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Emerging technologies for the Early location of Entrapped victims under Collapsed Structures & Advanced Wearables for risk assessment and First Responders Safety in SAR operations

D3.2 Situation Awareness Model - specification

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Executive Summary

This deliverable D3.2 "Situation Awareness Model - specification" presents the methodology and the actual technical work in the frame of the Situation Awareness model. Situation Awareness (SA) is the accuracy with which people perceive, understand and anticipate changes in their environment that are relevant to achieving operational goals. Based upon this principle, the respective model aims at providing the conceptual representation of the core entities, which will be represented by concepts and cover specific aspects of the SA domain. These aspects can be summarized as follows:

- The decisions that SNR actors make during the course of S&R operation.
- The conceptual representation of critical information required in order to support the various actors with their tasks.
- The conceptual representation of the important information flows that potentially exist between involved actors.

These key aspects, which derive from DoA will be the basis for the identification of the main concepts that will constitute the SA model. Finally, the effective implementation of this deliverable will assist the effective information retrieval instantly, during the S&R operations.

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ACRONYMS

BFO	Basic Formal Ontology
CCO	Common Core Ontologies
CFO	Chief Financial Officer
D	Deliverable
DO	Disease Ontology
DSS	Decision Support Systems
EDXL	Emergency Data Exchange Language
EMT	Emergency Medical Technician
EU	European Union
KM	Knowledge Management
KOS	Knowledge Organization Systems
OWL	Ontology Web Language
PS/EM	Public Safety and Emergency Management ontology
RDF	Resource Description Framework
RFID	Radio-Frequency Identification
SA	Situation Awareness
SAM	Situation Awareness Model
S&R	Search and Rescue
UAV	Unmanned Aerial Vehicle
WGS84	World Geodetic System 1984

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1 Introduction

1.1 Scope and Objectives

The current deliverable constitutes a report aiming at documenting the technical activities undertaken within the context of Task T3.2 "Situation Awareness Model" and more specifically, the definition of the model, which will constitute an extendable set of main concepts in Situation Awareness domain. Towards the accomplishment of the aforementioned goal, all the requirements, input and valuable feedback of Search and Rescue's consortium, which has been documented in the respective deliverables, will be taken into account. Subsequently, existing approaches in Situation Awareness domain, along with well-established ontologies will also be utilized towards the conceptual representation of the model. Moreover, the current requirements of resources and the respective information will also be documented, in order for the model to be defined properly. Finally, the ultimate goal of this model is to be as simple as possible, while allowing maximal flexibility and extensions throughout Search and Rescue's project lifecycle.

1.2 Relationship with Other Tasks and Deliverables

The S&R Deliverable D3.2 documents the technical activities undertaken in the frame of Task T3.2 "Situation Awareness Model" and more specifically, the definition of the model which will constitute an extendable set of main concepts in Situation Awareness domain. The main objective of this document is to provide a coherent version in terms of technical specification of the SA model, by taking under consideration the input from the following S&R deliverables:

- D1.2 "Report on the functional specifications of S&R", where the end-user requirements are identified, as well as the practical needs of operational procedures that will be used in the S&R pilots are defined.
- D3.1 "Requirements to knowledge management and SA Model", where the methods for finding the information requirements that first responders need to achieve a level of situation awareness are described.

1.3 Structure of the document

In order to address all the aspects relevant to the scope of D3.2, the present deliverable has been structured as follows:

- Section 2 describes the methodology and procedures taken into consideration when designing the model.
- Section 3 discusses existing approaches around situation awareness in general, as well as the current state-of-the-art.
- Section 4 documents the gathered requirements for the model, regarding Knowledge Management (KM), Decision Support Systems (DSS), as well as user requirements.
- Section 5 presents the model specification (vocabularies and ontologies incorporated into the model for additional usability and compatibility with existing widely used standards) and the model itself.
- Finally, Section 6 concludes the document and discusses future work.

2 Methodology

In the current section both the working and model methodology will be presented. More specifically, at first, the working methodology will be specified, not only up to M9, but also until M18, when the second and final version of the Situation Awareness model is expected to be delivered. Apart from the working methodology, several approaches that focus on the semantic meaning of the data, resolving issues of data redundancy and semantic interpretation during the data integration process will also be described.

