threat simulations.

The explosion and chemical pollution simulations allow the user to simulate which areas will be affected by the threat. The result would include spatial features in the form of polygons with additional information concerning the affected regions. Flood simulation is used to determine size of the area awash. This simulation model uses a Digital Terrain Model (DTM) and data related to the soil and ground properties. Service results includes the information on the flooded area.

Explosion and chemical pollution simulation will produce vector data, which can be served as a shape file or in GML form dynamically via FTP. On the other hand, the results from the flood simulation model – as being more complex – will be presented in a raster form. The output will contain information concerning the water level altitudes for the gridded area.

<u>Data dissemination services</u>

The data dissemination service being implemented and deployed in the SSE is the Advanced Very High Resolution Radiometer (AVHRR) data catalogue. The catalogue will allow the user to download earth observation (EO) satellite data received with the 1.5m HRPT/MetOp satellite ground station. In the AVHRR data catalogue service the data is provided to the user for any pre-requested location in the area of Poland and Southern Baltic.

The AVHRR data catalogue service may be used as a source of the input data to any models and simulations developed in case of a specific need. Since the AVHRR data catalogue service provides the data in a nearly real time manner these specific models and simulations may also assume such a requirement. The AVHRR data catalogue will allow one to download statically served satellite data. This data will be available via FTP.

Exploitation of the SSE services and complex services in the GeoSPAR

In the second mode the services already existing in the SSE are used by the GeoSPAR system. In this case the results from chosen third party SSE services which are thematically and technically compliant with the GeoSPAR are used. The services may be chained together with the GeoSPAR system modules to form a complex service. The scheme of cooperation in such a mode is presented in the Fig. 8.

