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The Value of Spatial Information for Emergency Services

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Table of contents

Executive Summary

The value of spatial information in emergency management arises directly from the benefits of integrating technologies designed to support spatial decision making into a field where the aim is to reduce, or to avoid the potential losses from risks and hazards, assure prompt and appropriate response, and achieve rapid and effective recovery. Access to complete, credible, easy-to-use and timely provisioning of spatial - and non-spatial - information about geographical objects and factors and their influence become the prerequisites for making the right decisions or support geographical inquiries.

The development of aerospace technologies with remote sensing, location and navigation services, leverage the penetration of spatial information in all phases of emergency management: mitigation, preparedness, response and recovery. Therefore, Geographic Information Systems (GIS) deliver a valuable spatial framework for reasoning about many problems that arise in the context of emergency management. EU-wide standardisation efforts of spatial data, being increasingly online accessible, accompany this journey.

Overall, the paradigm of "map-centric" visualisation and analysis at the dispatcher workplace is more and more complemented by the introduction of several sources of shared spatio-temporal information – in real or quasi-real time if necessary. Accordingly, spatio-temporal data management and its flexible deployment is pivotal for spatial awareness everywhere, from any device which implies new challenges but also offers new and efficient features and services for robust and secure emergency services operations. Thus, emergency services operations are encouraged to transition towards a service oriented spatio-temporal data service delivery and service management organization, where the ability to cope with a constantly changing real world can be improved.

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1 Introduction

The development of aerospace based technologies and services with improved remote sensing and photogrammetry capabilities accelerate the comprehensive penetration of spatial information in every phase of the emergency management cycle (mitigation, preparedness, response and recovery). Without any doubt, spatial information has become a mission-critical attribute which offers tangible benefits for emergency services but also requires thorough requirements and feasibility analysis, tests and the implementation of a flexible and efficient geodata management.

Public awareness of risk has been raised to a new level in public safety. More than 60% of emergency calls in the EU are from mobile devices, the smart-phone penetration rates easily exceeded 60% in the member states – citizens take ambient location information in daily life for granted. Therefore, upcoming location/ routing services in the emergency services network infrastructure utilize spatial data services in next generation 112 architectures (NG112) for efficient emergency call handling.

Global satellite navigation systems (GNSS) deliver accurate positions and enable tracking and navigation support, which is accompanied by emerging indoor-location technologies e.g. Wi-Fi, iBeacon. In combination with these mobile technology advancements, spatial intelligence does no longer reside in the control room, exclusively. In fact, geodata can be accessed from anywhere with almost any device which for instance resolves potential issues in getting accurate information back from field operations to the command centre and vice versa (field enablement).

With EU-interoperability and standardisation activities for spatial data interfaces and infrastructures as a key enabler, geo-information merges towards standardized and interoperable base datasets which eases cross-border and multi-agency interoperability. Accordingly, existing local geo-databases maintained by emergency services, can be orchestrated with various shared geo-information sources. Hence, the prevalent "map centric" visualization approach of a digitized map at the dispatcher's work place is accompanied by further available base and thematic geodata. Even real-time or quasi-real time processed spatial information can be acquired and integrated from emergency management services like the EU Copernicus initiative in case of disasters, or by self-operated unmanned aerial systems (UAS) and unmanned vehicles (UVS), including improved imagery algorithms, and smart sensor solutions, more easily. Improved situational awareness and decision support e.g. for special response teams in terror attacks, weather related disasters, crisis management centres, field staff safety and support can be provided "on-the-fly". Besides, the driving consumer market will continue to reduce so far expensive geodata acquisition and aerial image processing effort.

It becomes obvious, that the key challenge for emergency services is the ability to discover, access, integrate and share spatial information with its users. Geodata management is expensive and requires skilled resources to cope with lack of data or weaknesses of existing data, to keep pace with a constantly evolving real world, while quality decision standards must be met and the compliance with IT security and data privacy regulations and guidelines is ensured. Hence, emergency services are encouraged entering a transition process towards a service oriented spatial data service delivery and service management organization to utilize technology enablement and maintain a sufficient geodata quality level in emergency management processes where lives and property are at stake.

The subsequent sections discuss the application of Geographical Information Systems (GIS) as a means for geographical inquiry in the emergency management phases and provide scenarios where spatial decision making for faster response & relief is required. A brief discourse in geodata management, from early acquisition, provisioning, maintenance and distribution with tangible hints, sources and examples complements the application perspective. The final chapters conclude the findings and share recommendations for the involved parties.

1.1 Definitions

A Geographical Information System (GIS)[1] is defined as a computer-aided system for geographic data management, modelling, analysis, simulation and presentation. A GIS is an organized collection of computer hardware, software, geodata and skilled operators. It is an integrated mapping system that takes words, numbers and other data that can be correlated to geography (i.e., location) from a database and visualizes them on a map, making the information easier to understand, analyse and work with. More precisely, it is spatial representation, capture, storage, retrieval, analysis, display of information (attribute data) that is positioned to correspond to the same X, Y, Z and t coordinates (latitude, longitude, height and time) throughout the various map layers. Its main goal is to provide insights to a specific situation and support the user in taking the most appropriate decisions.

GIS uses datasets with a spatial aspect or component which can be defined as Geodata[2] (also "spatial data", "geographic data", "geographic data sets", "geoinformation", or "GIS data"). Geodata has a spatial, temporal and thematic aspect, can be linked to other data sources and represents the core value of geographical information systems. Hence, spatial queries, analysis and simulations can be conducted if such larger and complex data structures can be managed. It is appropriate to distinguish between spatial base data and thematic data as a subset of geodata.

- Geographic base data is usually provided by national or international surveying and mapping agencies and includes mainly topographic information stored in maps or landscape models. Satellite and aerial images can also be regarded as spatial base data, as long as they only provide topographic information in the human-visible bands.
- Thematic data is acquired by specific domains. Thematic data can but does not necessarily have to include a geometry component. It is often linked to spatial base data using coordinates, administrative units, full addresses, or zip codes. Examples include soil data, geology data, geostatistical data, weather data, meteorological and oceanographic information, etc.

Base and thematic data are complemented by operational data of the public safety and emergency management context (e.g. vehicle and staff positioning, access routes and tactical zones, hazardous areas, building plans, soil type, vegetal coverage, etc.)

1.2 GIS Standardisation Process

The introduction of appropriate standards in collecting, preparing and maintenance of spatial information enables their use in various applications regardless of the source. International standards give organisations a way to abstract their process functionality in such a way that they will be able to swap in and out of vendors or use open source components. Geospatial standards are becoming increasingly important now, especially when international, regional, and national bodies are trying to build or/and harmonize their Spatial Data Infrastructures (SDI). Guided by this principle, most European countries, as well as several international organizations invested considerable effort and resources into the creation of standards of Spatial Data Infrastructure. Regional and national efforts led to a launching of initiatives to create and adopt of global standards in the scope of International Standardization Organization (ISO) and regional within European Committee for Standardization - *Comité Européen de Normalisation* (CEN).

International standardisation

ISO/TC (Technical Committee) 211[3] geographic information standards specify methods, tools, and services for data management (including definition and description), acquiring, processing, analysing, accessing, presenting, and transferring such data in digital/electronic format between different users, systems, and locations. The ISO/TC 211 family of standards defines rules and standardized schemata for the definition and description of geographic information and information management.

[1] https://geodata.ethz.ch/geovite_tutorials/L1IntroToGeodata/en/text/L1IntroToGeodata.pdf
[2] https://geodata.ethz.ch/geovite_tutorials/L1IntroToGeodata/en/text/L1IntroToGeodata.pdf
[3] http://www.isotc211.org/

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Regional standardisation
A pan-European body called CEN is the main regional European standardization body and operates through the European Commission. CEN/TC (Technical Committee) 287 (Geographic Information) is responsible for development and publishing of geographic information standards. In the Geographic Information area, CEN works closely with the ISO. CEN standards are mandatory in Europe.

Industrial Consortia
One of most active industrial consortium involved in geo-spatial standard development and promotion is the Open Geospatial Consortium (OGC), formerly the Open GIS Consortium[4]. OGC has concentrated its efforts on the following areas:

- The encoding of information in software systems (data format standards and data transfer standards);
- The naming of features and feature relationships (data dictionaries);
- Schema for descriptions of data sets (metadata).

The OGC works closely with ISO/TC 211. Many common work items exist between the OGC and ISO/TC 211 that result in OGC specifications being adopted as International Standards or Technical Specifications.

There are some differences between ISO and OGS procedures and products. ISO/TC 211 is the *de jure* formal standards technical committee. OGC is the *de facto* industry technical specification developer. ISO standards have a formal life cycle that includes official approval, publishing, and periodic revisiting once every few years. All international standards are reviewed at least once every three years (after publication) and every five years (after the first review) by all the ISO member bodies. OGC specifications can be used by users before formal approval and could be updated a few times in any given year.

The INSPIRE Directive
In a major effort to normalize spatial information within the EU, the European Commission established the INSPIRE[5] (Infrastructure for spatial information in Europe) initiative, May 15, 2007 with full implementation required by 2019. INSPIRE aims to create a European Union (EU) spatial data infrastructure. This enables the sharing of environmental spatial information among public sector organisations and better facilitates public access to spatial information across Europe. A European Spatial Data Infrastructure will assist in policy-making across boundaries. Therefore, the spatial information considered under the directive is extensive and includes a great variety of topical and technical themes. It covers more than 20 thematic clusters[6] which are partially relevant for emergency services, e.g. human health and safety with locations of hospitals, police stations, PSAP location and service areas, population areas, natural risk zones, energy resources, buildings, elevations statistical units, and ortho-imagery. INSPIRE uses CEN/TC 287, ISO/TC 211 and OGC standards and specifications.