2.1 Working methodology

The definition of the Situation Awareness model will be delivered in two releases. The first release, which is documented in the present deliverable, constitutes the work that has been performed in the frame of task T3.2 "Situation Awareness Model" until M9. The second release will be delivered in M18 and will document the updated version of the SA model based on the relevant work.

The methodology that has been followed for the first version of the definition of the Situation Awareness model includes the following steps:

1. Identification of the main actors and their roles through S&R use cases from the work that have been conducted in the frame of WP1.
2. Definition of the main concepts that have been identified from the technical workshops in the frame of WP3, as well as from D3.1 "Requirements to knowledge management and SA Model", where the SA requirements have been described in detail.
3. Construction of the ontology that will represent the SA model by interconnecting the concepts among them, in order for the proper information flow to be established.
4. Enhancement of the semantic model with widely used ontologies in order to support both interoperability and reusability of state-of-the-art approaches in the world of RDF representation.

2.2 Semantic Model Objectives

Due to the fact that the Situation Awareness model aims at representing information through concepts, which will be derived from entities of various domains, an ontology that will facilitate the coherent representation of such information will be constructed. More specifically, an ontology is used to explicitly define schema terms and address any semantic conflicts in heterogeneous information systems. Moreover, it provides the accurate semantic interpretation of data from multiple sources and verifies the mappings used to integrate data from multiple sources [1]. Taking all these into account, the concepts that have been identified from the Situation Awareness domain, along with their interconnections constitute the SA semantic model, which will be represented by the respective ontology. Based upon this approach, the main objectives that can be satisfied by a semantic model are presented below.

- **Interoperability**: A semantic model should provide an ontological model to enable the exchange of information through different agents during an S&R operation. Thus, within the context of Search and Rescue, a representative model of emergency management is provided in order to support internal and external usage scenarios.
- **Data Harmonization**: A semantic model should be used for data harmonization. Within the context of Search and Rescue, the semantic model covers the domains of the requisite areas

of the platform in order to conceptualize the data which are imported from the various data resources.

- **Provisioning of linked data**: Within the context of Search and Rescue, the harmonized data will be provided as linked (RDF) data to the Decision Support System (DSS) components of the overall architecture. In order to address linked data provisioning, the semantic domains of the semantic model will be extended in order to provide the right vocabulary so as to integrate and exploit external content from the various linked data providers.

2.3 Model Construction

The domains of knowledge of Search and Rescue focus mainly on the Emergency Management and first responders, while capturing a wider area of knowledge, semantically related to Emergency Management. These domains of knowledge need to be brought together under the umbrella of the semantic model. This section describes the methodology used to develop this conceptual model. The approach adopted to develop the semantic model in many aspects mirrors the one used in METHONTOLOGY, a methodology to build ontologies from scratch defined by Fernandez et.al. [2], with the ontology lifecycle being viewed as an evolving prototype in both approaches.

METHONTOLOGY activities consist of specific steps. Initially, the main tasks are planned, followed by specifying the ontology purpose, as well as the end users and use cases it needs to cover. Then, by using knowledge-based systems knowledge elicitation techniques, knowledge must be acquired, so that conceptualization by making a conceptual model structuring domain knowledge is possible, including making a terms glossary and grouping related terms. After the integration of existing ontologies to our own, the ontologies must be implemented in a formal language, while the model must be evaluated with respect to the specification. Finally, the ontology needs to be documented and maintained.

Following and adapting this method, the development of the semantic model consists of the following steps:

1. Specification of the high-level requirements for the semantic model based on the feedback we gathered from D3.1 “Requirements to knowledge management and SA Model”.
2. Definition of the actors: they are defined in both WP1 and D3.1.
3. Definition of simple use cases. Simple use cases are used to provide a first instantiation of the conceptual model, based on the defined use cases.
4. Acquisition of knowledge through literature review, in parallel with requirements analysis. This stage also involves exploring and examining relevant existing ontologies that could be reused. Section 3 provides the results of this step.
5. Development of a first draft of the overall conceptual model to structure the domain knowledge. This draft will be further developed and updated during the development of Search and Rescue.
6. Formalisation and extension of a glossary of terms for key domain concepts, in addition to grouping together related terms. This also takes into consideration the work that has been undertaken in D3.1 for the definition of the model’s actors and main concepts.
7. Formalisation of the first definitions for the model through their implementation in Protégé (version 5.5.0), with the main classes, object and data properties specified.