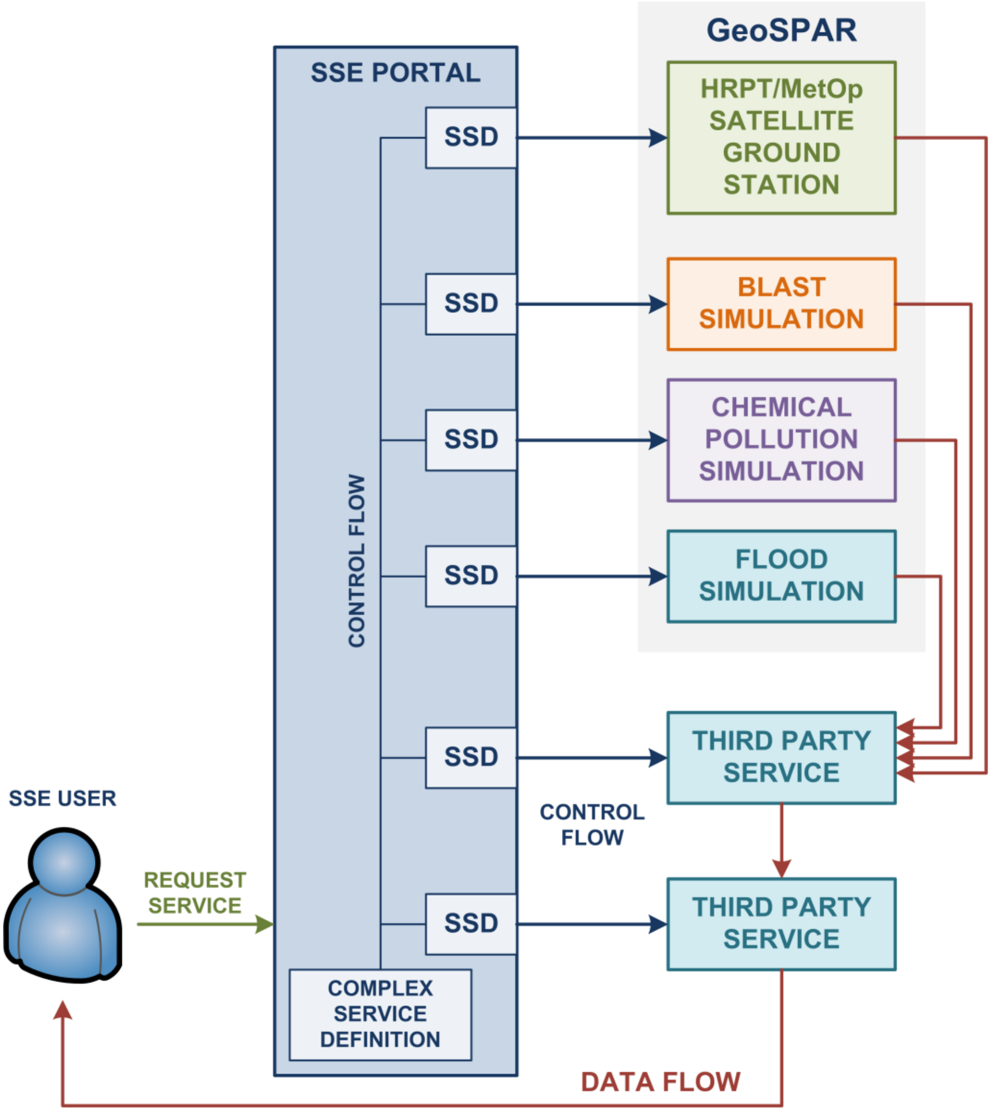

Fig.8. Using of complex SSE services in the GeoSPAR.

Services from SSE and their results can be used separately or as a part of so-called complex/chained services. The complex service defines the dedicated process flow and may take advantage of any other services deployed inside the SSE which are compliant to a specific need, e.g., to perform more advanced componential analysis of these threats. Moreover, beside the complex models and simulations developed in the GeoSPAR, some of the services may also be implemented by the third party. For example, the GeoSPAR's AVHRR data catalogue may be used by the third party in their chained service. Results from all the simulations are assumed to be used in combination with the satellite data, to perform narrow analysis of specific Area of Interest and increase situational awareness.

Preliminary selection of SSE data sources

1. Fire detection

Data sources:

1) ESA SSE / risk management / FDSI (Fire Detection by Single Image)
   The service analyses the images uploaded by the user as input data – from NASA MODIS satellite in HDF format or from SEVIRI AATSR format. Analysis is performed by SOMAFID (Soil Mapper Fire Detection) module – see Fig. 9.
2) ESA SSE / risk management/ MSFRD (Multi Source Fire Risk Detection)
   The service uses data from SEVIRI/MSG images from METEOSAT-8 geostationary satellite and detects fire hot spots. Two algorithms are utilised for fire detection:
   - SFIDE (System for Fire Detection),
   - MDIFRM (Multisource Data Integration for Fire Risk Management).

The METEOSAT-8 satellite provides the EO with new data every 5 minutes for the European continent, spatial resolution: 3 km per pixel.

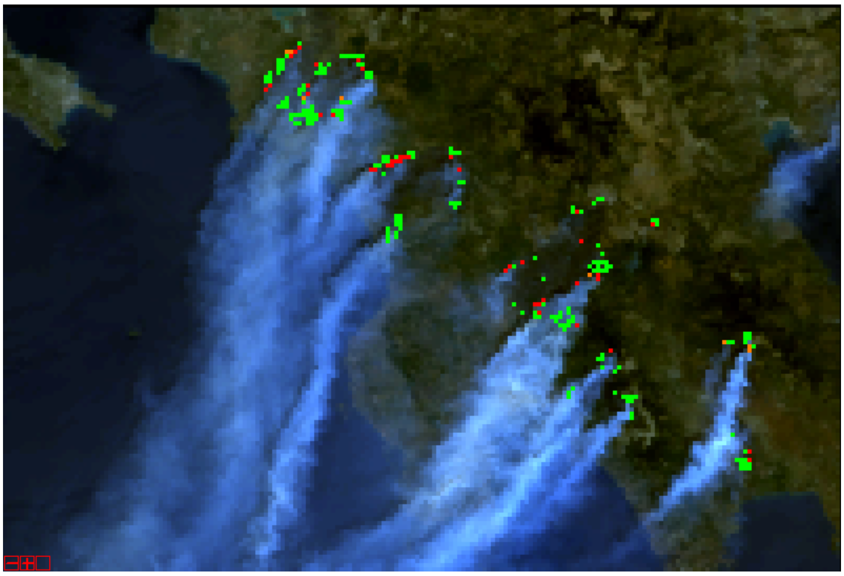

Fig.9. Fire detection by SSE SOMAFID using MODIS satellite images
(data can be also used for smoke detection).