ISA² Programme
The ISA² programme (interoperability solutions for public administrations, businesses, and citizens), launched in early 2016, supports the development of digital solutions that enable public administrations, businesses and citizens in Europe to benefit from interoperable cross-border and cross-sector public services. Its sub-activity European location interoperability solutions for e-government (ELISE)[7], jointly with INSPIRE, is established to remove obstacles to the efficient sharing and re-use of geospatial information. Legal/policy, organisational, semantic and technical interoperability requirements that will facilitate efficient and effective electronic cross-border and cross-sector interaction in the area of location information and services will be covered.

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[4] http://www.opengeospatial.org/standards
[5] http://inspire.ec.europa.eu
[6] https://themes.jrc.ec.europa.eu
[7] http://ec.europa.eu/isa/actions/isa2/04-geospatial-solutions/10action-en.htm

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2 GIS for emergency services process improvements

It is commonplace in PSAPs that geodata are used to provide accurate location information to dispatchers and first responders. However, GIS takes mapping far beyond simply showing specific locations, e.g. a street address or an intersection. GIS automates mission-critical tasks by submitting optimized response proposals by status, location and time-to-incident location complemented by routing calculations, to improve response times and situational awareness, leading to more effective incident resolution.

Geodata can also be used to deliver a great deal of additional thematic information concerning the relationships between people, places, time and things. Physical locations as points-of-interests, objects like schools or risk-prone areas can be correlated regarding their proximities and relationships between and among key community structures. In conjunction with the location of response teams, assets like video surveillance cameras, healthcare facilities, and fire and police stations, communities are better prepared for potential risks and hazards according to their local risk register. The subsequent paragraphs share some examples of GIS and geodata used in the mitigation, preparedness, response, and recovery phase of emergency management and point out a few key future scenarios.

2.1 Usage of GIS in different phases of the emergency management phases

PLANNING & MITIGATION: Evaluating the potential types of disasters and developing plans for reducing their probability or their impact on life & resources.

GIS' can help in understanding the geography of vulnerability. It's hard to predict exactly what could happen in an emergency situation. However, even a rough estimate can be a huge help to emergency managers and decision makers to develop plans for allocating resources and managing investigation or recovery operations. By collecting socio-economic and environmental data sources in a GIS, one can develop risk maps to highlight the potential impact of disasters on people and infrastructure.

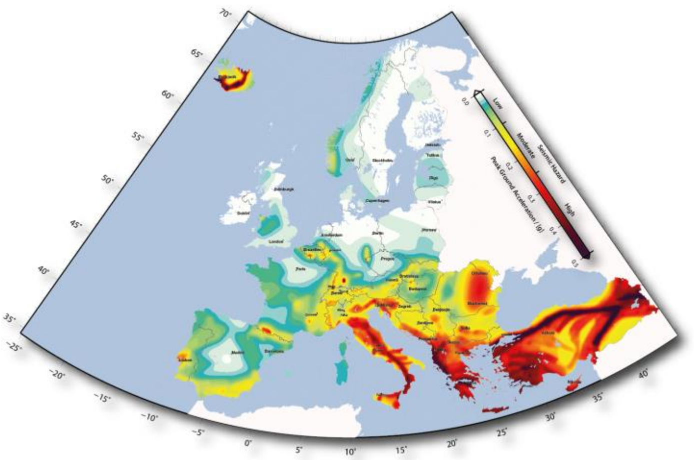


Figure 2-1: European Seismic Hazard Map[8]

In this phase, several major questions need to be answered like:

- Who is at risk? How many people will be affected?
- What is the spatial and temporal extent of the vulnerability?
- What capacity does the population at risk have for coping with the disaster?
- What is the range of possible victim scenarios given different conditions?

[8] http://www.share-eu.org; Project SHARE (Seismic Hazard Harmonization for Europe); reference to European Facilities for Earthquake Hazard & Risk (EFEHR) at www.efehr.org

The use of GIS can also help to assess the spatial and temporal distribution, such as areas which have the highest concentration of known gang members or to analyse burglary series helping to identify patterns and providing a forecast for mitigation measures (predictive policing) to enhance community safety.

PREPAREDNESS: Actions undertaken when mitigation efforts have not prevented or are unable to prevent a disaster from taking place.

GIS is a key element of disaster preparation through computational simulation and modelling. Wide arrays of specialized modelling software extensions are available. This enables users to tweak disaster parameters and simulate damage patterns due to natural disasters, pandemics, or fires. Different disasters present different types of opportunities for preparation – some, like terror attacks or earthquakes provide little or no warning time at all. Others, like hurricanes or other severe storms, may offer a window of preparation time, where GIS is used to coordinate evacuations and other types of preparation efforts (sandbagging levees, for example).

One way to prepare for disasters that offer little or no warning is to develop spatial computational models of disaster impacts and use a GIS to run simulations of hypothetical emergency situations. A second part in preparedness regards training. The GIS usage in support of operations training is paramount on any system. The GIS, as any other tool in the emergency personnel arsenal, needs to be used in day to day operations and used within the training for any incident type.

RESPONSE: Activities that occur in the wake of a disaster that are intended to identify and assist victims and stabilize the overall disaster situation.

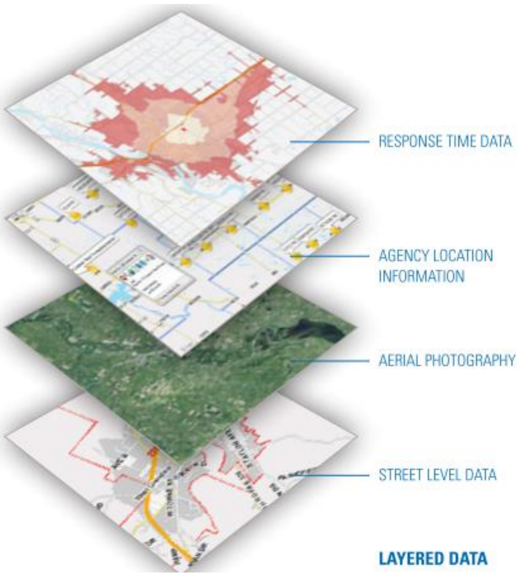
Here comes the real-time GIS usage, one of the most important features of the system. An example of a GIS application in PSAPs can be found in the EENA GIS 112 in Estonia case study[9]. More about this is discussed in the following chapters (Situational Analysis, Optimised Routing and Enhanced Analysis).

RECOVERY: Actions following a disaster to restore human and environmental systems back to normal.

Recovery from a disaster can take a very long time and there are a wide range of roles that GIS can play in the recovery process. For example, GIS may be called upon to identify areas for redevelopment projects or to recalibrate vulnerability models to help predict future disaster impacts.

2.2 GIS and Situational Analysis

GIS deliver detailed situational awareness for dispatchers and first responders by geographically tying persons, processes and data together. Dispatchers, police officers, fire-fighters and EMTs can access a common view of information from street maps and agency boundaries to real-time or quasi-real time localization of events, equipment or personnel, to infrastructures (utilities, hospitals, etc.), to risks and hazards, giving a complete view of the operations area. Each one of the elements at hand are located via latitude, longitude, height and time. These integrated map views help them assess the situation at a glance, and can be enhanced by overlaying other information pertinent to the safety and security of each operator in the area. Information like gang territories, older people localization, schools per type and number of students etc. allows for a better understanding of the equipment and measures needed to be taken to support the overall mission. Other data — such as live video from street cameras or images sent from mobile phones — can also be displayed to enhance awareness and safety. Because each responder can



9 http://www.eena.org/download.asp?item_id=178

view exactly what others are seeing, it's also faster and easier to collaborate and coordinate with other jurisdictions and agencies. GIS-video integration enables point-and-click control of video cameras; security personnel can easily control camera movement such as pan, tilt, and zoom by pointing and clicking on a map. GIS-enabled video surveillance provides security for law enforcement personnel with live video as well as the spatial knowledge to best respond to any threat. To note that the access to some of the information needed may be protected or restricted and so the GIS needs to guarantee that all the access authorizations are maintained under strict rules.

2.3 Next-Generation networks and architectures (NG112)

GIS helps PSAPs solve many of today's call processing issues. In legacy systems, for example, GIS data is normally accessed *after* the call reaches the PSAP and permits dispatchers locate the caller. Efficient and effective response can be compromised due to missing or incomplete geographic data. This can lead to incorrect or imprecise caller location determination and misinformation when directing responders to the location of an incident, which can cause significant delays in response that may be life threatening for both, citizens and responders. In NG112 systems, however, the comprehensive use of GIS datasets helps eliminate the manual caller location lookup of today's traditional address databases. Instead, using a more accurate position provided by the calling device itself and/or the mobile network operator, and GIS data representing the PSAP service areas, the call is automatically routed to the correct PSAP, reducing the number of misrouted calls, and dispatch can therefore be faster and more accurate.

Civic addresses are also being considered in standards as "dispatchable" addresses e.g. *0112 Church Street West, 2nd.floor apartment 410, Nowhere county*. This will give call-takers additional information for the validation of the location and ultimately reduces response times.