3 Existing Approaches Around Situation Awareness

In this section, existing widely used approaches in situation awareness tasks will be presented while, the definition of situation awareness and knowledge management is provided in D3.1 "Requirements to knowledge management and SA Model". It should be noted that situation awareness can be applied in a number of domains, some representative ones briefly described in section 3.1. Moreover, relevant ontologies that can be utilized in the context of SA domain will also be specified in section 3.4.

3.1 Situation Awareness domains

3.1.1 First Responders

When lives are on the line, optimal situational awareness for law enforcement officials, firefighters, and Emergency Medical Technicians (EMTs) is crucial. First responders must be able to perceive their environment and understand the threats they're facing in order to respond appropriately. They should be properly informed about the situation at hand, in order to be fully prepared to assist without worsening the situation or putting themselves at risk.

Today, firefighters, first responders, police officers, and other decision-makers in public safety understand the vital role that situational awareness plays in successful missions — whether that's responding to a noise complaint, putting out a four-alarm fire, or rescuing flood victims.

For instance, let's consider a building fire scenario. For a firehouse that's established robust SA, much of the logistical work will have been done before the crew even arrives on the scene. If a building's fire system has connected alarms, sensors, and cameras, firefighters can use that information to understand the fire's location and cause; the building's layout; and whether or not there are individuals in need of rescue. This kind of information is invaluable — it saves lives, mitigates damage, and keeps firefighters safe.

3.1.2 Transportation and Logistics

In the transportation and logistics sector, the challenge has remained the same over the years: getting products from one place to another at competitive speeds, while maintaining margins. In today's era, that means investing in technologies that can improve visibility and logistical decision-making at every stage.

For logistical awareness, technologies like RFID tags and blockchain can improve load tracking, allowing partners up and down the supply chain to instantly check delivery status. Having comprehensive and up-to-date visibility into logistics operations allows the supply chain to find efficiencies, cut costs, and improve delivery times. With systems designed to make the status of drivers and trucks visible, managers are able to ensure their fleet can cover all routes, compensate for breakdowns, and even take advantage of last-minute load opportunities.

3.1.3 Enterprise / Business / The Corporate Office

Enterprise leaders must address a variety of challenges and threats — from venturing into new markets to responding to all manner of crises. If the stock tanks, is the enterprise equipped to respond? To succeed, corporate leadership must understand both the current context and the potential consequences of their decisions. That boils down to collecting and surfacing the right data. Critically, what the "right data" is will change depending upon the situation. What is relevant information during a hurricane will not be the same information that is relevant in the hours following the announcement of a major tariff. Likewise, that which is relevant to a branch manager will be different from that which is relevant to a Chief Financial Officer (CFO).

Leveraging data in this way is easier said than done. Data is often difficult to access, manipulate, or transport, and is often tied up in legacy applications and databases. Other data sources — from the still-nascent IoT, for example — may not have been configured to allow the people that need the information to get it at the right time. In the context of the corporate workplace, neither the concept of situational awareness nor the fundamental technologies required to enable it are any different than in, say, the military. There are, however, certain cultural idiosyncrasies, and technological hornet's nests which make this area a particular challenge.

3.1.4 Security

Most event and venue security teams are already working with an array of technologies that includes cameras, alarms, sensors, and other systems. What they're often missing is the one technology that brings these arrays into a single pane of glass. Shifting between a pager, three iPhone apps, and a walkie talkie is conducive to neither speed nor efficiency. Security teams need to respond to threats quickly — if the nature of the threat is not understood fully and immediately, the danger multiplies.

A powerful situational awareness security solution will integrate the information from these disparate systems into one application or platform. Ideally, security teams should be able to have instant access to status and alerts across all their devices. If a gun goes off, security staff should be able to view the location of the gunshot on a map, see video footage of the area, and push commands to relevant personnel. The staff in closest proximity could receive an immediate notification that they must move to the area. At the same time, the nearest hospital could receive an alert that could help them prepare.