2. Smoke detection

Data sources:

1) MODIS Terra and MODIS Aqua data by means of:

ESA SSE / Catalogue Search / MODIS data catalogue

The service provides unlimited access to NASA MODIS EO data. The MODIS Data Catalogue Service allows searching and ordering MODIS Level 1 B data from the NASA Ladsweb Public FTP archive. Delivery time: 0.25 days.

The MODIS satellites visit a given location of the Earth twice a day and provide images containing 36 band (visible and infrared) of spatial resolution 250 m/pix (band 1-2), 500 m/pix (band 3-7), or 1km/pix (band 8-36).

2) MSG-2 SEVIRI METEOSAT-8 and 9

These geostationary satellites provide new EO data for every 5 minutes for Europe (METEOSAT-8) or every 15 minutes for the whole Northern hemisphere (METEOSAT-9), with spatial resolution of 3 km per pixel.

3. Air pollution (particular matter – PM) detection

Data sources:

1) ESA SSE / risk management / PM MAPPER

This service provides the satellite data analysis results obtained by the PM MAPPER system that allows extracting near surface particulate matter concentration maps using multispectral (visible and infrared) data. PM MAPPER is based on MODIS satellite images (see description earlier in this section) and generates the following maps:

- PM2.5 maps with ground resolution of 3km x 3km,
- Air Quality Index (AQI) maps with ground resolution of 3km x 3km.

2) NOAA / MetOp-A/B satellite data received by 1.5 metre HRPT/MetOp ground station; the development of a specialised algorithm is needed in this case.

4. Flooding detection

Data sources:

A. Primary:

High spatial resolution satellite imagery from the platform: SPOT5 / IKONOS / GeoEye-1 / QuickBird / WorldView1/2 (to be purchased from the provider)

B. Secondary (for complementary monitoring in lower spatial resolution):

1) MODIS from ESA SSE Catalogue,
2) NOAA/MetOp AVHRR via the satellite ground station.

The Advanced Very High Resolution Radiometer (AVHRR/3) NOAA/MetOp is the 6-channel visible/IR (0.6-12 μm) imager of 2000 km swath, 1 x 1 km spatial resolution, for global imagery of clouds, ocean and land.

Sample satellite image of flooding is shown in Fig. 10.

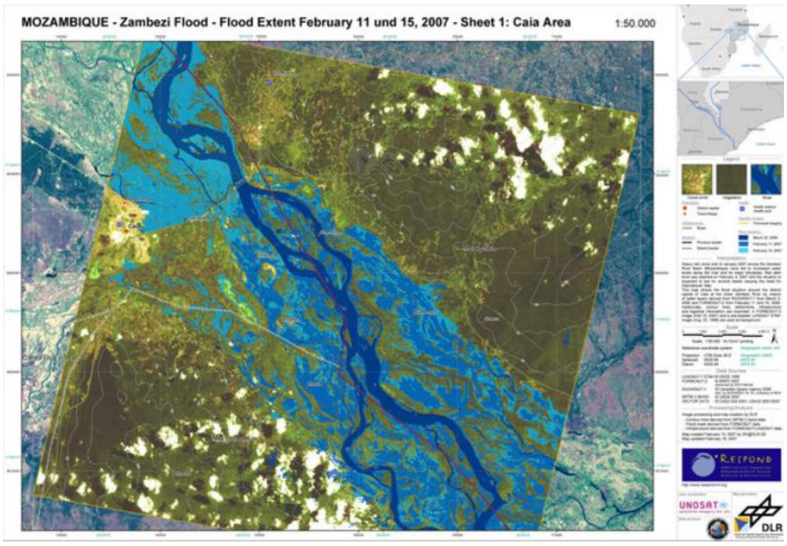

Fig.10. Satellite imaging of flooding.

5. Critical Infrastructure (CI) monitoring

Data sources:

1).High spatial resolution satellite imagery from the platform: SPOT5 / IKONOS / GeoEye-1 / QuickBird / WorldView1/2 (to be purchased from the provider)