As the emergency caller location accuracy improves, the more PSAPs are capable to efficiently handle emergency calls from across boundaries. PSAPs can develop their ability to coalescence spatial information, creating seamless maps from other/ neighbouring jurisdictions to enable call takers to identify emergency locations or search for locations outside of their region – a valuable measure for creating borderless boundaries in map displays. As standardized spatial interfaces and services have matured, the prevalent "map-oriented" geodata set as a self-contained information silo in the PSAP is complemented by the utilization of distributed spatial information which fosters collaboration and interoperability between emergency services. Call-takers and dispatchers will be able to provide quick and effective response, even in cases where emergency callers might be located near – but not within – a PSAP's jurisdiction.

2.4 Real-time spatial analysis

With the orchestration of sensor data and existing thematic data, it is possible to perform further real-time or quasi-real time analysis in the command centre. For instance, social media messages can be queried for specific key words in the vicinity of an emergency call location. But also, routing assistance for dispatcher is possible e.g. "*present closest hospitals in an incident area*". By enabling real-time or quasi-real time mapping of events and objects, GIS is capable to illustrate a wealth of information that is tied to a location or area, at a glance. Meteorological and oceanographic data, operational data like plumes of gases, fire propagation in a specific environment, or response team localization, can be mapped with additional geospatial datasets, to reveal patterns that might go unrecognized without this functionality. Agencies are then enabled to analyse traffic accident to better view, understand and investigate geographic patterns to help remedy or resolve recurring problems in locations such as intersections and neighbourhoods, or access models that will allow better locating equipment and personnel to support the resolution of a specific emergency.

2.5 Big data spatial analysis

This is a new area of GIS analysis that supports the analysis of information fostered by IOT (internet of Things) mega trends. All the time enabled data from sensors and social media tends to grow exponentially in any given incident. This implies that the GIS analysis will need to support big data analysis. The main question here reflects the need to process and analyse large volumes of data in very small time which implies a different type of analysis approach. However, it will provide a new level of abstraction that could provide new insights on patterns from the incident that can be important within the command and control processes.

2.6 Indoor location and mapping

It must be acknowledged that a fair number of incidents occur indoors, and many times in public buildings or in private areas, such as universities, arenas, and sports facilities. GIS enables emergency services to collect and visualize indoor building maps, which contain all relevant building information including room numbers, floors, doors, objects and facilities. If such sensitive objects and sites are spatially modelled and complemented by real-time location information of callers hiding inside buildings, or support university campus evacuation activities, it becomes a valuable tool for decision support to efficiently conduct Search and Rescue (SAR) or establish counter-measures for instance during terror attacks. As the accuracy of indoor locations improves through initiatives such as Advanced Mobile Location (AML) and Wi-Fi and beacon positioning technology, Geodata must evolve in parallel to provide call-takers, dispatchers, and responders the ability to accurately locate callers indoors by providing a visual base, or reference. It is anticipated that indoor geodata provisioning is required similarly to compliment radio communication coverage inside of buildings for self-protection of the field response staff.

2.7 Mobile spatial application

Mobile technologies enable a tighter collaboration between command centres and field staff as spatial and incident information can be conveniently shared in a two-way communications pattern. Caller name, address, incident type, incident locations, object information, relevant geodata of the area with safety hints, access information, or the involved field staff location and their status as well as possible associated further incidents in the vicinity is then available from everywhere. As existing sensors like surveillance cameras have become a geo-referenced asset, the real-time access from mobile devices and the command centre to the most applicable cameras in the affected area can be performed. This applies also to further emergency calls in the area, where routing services utilize the deployment of a mobile command centre where all calls in the neighbourhood can be answered. Overall, mobile spatial applications are the key means to provide a contextual spatial and task oriented operational picture in real-time for staff and incident commanders in the field.

2.8 3D Models

The increasing geodata quality makes it possible to visualize the third or fourth dimension as well as increasingly accurate and rapidly available (real-time) GIS solutions[10]. With 3D point clouds[11], the world defined by X, Y, and Z coordinates can be imaged with a high level of detail as the utilization of drones and advanced sensor technologies makes the cost efficient automatic derivation 3D city models feasible. Buildings, objects with textures and roof structures (Level of Detail 2 - LoD 2) has become a standard resolution, meanwhile, and is frequently combined with the existing 2D maps, thematic data and aerial images.

In parallel mobile technologies, accompanied by standardization work, extend the level of detail of the emergency caller location. Elevation, in the form of Z-axis data is added to geodetic locations, enhancing them from today's 2-dimensional X/Y points to 3-dimensional X/Y/Z points and other shapes (such as 3D spheres). This emergency trend offers PSAPs to utilize a contextual 3D representation of an incident area.

Police services employ 3D city models for the preparedness of demonstrations and their safeguarding, for instance with analysis of possible escape routes and barriers etc. For this purpose, the city development plan, vegetation and street visualization is needed to provide an accurate overview of the area. Efficient evacuation planning in urban areas prior to public safety bomb disposal (PSBD), but also the identification of access routes, potential blockings, or the determination of response teams' positions with direct line-of-sight in case of terror

[10] http://www.sogi.ch/fileadmin/redaktion/sogi2013/Innovationsbericht_GEOSummit_2016_final_d_f.pdf
[11] https://en.wikipedia.org/wiki/Point_cloud

attacks, siege or man hunt are supported, as well. Fire and rescue services find 3D city models particularly important during hazardous material accidents - accidents in plants with toxic, environmentally hazardous and flammable substances - as the threat area with adversely impacted population, objects, infrastructure and the environment can be analysed and visualized. Overall 3D model technologies have created a considerable number of research papers[12] and continue to be considered in future GIS deployments in emergency management.

3 GeoData Management

Emergency services organizations require an exceptionally well-organized communication between different actors, providing information timely and in an immediately understandable and not misleading format where spatial awareness is a critical capability. Fundamentally, a GIS system is only as good as its data, and data accuracy is essential for next generation emergency call systems to deliver their substantial benefits. The reality is when there are delays in emergency call response today, they are primarily due to data inaccuracy or missing and incomplete data. This is a major concern of today's public safety professionals, worldwide. Geodata accuracy issues and update cycles – such as the accuracy of address data and the time it takes to incorporate address updates in GIS data - are to a certain degree a problem for virtually every PSAP in every city, region, state, province or county. Furthermore, it is important to highlight that the risks of obsolete information for decision makers are enormous.

Geodata as representation of the real world are *per sé* not static; it's evolving and changing continuously. The number of geoinformation sources and sensors significantly increases, driving interoperability requirements, and creating burden for geoinformation management. New roads, new buildings and new addresses, objects, infrastructure are constantly being added in the service zones. Existing address databases must be synchronized to assure that boundaries in current maps are accurate and gaps between emergency services zones are covered. Besides, tactical requirements ask for further spatial information e.g. 3D models, where a complete scenario with line-of-sight simulation, detailed information of objects like height, entrances and access paths, blockings etc. can be visualized. Therefore, emergency services must cope with a growing demand for high-resolution, up-to-date geoinformation as location information due to new satellite navigation systems has become more precise and reliable. Further, new data service architectures like NG112 are designed to utilize the geodata including road centrelines, address locations and jurisdictional boundaries — if accurate and up-to-date geodata are used for emergency call routing. GIS, in NG112, truly becomes mission-critical, because it powers the near-real-time routing of emergency calls to PSAPs. Geodata must be accurate, up-to-date, and free of as many errors as possible to make this a reality. Also, mobile technologies meet the need of emergency service staff to get access to spatial information from everywhere with any device.

It becomes obvious that processing and displaying large amounts of geoinformation dynamically is a challenge and yet, geoinformation – address data, road names, 3D maps and beyond– is expensive to create and requires expertise to maintain. Hence, geoinformation has become a fundamental infrastructure of emergency services, public authorities and critical infrastructures. In fact, every command centre is tasked with these requirements daily where a transformation from the "map-oriented" paradigm to a flexible geoinformation infrastructure, where on-line and ad-hoc provision of geodata is provided by an interoperable data set, being maintained and be used everywhere and anytime must be executed. If the data is outdated or incomplete, safety is compromised.

As efforts in EU-wide interoperability[13] capabilities are progressing at a rapid pace, the orchestration of "own" geodata with other data sets becomes a key requirement for emergency services operations. The implementation of a geospatial data infrastructure must provide interoperable data and services based on commonly agreed standards, to enable emergency services to build and execute their work on it. This operational requirement describes how to acquire spatial data, to provide spatial data, to update spatial data, and finally how spatial data are shared and utilized (Figure 3-1).