3.1.5 Smart City and Public Service

Investing in situational awareness solutions has the potential to benefit a wide variety of municipal departments and services. For instance, automatic alerts and instructions could save lives if sent in response to dangerous weather conditions, electricity outages, health alerts, and other urgent situations. Smart city sensors could also respond to localized or individual dangers, sending out alerts based on nearby shootings or notifying the nearest hospitals and EMTs in the event of a car crash.

Greater visibility can also help citizens on a day-to-day basis. For instance, managing traffic is a major task for cities, and smart city technology can contribute in this regard, helping drivers avoid road closures, accidents, and slowdowns. Similarly, providing tracking information for buses and subways allows public transit users to plan their commutes more efficiently.

3.1.6 Customer Service and Retail

In the shifting retail landscape — where e-commerce is setting a high (and quickly rising) bar — retailers are being forced to evolve, develop new capabilities, and compete in emerging spaces. To succeed in this environment, companies are turning to situational awareness technology built for retail and designed to elevate the customer experience.

When it comes to product management, alerts can provide critical insights. Refrigerators with digital thermometers can ping the appropriate personnel in the event of an issue. Cameras with facial recognition and robust system integration can help staff address suspicious behavior and theft. Such improvements play into effective customer service, too. With RFID tags and integrated inventory systems, low levels of products on the shelves can trigger manager alerts and automatic re-ordering, ensuring that customers can always get what they need, when they need it.

3.1.7 Military

During military operations, fully understanding the conditions of the situation at hand can mean the difference between life and death. The concept of situational awareness was, in fact, born in the U.S. military, and is as significant today as ever. Military forces need a tactical edge — and that can come from insights into elements like enemy position, hazard location, and troop readiness.

With the right technologies, these insights are possible. Unmanned aerial vehicles (UAVs) can scan enemy areas to create layout and hazard maps before action must be taken. Troops can use voice communication and automated tracking technologies to avoid friendly fire and register commands. Wearables can send ongoing situational updates to commanders, including video and audio information.

The key is to bring all this data and more into one situational awareness system. Commanders must make decisions based on all available information, and there isn’t time to look through five different databases or five different applications. Technology should deliver fast, critical, and accurate updates that can enable live-saving decision-making.

3.2 Characteristics of Situation Awareness

While the above domains are vastly different, they all include common characteristics a situation awareness model should have:

- Integration of numerous datasets and services in a unified and efficient way. The resources are most likely heterogenous and, consequently, must be homogenized first.
- Fast performance in decision-making. In risky situations, every second matters.
- Efficient representation of information. Since resources are certain to have overlapping terminology and involved actors and properties, it is paramount to provide a representation that will be minimal and cover everything. Additionally, the representation should be as flexible as possible to foresee potential adaptations and extensions.

Most developed situation awareness models are descriptive. Endsley [3] presents a descriptive model of situation awareness in a generic dynamic decision-making environment, depicting the relevant factors and underlying mechanisms. Figure 1 illustrates this model as a component of the overall assessment-decision-action loop and shows how numerous individual and environmental factors interact. Among these factors, attention and working memory are considered the critical factors limiting effective situation awareness. Formulation of mental models and goal-directed behavior are hypothesized as important mechanisms for overcoming these limits.

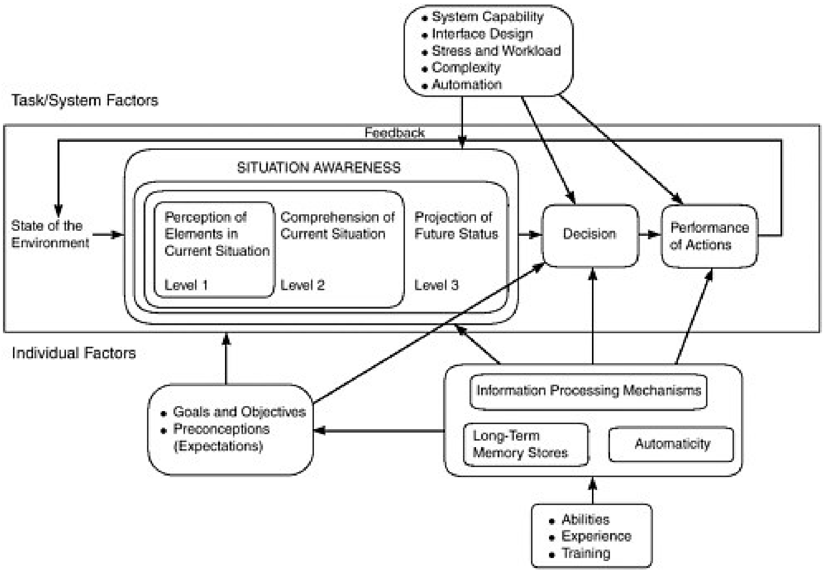

Figure 1: Generic decision-making model centered on the situation awareness process.