2) FengYun-3 by means of the HPRT satellite ground station

3)MODIS from ESA SSE Catalogue

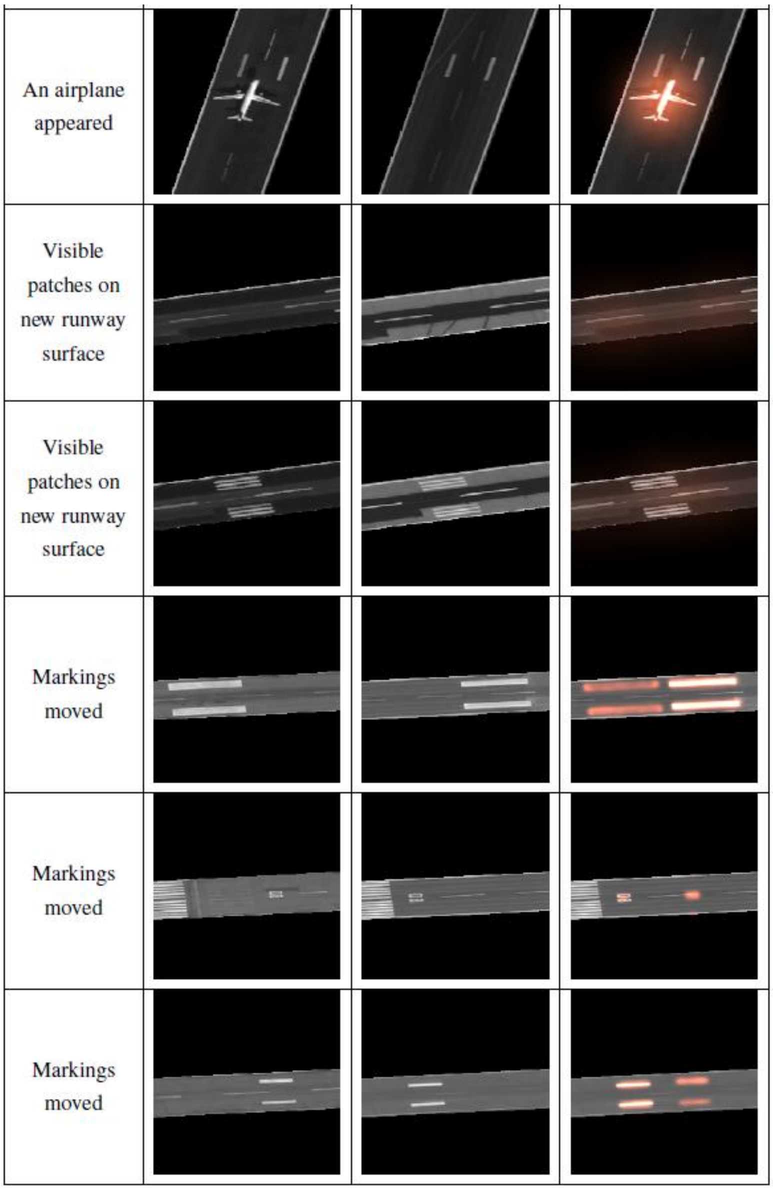

Fig.11. Sample results of image change detection for sample parts of a runway.

The requirements regarding the GeoSPAR project call, among others, for detection and monitoring of changes in Critical Infrastructures by means of the comparison of several high spatial resolution images from the same area. For this purpose, a specialised algorithm of image processing and successive images comparison is needed. The prototype version of this algorithm has been already developed and preliminarily tested as applied for airport area topography change detection (in co-operation with Jeppesen a Boeing Company) - see sample results in Fig. 11. It composes of several stages of image processing, including histogram matching, edge detection by Sobel filtering, straight lines detection by Hough transform, and pixel-by-pixel comparison.

The table specifying the hazard types foreseen to be monitored by the GeoSPAR web-GIS system along with the matched satellite platforms as sensor support is enclosed below.

Tab.1. Hazard types monitored by GeoSPAR along with the matched satellite platforms as data sources.

Application (hazard type)	Satellite platform					
	MSG	MODIS	NOAA/ MetOp/ FY-3	Landsat	SPOT	Ikonos/ QuickBird/ GeoEye/ WorldView1,2
Fire	X	X	X			
Smoke	X	X	X	X	X	
Atmospheric pollution		X	X	X		
Flooding		X	X	X	X	X
Critical infrastructures					X	X

4. GROUND-BASED DATA SOURCES

The activities on specification and selection of ground-based data sources are still ongoing. Among others, the systems like AIS-VTS combination, TV monitoring cameras and mobile agents equipped with mobile devices are under consideration and testing.

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REFERENCES

[1] NCBR Project Proposal No ROB/0004/03/003, call 03/2012.