[12] Applications of 3D City Models: State of the Art Review; http://www.mdpi.com/2220-9964/4/4/2842
[13] http://ec.europa.eu/isa/actions/02-interoperability-architecture/2-13action_en.htm

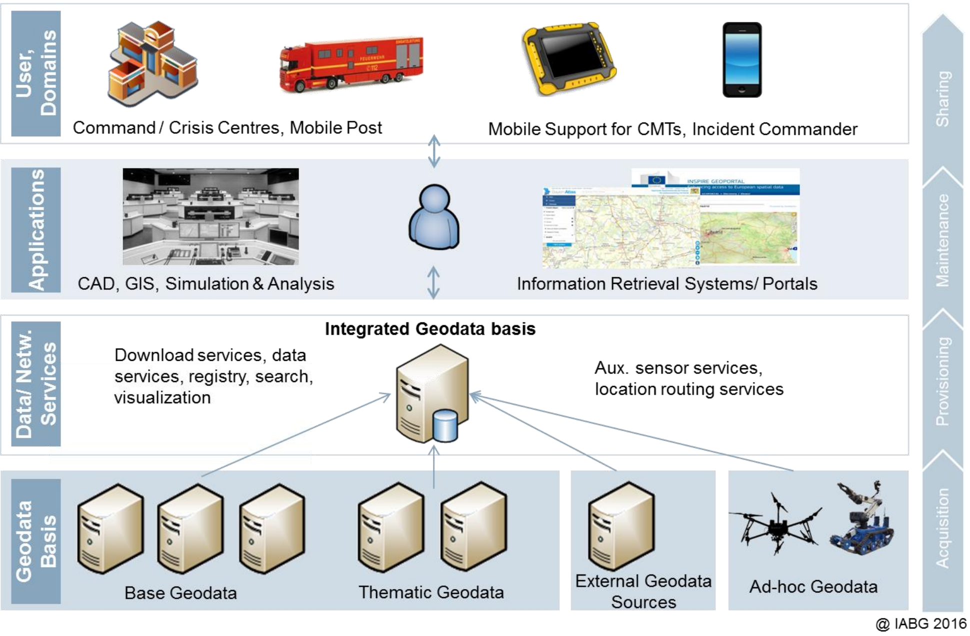


Figure 3-1: Emergency services geodata infrastructure framework

3.1 GeoData acquisition

Geodata acquisition ensures the collection of geodata for further processing. It comprises geometry (spatial information), date and time (temporal information) and any non-graphical related attributes (thematic information).

Primarily, geodata are directly derived from the objects to be monitored via terrestrial surveying, photogrammetry and remote sensing[14] methods which predominantly produce topographic base data. Photogrammetry in this context allows measurements from pictures and photographs, and is a cost-effective method to provide detailed topographic data. Hereby, a collection of images about a larger area is mapped into a single model, and the orientation of this model by extracting 3D vector coordinates to describe geographic objects is processed (ortho-images).

Besides, secondary geographic data are derived from such primary data sources. It is quite common to develop digital data by scanning maps or aerial images to be georeferenced and to provide the geographic context for other data, e.g. emergency services relevant information for areas, buildings. But also, vector data can be generated by converting raster data into vector objects. It is likely that secondary data are of lower quality and less up-to-date and e.g. data processing from smaller scale maps carries generalization effects that result in a lack of accuracy of object selection or displacement.

In addition, fieldwork and the monitoring of sensors, e.g. water gauges, weather stations, complemented by results of interviews, census and polls result in comprehensive thematic data sets. Both acquisition methods are significantly facilitated by the development of space based assets in regards to satellite navigation systems (GNSS) in conjunction with mobile technologies. It becomes obvious that geodata is frequently based on complex data structures which is expensive to acquire, to manage, and carries special skills in information processing.

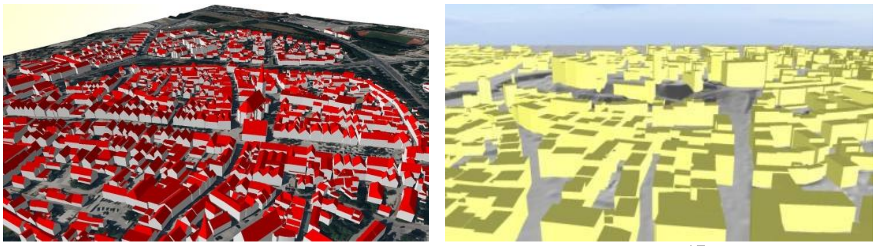
[14] https://en.wikipedia.org/wiki/Remote_sensing

3.1.1 Spatial data types

Geodata are defined in spatial data models which conceptualize how spatial information is arranged in a computer system. These data sets refer to a coordinate system (geo-reference) to locate the information on the surface of the earth, to align data relative to other data, to perform spatially accurate analysis, or to create maps[15]. As several coordinate systems exist, for instance the eCall location information is based on the World Geodetic System (WGS84) coordinate system, additional complexities arise with projections and transformations to coherently present such datasets. Due to the operational nature of this document, though, further technical details will be avoided and the focus of the subsequent sections is on the two main basic data models – raster and vector format in the context of the geodata acquisition.

Vector data. Vector data[16] are a coordinate-based data model that represents geographic features (objects) as points, lines, and polygons. Each point feature is represented as a single coordinate pair, while line and polygon features are represented as ordered lists of vertices. Attributes are associated with each vector feature, as opposed to a raster data model, which associates attributes with grid cells. With these attributes, the geometry is associated with the thematic information. For instance, lines could represent everything that has a length: underground and overhead cables, communication systems, roads, rivers, etc. The shapes and polygons represent everything that fits within a limited area, either political, natural or administrative boundaries (state, municipalities, cities, parcels, PSAP service areas etc.). Therefore, vector data are necessary to represent real world features in a spatial-analysis in a GIS, for example to find the nearest PSAP, hospital, or fire station.

Example: 3D building model / 3D city model. Three-dimensional building information based on building footprint and height information which is usually offered by ordnance survey agencies. This is a model which can be used for line-of-sight simulation, emergency staff positioning, general resource planning.



LoD-2 LoD-1[17]

Figure 3-2: LoD 3D models

Raster data. Raster data[18] describe spatial objects based on pixels, whereas a pixel in addition to its position contains only one information. Frequently raster data are used in a GIS is as a background image for other GIS-layers. For example, ortho-images displayed underneath other layers ensure that the map layers are spatially aligned and represent real objects. Raster data can be created from satellite images, aerial photo images (ortho-photo), scanned data (analogue paper maps into digital format), or sensor data like radar data, laserscan data.

Raster grids are well suited for representing data that changes continuously in a landscape (surface map). They provide an effective method of storing the continuity as a surface. Elevation values measured from the earth’s surface are the most common application of surface maps, but other thematic data, such as rainfall, temperature, contamination areas, and population density, are available for spatial analysis. As an example, a digital elevation model (DEM) is a digital model or 3D representation of a terrain’s surface:

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[15] http://pro.arcgis.com/en/pro-app/help/mapping/properties/coordinate-systems-and-projections.htm
[16] Basis: http://support.esri.com/other-resources/gis-dictionary/term/vector
[17] www.ldbv.bayern.de
[18] Basis: http://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/what-is-raster-data.htm

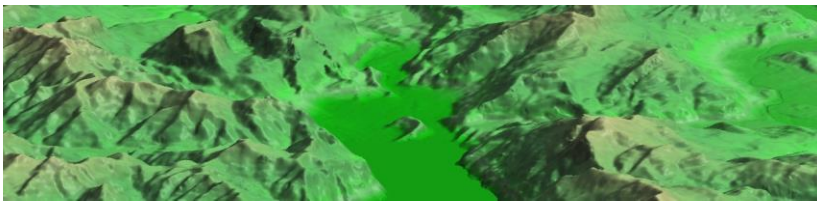


Figure 3-3: Example of a digital surface model (upper Garda Lake area) at 25m[19]

DEMs are available in different resolutions, e.g. 1m, 25m, 30m, 200m for defined geographical areas. Depending on the grid size, they are available free-of-charge (e.g. EU-DEM for Europe with 25m grid size from the European Environment Agency (EEA)[20])

Raster data representing thematic data can be derived from analysing other data, for instance if a satellite image is classified by land-cover categories or additional multispectral data are applied, or existing vector, raster, and terrain data are combined and processed for specific activities. For instance: crime risk zones, potential flooding areas etc. Raster data offer the possibility of obtaining rapid spatial data for large areas, and is significantly less demanding regarding time and money than to vectorise map layers one by one. It offers a simple data structure suiting advanced spatial and statistical analysis.

On the contrary, the picture is still one file, or one layer, from which it is not possible to take out a specific object and associate it with thematic data. One must consider that spatial inaccuracies due to the limits imposed by the raster dataset cell dimensions exist and these datasets are potentially very large, especially for high resolution images.

Geodata converters allow transforming existing raster data in vector types. Images can be displayed together with vector data, so-called hybrid graphics, which enables vectorization of only those objects that are essential in the work.

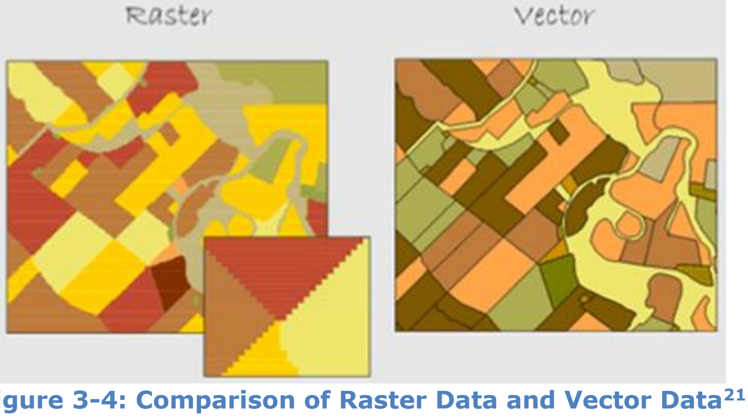


Figure 3-4: Comparison of Raster Data and Vector Data[21]

Side note: Geodata are encoded in a variety of different formats (geofile formats). Most of them are proprietary, some of them related to a specific country and some are related to manufacturers. However, a multitude of tools and applications is available to get access to, modify, reuse and present geodata through application programming interfaces, e.g. OGC, or to perform file format conversion for instance in case of GIS migration

[19] http://courses.neteler.org/eu-dem-new-digital-surface-model-at-25m/
[20] http://www.eea.europa.eu/data-and-maps/data/eu-dem
[21] http://giscommons.org/introduction-concepts/

activities. The translation process must address both syntactic and semantic problems, whereas the latter is an inherent issue of geodata.