Generally speaking, there are four main approaches in order to define and explain SA:

- User of the *information-processing* model in defining and explaining SA. Our proposed model falls into this category.
- Use of the *perception/action cycle* in definitions and explanations of SA.
- Equating SA with *expertise*.
- Use of SA as a mere *description* of a behavioral phenomenon.

The potential limitations/criticism towards each approach, as well as a short summary for each are provided in Table 1.

Table 1: Summary of approaches used to discuss SA and potential problems/criticisms with each of them.

Approach	Summary	Potential Problems/Criticisms
Use of Information-Processing Models	Traditional, psychological constructs are discussed in terms of their impact on SA (e.g., attention, long-term memory, perception, and automaticity).	• Many of these psychological constructs are themselves not well understood. • This approach may cause one to conceptualize SA as a static end-state rather than a dynamic process.
Use of Perception-Action Cycle	SA is discussed in terms of the cyclical process of perceiving information in the environment, utilizing pre-existing knowledge structures, and exploring the	• This approach also utilizes several psychological constructs that are themselves not well-understood (e.g., schemata, exploration). • The measurement of SA implied by this approach is unclear at best.

	environment.	
Decision-Making Models	SA is demonstrated by expert-level performance, and SA is equivalent to situation assessment.	• Expert-level performance is a necessary condition for SA, but it is probably not a sufficient condition for SA. • There may be difficulties in operationally defining expert-level performance. • Models of situation assessment emphasize one psychological construct in particular that is not well-understood (i.e., the schema).
Phenomenon description	SA should be used as a tool for categorizing situations (i.e., as a Level 2 construct) but should not be used as a psychological construct implying cause and effect (i.e., as a Level 3 construct).	• Why SA is needed to categorize events is questionable.

3.3 Existing Situation Awareness models

Due to the nature of Situation Awareness, there are numerous ways they can be represented and function. With the evolution of Semantic Web technologies and Internet of Things (IoT), semantic models have been proposed to cover numerous SA scenarios.

One of the very first was presented in the work of Matheus et al. [4]. The model is oriented towards military applications and as a result represents mainly entities such as battalions, formations, goals and physical objects. However, the concepts and schemes described are generic, increasing the reusability of the proposed model. Additionally, of special note is the incorporation of a temporal dimension in the representation of information.

A step towards evolving situation awareness focused on images and streaming was proposed by Pimentel-Nino et al. [5]. Their intent was to enhance situation awareness in non-computer aided processes as in emergency operations. The proposed perceptual semantics relate to end user requested resolution in the temporal domain for a better assessment of event's evolutions seen from streaming video. Adaptation is enabled at transmission via a perceptual semantics feedback loop to adapt source coding on-the fly in terms of frame rate.

Furthermore, the work of [6] explores the visual design of SA for large-scale data with a focus on Social Media. The use of online Social Media is increasingly popular amongst emergency services to support Situational Awareness (i.e. accurate, complete and real-time information about an event). They describe an approach where levels of SA have been matched to corresponding visual design recommendations using participatory design techniques with Emergency Responders in the UK.

3.4 Relevant ontologies

In this subsection, we are going to discuss existing relevant ontologies which are state-of-the-art and widely used in the world of RDF representation.

3.4.1 FOAF

FOAF[1] (an acronym of friend of a friend) is a machine-readable ontology describing persons, their activities and their relations to other people and objects. Anyone can use FOAF to describe themselves. FOAF allows groups of people to describe social networks without the need for a centralized database. FOAF is a descriptive vocabulary expressed using the Resource Description Framework (RDF) and the Web Ontology Language (OWL).