3.1.2 Satellite images

Satellite image are images of the whole or part of the earth taken by satellites[22] in a sun-synchronous orbit or geostationary location in altitude between 200 – 36.000km. The images serve a variety of uses, including cartography, military intelligence, meteorology, climate & environment. Therefore, satellites are equipped with a variety of multispectral sensors with different resolutions to submit visible light images, water vapour images or infrared images, depending on the purpose. High resolution pictures are costly. Generally, satellite images are weather dependent due to potential cloud coverage in the monitored area.

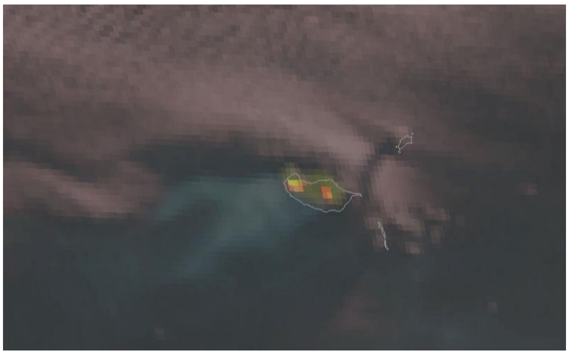
Table 3-1: Selected sensors and provisioning services

Sensor	Actuality	Price	Provider
Pleiades	Emergency Services: 24h	€	Airbus Defence and Space (France)
Spot 6/7	Emergency Services: 24h	€	Airbus Defence and Space (France)
Rapid Eye	Priority Tasking: <45 days	€	BlackBridge
Sentinel-2	Archive: 10 days	Free of charge	ESA-Copernicus
Landsat 8	Archive: 16 days	Free of charge	NASA, USGS (USA)

Table 3-2: Satellite image examples

Very High Resolution	High Resolution
- WorldView-3: 0,3m - GeoEye-1: 0,4m - Pleiades: 0,5m - SPOT 6/7: 1,5m  www.digitalglobe.com (Flooding Madagascar 2015), WorldView-3	- RapidEye: 5m - Sentinel-2: 10m - Landsat8: 15m  www.satimagingcorp.com (Burghausen Germany), RapidEye

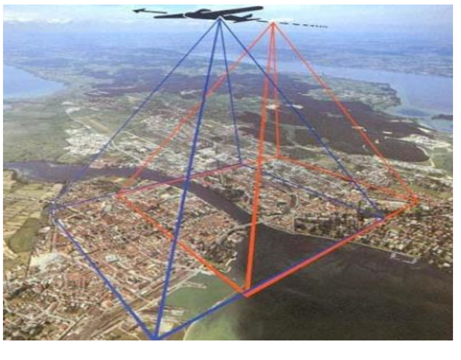
[22] www.esa.int/spaceinimages/content/search?SearchText=&img=1&SearchButton=Go

Medium Resolution	Low Resolution
- Landsat 1-5: 30m - Deimos: 22m  www.usgo.gov (Tschernobyl ,1986), Landsat 5	- Meteosat: 2500m  www.eumetsat.int (Fires on Madeira, August 2016)

3.1.3 Aerial images

From an original aerial photograph an ortho-image can be derived by computational equalization, which is characterized by exact scale and spatial reference. Digital ortho-images form the basis to produce aerial maps. The terrain is represented in scale and in the correct position. Dimensions and coordinates can be associated with other base geodata or combined with further thematic data due to the consistent spatial reference. Aerial images are relevant for incident management and emergency planning purposes.

Table 3-3: Aerial images

Aerial image	Orthoimage
 www.lgl-bw.de	 www.ldbv.bayern.de/produkte/luftbild/orthophotos.html

Drone footage. Meanwhile there are several solutions available which enable emergency services to collect and process aerial images by means of RPAS (drones). Photogrammetry software, available on the market, can utilize live-video streams or pictures of an affected area to create professional ortho-mosaics, point clouds, models (terrain, 3D georeferenced maps combined with open source software) in an automated process. This complements the existing surveys –terrestrial separated from aerial– and uses low cost gear –small remotely controlled aircraft (RPAS)- presenting thus a much less expensive option delivering most accurate images (less than 1cm) in short time (minutes, hrs.) to increase situational awareness of an incident scene or to document areas during or after an incident.

Due to technology innovation of drones and sensors, solutions emerge where simultaneous aerial localization and mapping (SLAM)[23] solutions for outdoor applications makes such accurate positioning over longer distances feasible for emergency services staff. Mostly, commercial off-the-shelf drones and sensors are employed.

Table 3-4: Aerial image examples

Drone-based cameras Flight Height: 30m Ground resolution <1 cm  Amtrak disaster, Vermont USA 2015 http://uavsurveys.plsurvey.com	**Drone-based imagery** (ortho-mosaics, 3D meshes …) Processing, Photogrammetry, LiDAR … Provisioning in minutes, hours  3D GIS imagery provisioning with drones http://www.esri.com/products/drone2map

3.1.4 3D City models and 3D-visualisation

3D visualization and localization, especially of urban areas with 3D city models, is a valuable contribution for emergency services. INSPIRE and the OGC have taken up requirements[24] of different domains and provided the City Geography Markup Language (CityGML)[25] as a concept for the modelling and exchange of 3D city and landscape models. It ensures interoperability and simplifies the exchange of datasets and the design of interfaces. CityGML consists of a general-purpose information model which contains complex and geo-referenced 3D vector data along with the semantics and in addition to geometry and graphics information. An extension mechanism for data enrichment is available to ensure the semantic interoperability. Meanwhile various large scale 3D city models are available and several commercial vendors offer comprehensive 3D acquisition and modelling services.

[23] https://en.wikipedia.org/wiki/Simultaneous_localization_and_mapping
[24] In a broader sense 3D city models may also comprise 2.5D data sets (visual perception of a 3D perception) like a digital elevation model (DEM)
[25] http://www.sig3d.org; http://www.opengeospatial.org/standards/citygml

In parallel, the adoption of building information modelling (BIM) in EU member states is promising[26]. Physical and functional characteristics of places, e.g. buildings, or physical infrastructures, such as water, refuse, electricity, gas, communication utilities, roads, bridges, ports, tunnels are generated. Once this effort matures, emergency services will be able to utilize such building information models for their purposes, e.g. 3D indoor information.

Figure 3-5: 3D Model, City of Munich[27]

These interoperability-driven, activities are challenged by web-based applications, where mobile devices require simplified data structures with lightweight formats e.g. HTML5, WebGL[28] to reduce bandwidth requirements and improve response times. Besides, augmented/virtual reality (VR) technologies with VR glasses and game controllers offer an encouraging opportunity for the 3D world. Virtual reality allows users in the command room to explore a place with a virtual photorealistic view using special glasses. Although the geo-industry is in their early development stages, the realistic possibilities of presentation promises an even better imagination of the incident site like walk through animations, add analysis capabilities like potential security threats for crisis planning purposes, and most importantly, provide interaction (with gestures) in a real-time environment. Overall, emergency services should recognise that the importance of 3D visualization continues to grow. The central aspect in 3D visualization is the topic of platform-independent solutions. Therefore, emergency services should strive for linking 2D and 3D representations of their service area in a first step.

3.1.5 Spatial data sets and metadata[29]

The distributed responsibility and nature of geodata with overlaps and different descriptions requires the provisioning of interoperable geodata. Therefore, metadata are used and are increasingly standardized describing spatial data sets and spatial data services and making it possible to discover, inventory and use them. With metadata the spatial data sets become an identifiably collection of spatial data, which can be processed and are the key ingredient for spatial interoperability.

3.1.6 Geoinformation sources

The key source for GeoData are the national Cadastral and Surveying Authorities and commercial vendors where products like topographic maps and elevation data, aerial view products, or real estate cadastre (partially chargeable depending on resolution) are available. Further data portals, e.g. with satellite images, terrain models or digital elevation data in different solutions and actuality are available as well.

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[26] https://en.wikipedia.org/wiki/Building_information_modeling#Europe
[27] http://www.3dis.de/download/3d-pdf-stadtmodell-muenchen/ (source: http://www.citygml.org/)
[28] https://www.khronos.org/webgl/
[29] http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32007L0002&rid=1

Table 3-5: Data portals – Examples

Portal	Offer	Region	Price	Link
Copernicus Emergency Management Service	Rapid Mapping, Risk and Recovery; activation by "authorized users" (EU member states).	World	Free of charge	http://emergency.copernicus.eu ; access via the 24/7/365 Emergency Response Coordination Centre (ERCC) at the Directorate-General for Humanitarian Aid and Civil Protection (DG ECHO).
European Environment Agency	305 European cities (>100k inhabitants); update for appr. 700 cities (European cities >50k inhabitants)	Cities	Free of charge	www.eea.europa.eu/data-and-maps/data/urban-atlas Preliminary download (2012 data): http://land.copernicus.eu/local/urban-atlas/urban-atlas-2012
EarthExplorer	Landsat, OrbView-3, Sentinel-2 SRTM	World	Free of charge	http://earthexplorer.usgs.gov/
Digitalglobe ImageFinder	WorkdView, GeoEye-1,Quickbird, IKONOS	World	€	https://browse.digitalglobe.com/imagefinder
Reverb|ECHO	Landsat, SRTM, ASTER MODIS	World	Free of charge	http://reverb.echo.nasa.gov
Sentinel Data Hub	Sentinel-1, Sentinel-2	World	Free of charge	https://scihub.copernicus.eu/s2/#/home
National Cadastral and Surveying Authorities	Comprehensive map product offerings (analog, digital, on-line)	Country, State, Region	€ partial	Example Germany: http://www.geodatenzentrum.de/geodaten/gdz_rahmen.gdz_div?gdz_spr=eng&gdz_user_id=0
INSPIRE Geoportal	Spatial data sets and spatial data services, to view spatial data sets from the EU Member States	EU	Free of charge	http://inspire-geoportal.ec.europa.eu/discovery/
OpenStreet Map (OSM)	Free editable maps of the world (scale up to 1: 10.000)	World	Free of charge	www.openstreetmap.org Vector data: https://www.geofabrik.de/en/data/download.html
European Environment Agency	305 European cities (>100k inhabitants); update for appr. 700 cities (European cities >50k inhabitants)	Cities	Free of charge	www.eea.europa.eu/data-and-maps/data/urban-atlas Preliminary download (2012 data): http://land.copernicus.eu/local/urban-atlas/urban-atlas-2012

On-line access. Online-access of spatial information has become a standard functionality based on common technical standards via web map services (WMS)[30] and internet protocols (http). WMS are a synonym for standard web interfaces for obtaining spatial data (maps, aerial photographs, etc.) from distributed geospatial databases to complement the own spatial database. The OGC (Open Geospatial Consortium) has defined a set of standard interfaces which are broadly used in various industries on a global level. Predominantly, the WMS, the web feature service (WFS), and the web coverage service (WCS) are some of the main standards.

- **A WMS** is a standard web (http) interface for obtaining spatial data (maps, aerial photographs, etc.) from distributed geospatial databases. With WMS, remote GIS database can be accessed and the possibility of

[30] From en.wikipedia.org, www.opengeospatial.org

incorporating current geospatial data directly into the GIS of PSAP is possible. The response to a WMS request is one or more map images e.g. as JPEG, PNG …. That can be displayed.

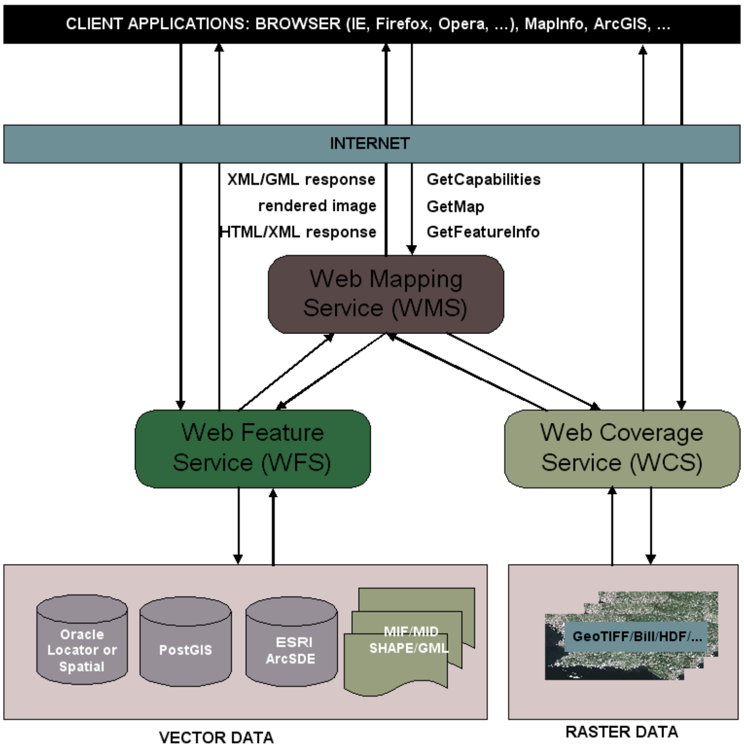


Figure 3-6: Illustration of Web Services[31]

- **The WFS** offers access to geographic information at the feature property level. As opposed to WMS, where only images are submitted, the WFS provides property information e.g. a "lake" is described as lake including its polygon which can bey spatially analysed.
- **Gazetteer Service (GS)**[32]. In many situations, geographic names provide one of the most important keys for referencing and accessing a variety of other information and GeoNames databases, called Gazetteers, are an information resource for representing places, groups of people and cultures. The GS is a specialization of the WFS which allows clients to search and retrieve elements of a georeferenced vocabulary of well-known place-names. Metadata are being used for platform-neutral access via an open web standard.
- **The WCS** defines the retrieval of multi-dimensional coverage data over the internet (space/time-varying phenomena. For instance, satellite images may contain varying degrees of light pollution, or coverages determine 1D sensor time series, or 3D X/Y/t image time series etc.

Usually, a combination of different GIS services is deployed to handle such datasets. As PSAPs have to cope with mission critical requirements, often the web services implementations are optimized to meet the performance requirements in the call collection and dispatch processes. A local caching mechanism makes sure that the geodata are available even if the remote source is temporarily not available or access times are too long. Also, further geodata processing is executed to cut larger map images into smaller images to optimize transmission times.

[31] Johan Vanhopplinus, Wikipedia, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=3223549
[32] https://portal.opengeospatial.org/files/?artifact_id=46964

Literally thousands of OGC web services are offering hundreds of thousands of maps and datasets meanwhile, partially free-of-charge. The key ingredient in these searches is the OGC Catalog Services – Web (CSW) Interface Standard. These services provide the ability to publish and search metadata for data, services and information objects to discover registered information resources – the prerequisite for spatial interoperability. Further search considering 1300+ WMS's and then some WFS, WCS, Sensor Observation Service (SOS) to query real-time sensor data, and CSW can be conducted here[33]. The national Cadastral and Surveying Agencies provide the online base data for PSAPs, as well.

It must be considered that in cross border/jurisdiction activities - e.g. an emergency caller is identified beyond the own jurisdiction – the incident location can only be pinpointed with the help of additional geodata from this area.

In terms of incident specific geodata requirement - e.g. missing persons, terror attacks or larger scale natural disasters - additional sources are available. Public agencies in EU member states frequently offer services which provide a 24/7 service for the rapid acquisition, processing and analysis of satellite data in conjunction with natural and environmental disasters. These services are often employed with worldwide humanitarian relief activities and for civil security purposes. Besides, private companies offer similar services for complex or long lasting image processing, continuous monitoring of geographical areas, quality measures and special purpose analysis, as well[34].

3.2 GeoData provisioning

There is no general rule to describe what geodata PSAPs usually require. It depends on the duties and responsibility as well as on the topographic situation in the PSAP service area. In case of mountainous situations more emphasis is probably on more detailed scales and elevation models, whereas urban areas require a more detailed view on streets and buildings with appropriate resolutions. Increasingly 3D-city models are being introduced to cope with the third dimension, and in some regions, indoor building maps such as floorplans or 3D models of interior spaces are used to provide understanding and awareness of the layout of critical infrastructure such as universities, corporate campuses, and industrial facilities.

As geodata like an incident location or the area of a venue or service area have direct relevance for incidents, frequently a split between the GIS and the CAD can be experienced, whereas the GIS is utilized for the visualization of Geodata kept in the CAD. GIS integration creates additional value in providing both the dispatchers and field personnel with situational awareness. Most CADs (used for call taking and dispatching) have integrated caller location identification, mapping of resources, mapping of streets and important objects, best route calculation for the first responders, maintain the attribute files of addresses, possibility of calling the vehicles via radio by a click on the map etc.. Table 3-6 summarizes typical geodata to exemplify the broad geodata foundation in PSAPs.

Table 3-6: GeoData examples in PSAPs

Base Data	Format / scale / system
Digital topographic map	TiFF 1:500.000, 1:200.000, 1:100.000, 1:50.000, 1:25.000, 1:10.000, 1:5.000 100 Pixel/cm, 200 Pixel/cm, 320 Pixel/cm and usually combined with cadastral information like street names, of geo-referenced buildings
Vector Data	Shape 1:500 000
Digital cadastral map	Raster data Tiff tiles 5kmx5km

[33] http://gptogc.esri.com/geoportal/rest/find/document?searchText=WMS&start=1&max=10&f=searchpage
[34] Example: Digital orthophotos DOP80 (WMS): Digital aerial images with 80cm resolution (LDBV Bavaria): http://www.geodaten.bayern.de/ogc/ogc_dop80_oa.cgi

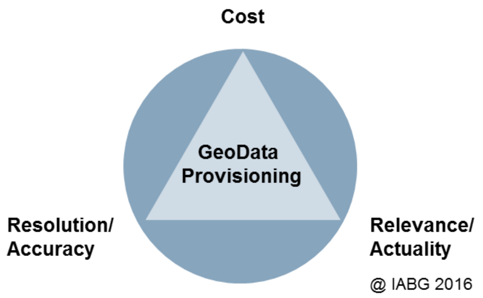
EENA asbl
info@eena.org - www.eena.org
is a non-for-profit association

Orthoimages	Raster data (Tiff) surface resolution: tiles: 0,2m: 1kmx1km 0,4m: 2kmx2km
Cadastral information e.g. address data, streets, cities, post-codes	Shape 1:1.000, building coordinates as text-file
Digital Contour Model	Raster data (Tiff tiles 2kmx2km)
Digital Terrain Model	Raster Grid 25m 1:25.000 or as vector base data (shape) including attributes like street name, road width, or object groups like traffic, water for spatial analysis
3D City Model (emerging)	Heterogeneous set of 2D raster (e.g. GeoTIFF), 2D vector-based data (e.g. AutoCAD DXF), 3D models (e.g. 3DGML), and thematic datasets
Thematic Data	
Public rail network	Predominantly vector data (shape)
Waterways and shipping	
Motorway network	
Utilities e.g. pipeline-networks, power-lines	
Jurisdictive borders, police, fire, hospital stations, PSAP service areas …	
Emergency Services related data	
Base Database updates e.g. new crossings, streets, buildings, temporal blockings	Depending on the deployment model, Geodata are managed both, in the GIS and in the computer-aided-dispatch (CAD) application. If the spatial reference is maintained in the CAD, GIS is utilized for visualization purposes. The data representation is frequently derived from the database architecture of the application and the availability of the source information. For instance, building plans might only exist as pdf or png.
Points of interest (PoI)	
Building plans	
Service related data, e.g. building access codes, safety information, risks and hazards, historic data	
Events and venues (time and location/ area dependent)	
Incident related data	
Incident and response team/ asset locations	
Tactical information e.g. operations zones, risk zones …	
Dispatch proposals, route calculations	

Despite these application requirements, emergency services always must balance between cost, accuracy and actuality of geoinformation to be used and maintained in the emergency management processes.

Time & update cycles. The European Location Framework (ELF) study[35] revealed update frequencies of topographic data in 2012. It reported that about 50% of the countries in scale 1:50 000 update data in less-than 2-4 years, and in 95% of countries in less than 5-10 years. Meanwhile, the update cycle of official sources like ordnance survey offices are between 0,5-3 years. However, one can assume that costly production of e.g. for aerial images/ topographic maps will not significantly drop below the 3 years from the time the image was taken until the final product is published.

[35] www.elfproject.eu/sites/default/files/ELF%20White%20Paper.pdf



Consequently, emergency services operations must continuously improve data maintenance processes and workflows to update data, e.g. new streets, crossings, addresses, buildings, PoI to ensure a close to reality data base. Open source information has reached a fair quality level. Increasingly, additional sources have to be considered to improve interoperability between agencies and jurisdiction, for instance for cross-boundary missions or ad-hoc requirements to provide almost real-time 3D georeferenced images for defined emergencies or disasters with short-term (minutes – hours) update cycles.

Therefore, geoinformation skills are necessary for efficient discovery and provisioning per service delivery/accuracy requirements in the mission critical processes. With these capabilities in place, the possibility to derive the data from aerial/satellite images or use if original data sources from surveyors in case more up-to-date geodata is given.

Cost. Prices for geoinformation have big variances in EU countries, but at least it can be assumed that price levels continue to decrease. The costs are basically driven by resolution, a minimum amount - e.g. number of square kilometres - and actuality of the data; the better resolution and the better the actuality, the more it costs.

Table 3-7: GeoData cost estimations (random examples)

Map/ Sensor	Resolution	Cost estimation
Digital Terrain Model	1m / 25m	80€ / 5€ per km^2
3D Buildings	Level of Detail 2	0,65 EUR/building
Pléiades Sensor	24h-Service	56€/km^2 (minimum 100km^2)
Aerial Image Generation	3cm	50k€ per mission

Data accuracy. As PSAPs require position accurate data, predominantly digital topographic models or landscape models, which are directly derived from survey data or photogrammetry, should be used as no generalization steps during data processing took place. Cadastral and Surveying Authorities or private geodata companies - e.g. for car navigation systems - are the preferred sources. It is to note that the map scale significantly influences data accuracy. The smaller the map scale, the less space there is for the visualization of an object. If such data are derived from generalized maps, it is usually unknown which guideline for objects and classification, or aggregation was applied. Therefore, emergency services should strive for different scales of an area to mediate such data accuracy influences.

3.3 GeoData maintenance

The previous sections indicated the need for robust geoinformation maintenance which ensures that data are appended or existing data are replaced to reflect changes in the world or in the underlying datasets. Basically, the secure, easy access and the efficient use of geographic data must be facilitated for emergency services operations. Essentially, GIS administrators need to be educated and tools & instruments must be available for further analysis and quality improvement. Core is the familiarity with existing geo guidelines and standards.

The main **maintenance** tasks are:

- the review of new geodata
- the submission of new geodata including data transformation due to different coordination systems aggregate and compress data to meet performance requirements
- to ensure cross-border consistency and accuracy of the data, including conformance testing
- to sustain metadata for interoperability and quality measures

- to ensure consistency between spatial information in location databases (such as addresses of wireline telephone subscribers), the CAD, and in the GIS (data clean-up)

Geodata **development** comprises:

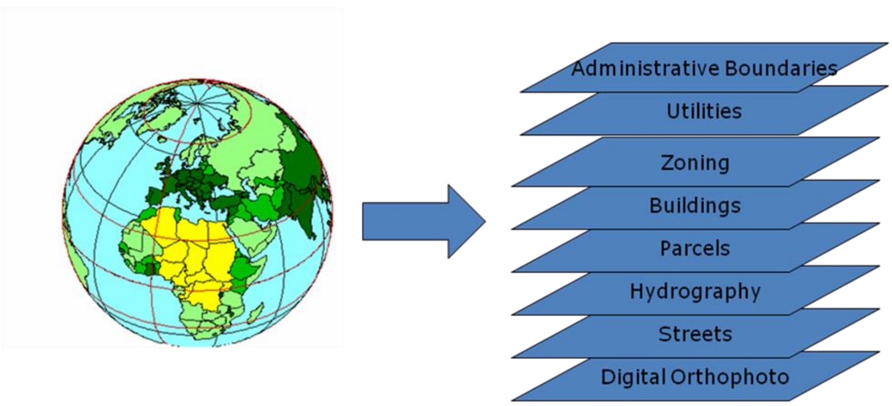
- Definition of data models and schemas of the geodatabase. For instance, for ad-hoc 2D/3D georeferenced images provided by drones, the application of 3D-city models etc. in addition to simple yet fundamental features like road centrelines, address points, and service boundaries
- Provisioning of additional layers for the convenience of the dispatchers in the control room and the introduction of new attributes for tactical analysis
- Processing and combination of new or revised datasets

Quality management. This is the core process in geodata management where the quality of geodata is measured and ensured. As quality is assessed, any errors that are identified must be conveyed to the original creators or the stewards of the data, so that problems can be remediated and data re-evaluated for quality. This cyclical maintenance workflow is key to managing the lifecycle of GIS data. In addition, mechanisms must be available to collect feedback on data quality from the geodata consumers as basis for the identification of errors and improvement areas.

Security and data policies. It is obvious that the utilization of geodata in a distributed environment creates security concerns. Usually, the on-line access to remote sources from secure PSAP infrastructure is prohibited. Vice versa, the access from mobile devices to central geodata requires secure networks. Therefore, a thorough network architecture must be implemented which copes with these requirements. Besides, license agreements to comply with legal prerequisites must be met, as well.

3.4 GeoData sharing and distribution

The main geodata consumer in the PSAP is the CAD which frequently itself embeds the GIS including the spatial database. Dispatchers are then in the position to visualize more in-depth spatial information on a specific area or location by overlaying multiple datasets and correlate them with each other.



The Geodata is organised by *layers*, with each layer representing a common feature.

Layers are integrated using explicit location on the earth's surface, thus geographic location is the organising principal.

Layers are comprised of **spatial** data which describes location (where) and **attributes** specifying what, how much, when.

Layers may be represented in vector format as points and lines, and in raster (or image) format as pixels. Raster layers can be combined with vector layers. The order in which layers are structured is very important to properly display the result.

All geographic data has 4 properties:

- **Projection:** the method by which the curved 3-D surface of the earth is represented by X,Y coordinates on a 2-D flat map/screen. Distortion is inevitable.
- **Scale:** the ratio of distance on a map to the equivalent distance on the ground. In theory GIS is scale independent but in practice there is an implicit range of scales for data output.
- **Accuracy:** how well does the database info match the real world? *Positional*: how close are features to their real world location?; *consistency*: do feature characteristics in database match those in real world?; and *completeness*: are all real world instances of features present in the database?

- **Resolution:** the size of the smallest feature able to be recognized. For raster data, it is the *pixel* size.

Two online examples for geodata combining thematic data will be shared. The first example exemplifies 112-PSAP locations, contact information and service areas in Bavaria, Germany, where raster, vector and thematic data are joined. One can imagine that future location-based routing services for emergency calls can easily utilize this dataset.

Figure 3-7: Bavarian PSAPs, service areas[36]

The second example provides on-line spatial information for communities and cities, which assume responsibility for coordination of disaster response.

GeoKAT[37] as a portal for counties and communities provides access to centrally maintained maps and thematic databases to answer typical questions of crisis management teams and incident leaders:

- Are schools, kindergartens, and nursing homes in the endangered areas that need to be evacuated?
- What age structures have the affected residents?
- Where there are gyms, trucks, camp beds, or sandbags located?
- Which area is impacted with an impending flood?

To be flexible, the geodata are stored on-site on laptops, as well. A synchronization mechanism keeps the data constantly updated and provides data offline in case the on-line connection is lost.

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[36] Example from the Bavarian Atlas (LDBV Bavaria): https://goo.gl/1lMkUE
[37] www.stmi.bayern.de/med/pressemitteilungen/pressearchiv/2016/100b/index.php

3.4.1 Deployment architectures

Geodata management infrastructures are being deployed more and more as services. These services act as a unit of abstraction for providing, changing and viewing spatial information. PSAP operators are then able to arrange the most efficient solution for their specific needs. This applies to a single PSAP deployment, to distributed command centres, or to multi-agency deployments.

Such deployment options allow to:

- decouple GIS management from incident management, protecting sensitive information in line with IT security and data privacy requirements.
- implement a secure on-line access to obtain and cache spatial information from remote databases. The geodata provisioning via standardized interfaces as well as for various devices of emergency services staff is possible from this site, as internet access is de-coupled from the sensitive command centre core infrastructure.
- setup a hosting/hybrid service in conjunction with partners. For instance, specialized geodata companies maintain the geodata on behalf of the government/emergency services or provide stand-by capacities in case of short term geodata processing tasks.
- deploy new services, e.g. location based call routing services, which utilize geodata as core feature.
- improve collaboration across agencies as access to spatial information can be granted more easily.
- utilize standard GIS products and services which eases compliance with geodata standards and also drives market and competition in the public safety niche

As for any centrally hosted service, the same advantages apply to centralized geodata management services:

- Consistent Geodatabase maintenance processes
- Used on demand
- Subscription based licensing
- Reduced operating expenditures (OPEX)
- Access on demand and available everywhere
- IT-Security compliant and multi-party GIS expert involvement

3.4.2 Interoperability

In today's emergency services environment, PSAPs generally build their own datasets, an archipelago of spatial information with little uniformity between systems. The direct reflex to this observation leads to the demand for wide-ranging interoperability of geo-spatial information to improve interaction between the emergency services organizations in Europe. A brief excursion into INSPIRE emphasizes the value of the orchestration of distributed spatial information and exposes the advantages and limitations of this EU wide initiative from an emergency services perspective. INSPIRE enables the sharing[38] of environmental spatial information among public sector organisations and facilitates public access to spatial information across Europe. The benefits for emergency service organizations are at least two-fold:

1. Base data (maps, images …) and thematic databases provided by the Cadastral and Surveying Agencies increasingly comply with interoperable standards, which enable PSAPs to acquire these datasets easier and with minimized integration effort.
2. INSPIRE significantly leverages the on-line provisioning of geodata, which results in shorter provisioning cycles. Emergency services increase their perception of trusted and official spatial information sources and become familiar with the distributed spatial databases.

[38] http://inspire.ec.europa.eu/index.cfm/pageid/2: Interoperability: Possibility to combine spatial data and services from different sources across the European Community in a consistent way without involving specific efforts of humans or machines. It provides access to spatial data sets through network services, typically via Internet and inherently comprises the harmonization of existing data or the transformation via services for further publication.

The full set of spatial data required for emergency services operations will not be covered, though, as standardized data models considering semantics and ontologies for incidents, resource types i.e. for incident/emergency/disaster related geodata are not subject of INSPIRE. Emergency services organizations and industry are encouraged to establish a geospatial working group for emergency services organizations, like DGIWG[39] as geospatial standardization working group for the defence organizations to leverage standardization in conjunction with emerging data services and collaboration requirements.

4 Conclusions

Without any doubt, spatial information has become a mission-critical attribute of today's emergency services operations. PSAPs are encouraged to accept that Geodata are more than just a digitized map at the work place. Situational awareness and operational needs require the composition of distributed spatial information online, which enables emergency services to complement existing geodata with additional data – it is no longer "map centric". INSPIRE is understood as one of the key enablers to assist ordnance and survey authorities in the EU member states to merge towards standardized and interoperable base datasets.

In combination with the advancement of mobile technologies, spatial intelligence no longer resides in the control room only. Geodata can be accessed from anywhere with almost any device, and emergency location/ routing services utilize such data service, as well. In addition, location accuracy is improving outdoors due to improvements in satellite navigation systems (GNSS) and indoor location accuracy is improving due to advances in Wi-Fi and beacon-based positioning technology (such as iBeacon). Higher-accuracy caller locations, both outdoors and indoors, support the emergency services mission of providing response more quickly. Call-takers can locate callers faster, with less error, and field responders can navigate to locations more accurately, even indoors. The multitude of positioning technologies will continue to grow and improve in the future, which will continue to improve response times and increase the importance and need for higher-accuracy geodata.

Aerial imaging for rapid orthophoto processing with RPAS is an increasing application. Broader technology penetration with smart algorithms and sensors in conjunction with the driving consumer market will significantly reduce so far expensive geodata acquisition and processing effort of emergency services organizations. Geodata, processes "on-the-fly", improve situational awareness and decision support e.g. for special response teams in terror attacks, weather related disasters, field staff safety and support.

As mature and worldwide accepted technical standards for geospatial interfaces are available for years, it is up to emergency services and governments to establish a secure network access, in line with IT security and data privacy regulations and guidelines. Intermediary steps with a decoupled staging area can help bridging the security concerns.

Accordingly, the transformation of PSAP operations from applications management towards a service oriented spatial data service delivery and service management organization should be considered in organisational planning and future technical PSAP architecture discussions.

[39] www.dgiwg.org

5 EENA Recommendations

Stakeholders	Actions
European Authorities	Continuous support of the standardisation process within ISO TC211 and CEN TC287
National Government	Continuous support of the standardisation process within ISO TC211 and CEN TC287 Setup bi-mutual agreements between states/countries to exchange geodata for emergency services purposes. Establish a geospatial working group for emergency services organizations to drive standardisation in conjunction with interoperability and collaboration
National / Regional Authorities	Complete assessment of current mapping capabilities, including datasets, maintenance processes, standards and workflow policies. Defining the cooperation policies between different institutions / GIS users; data access principles; conversion rules. Building the relevant databases themselves, taking the required actions to ensure that geodata remains accurate and well-maintained spatial, that updates to geodata are made in a timely fashion and made available as quickly as possible, and that spatial information are available and accessible when they're needed. Strive for online-access with along data security and data privacy guidelines, as EU-wide significant effort is spent on interoperable geoinfrastructures.
Emergency services	GeoData for emergency response represent a significant investment. Spatial information must be maintained and stringent quality assurance and quality control systems must be established to avoid gaps and inconsistencies. Improved location information (emergency callers, staff and assets) leverages the need for increased base map data quality and accuracy. Consider ad-hoc aerial imagery provisioning for improved situational awareness and field staff safety. Define geodata cooperation needs with other (adjacent) agencies. Establish pilot projects for 3D models to develop operational requirements.
National telecommunication regulator Network operators	Provide legal and technical framework for call routing and PSAP selection based on already available spatial information. Complete and maintain spatial database of their resources (transition networks, cellular networks, fixed telecommunication network).
Industry	Maintain cooperation and support interoperability through Open Geospatial Consortium and relevant standardization/ interoperability initiatives.

6 Terms and Acronyms

All definitions of terms and acronyms used in this document are listed below in alphabetical order.

Acronym	Description
AML	Advanced Mobile Location
BIM	Building Information Modelling
CAD	Computer Aided Dispatch Application
CEN	European Committee for Standardization - Comité Européen de Normalisation
CityGML	City Geography Markup Language
CSW	OGC Catalog Services - Web
DEM	Digital Elevation Model
DXF	Contour elevation plots in AutoCAD DXF format (Autodesk)
ELF	European Location Framework
ELISE	European location interoperability solutions for e-government, a sub-activity of ISA
EMT	Emergency Medical Technician
GeoTIFF	TIFF (Tagged Image File Format) variant enriched with GIS relevant metadata
GIS	Geographical Information System
GNSS	Global Satellite Navigation Systems
GS	Gazetteer Service
INSPIRE	Infrastructure for spatial information in Europe
ISA	Interoperability solutions for public administrations, businesses, and citizens
ISO	International Standardization Organization
JPEG	Joint Photographic Experts Group, lossy compression method of digital images
LoD	Level of Detail
NG112	Next Generation 112
OGC	Open Geospatial Consortium[40]
OPEX	Operational expenditure
Ortho-imagery	Aerial photograph/image geometrically corrected ("ortho-rectified") so the scale is uniform.
PNG	Portable Network Graphics as a raster graphics file format for lossless data compression
PSAP	Public Safety Answering Point
PSBD	Public Safety Bomb Disposal
RPAS	Remotely Piloted Aircraft System, see also UAS
SAR	Search and Rescue
Shapefile	vector data GIS format (ESRI)
SLAM	Simultaneous localization and mapping[41] problem of constructing/ updating a map of an unknown environment while simultaneously keeping track of an agent's location within it.
SOS	Sensor Observation Service
TC	Technical Committee
UAS	Unmanned Aircraft System, see also RPAS
UVS	Unmanned Vehicle System
VR	Virtual Reality
WebGL	Web Graphics Library
WCS	web coverage service, OGC standard
WFS	web feature service, OGC standard
WGS84	World Geodetic System with its latest revision in 1984 (standard coordinate system)
WMS	web map service, OGC standard

[40] www.opengeospatial.org
[41] https://en.wikipedia.org/wiki/Simultaneous_localization_and_mapping

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