3.4.2 SKOS

SKOS[2] is an area of work developing specifications and standards to support the use of knowledge organization systems (KOS) such as thesauri, classification schemes, subject heading systems and taxonomies within the framework of the Semantic Web. It provides a standard way to represent knowledge organization systems using the Resource Description Framework (RDF). Encoding this information in RDF allows it to be passed between computer applications in an interoperable way.

Using RDF also allows knowledge organization systems to be used in distributed, decentralized metadata applications. Decentralized metadata is becoming a typical scenario, where service providers want to add value to metadata harvested from multiple sources.

For the purposes or the project, SKOS is paramount in order to properly organize and represent entities and schemes.

3.4.3 GeoNames

GeoNames[3] (or GeoNames.org) is a user editable geographical database available and accessible through various web services, under a Creative Commons attribution license. The project was founded in late 2005. The GeoNames dataset differs from, but includes data, from the US Government's similarly named GEOnet Names Server which establishes the official repository of standard spellings of all non-US geographic names.

The GeoNames database contains over 25,000,000 geographical names corresponding to over 11,800,000 unique features. All features are categorized into one of nine feature classes and further subcategorized into one of 645 feature codes. Beyond names of places in various languages, data stored include latitude, longitude, elevation, population, administrative subdivision and postal codes. All coordinates use the World Geodetic System 1984 (WGS84).

Due to the nature of this project, this dataset can have great utility when describing geospatial information.

[1] http://xmlns.com/foaf/spec/

[2] https://www.w3.org/2004/02/skos/intro

[3] https://www.geonames.org/

3.4.4 WordNet

WordNet[4] is a large lexical database of English. Nouns, verbs, adjectives and adverbs are grouped into sets of cognitive synonyms (synsets), each expressing a distinct concept. Synsets are interlinked by means of conceptual-semantic and lexical relations. The resulting network of meaningfully related words and concepts can be navigated with the browser (link is external). WordNet is also freely and publicly available for download. WordNet's structure makes it a useful tool for computational linguistics and natural language processing. However, for the purposes of Search and Rescue, it can serve as a valuable accompanying dataset with the goal of correlating similar concepts and schemes, effectively grouping similar concepts of the numerous components involved in the project.

WordNet superficially resembles a thesaurus, in that it groups words together based on their meanings. However, there are some important distinctions. First, WordNet interlinks not just word forms—strings of letters—but specific senses of words. As a result, words that are found in close proximity to one another in the network are semantically disambiguated. Second, WordNet labels the semantic relations among words, whereas the groupings of words in a thesaurus does not follow any explicit pattern other than meaning similarity.

3.4.5 Empathi

In the domain of emergency management during hazard crises, having sufficient situational awareness information is critical. It requires capturing and integrating information from sources such as satellite images, local sensors and social media content generated by local people. A bold obstacle to capturing, representing and integrating such heterogeneous and diverse information is lack of a proper ontology which properly conceptualizes this domain, aggregates and unifies datasets. The empathi [7] ontology conceptualizes the core concepts concerning with the domain of emergency managing and planning of hazard crises. Although empathi has a coarse-grained view, it considers the necessary concepts and relations being essential in this domain.

3.4.6 POLARISCO

POLARISC Ontologies [8][9] (POLARISCO) is a modular ontology that defines the Knowledge of French emergency responders that are involved in the disaster response process. It is developed in the context of the French project POLARISC ("Plateforme OpérationnelLe d'Actualisation du Renseignement Interservices pour la Sécurité Civile"). The POLARISC project started in 2017 to propose an ontology-based crisis information management system for operational disaster response.

POLARISCO extends from Basic Formal Ontology (BFO)[5] as an upper-level ontology and Common Core Ontologies (CCO)[6] as a mid-level ontologies, and reuse classes from Public Safety and Emergency Management ontology (PS/EM ontology) and Disease Ontology (DO).

POLARISCO is composed of a set of ontologies including:

- POLARISC Common Core ontology
- Firefighters ontology
- Healthcare units ontology

[4] https://wordnet.princeton.edu/

[5] https://github.com/CommonCoreOntology

[6] : https://github.com/CommonCoreOntology

- Police ontology
- Gendarmerie ontology
- Public Authorities ontology
- Messages ontology
- Healthcare resources ontology

3.4.7 IMPRESS

The IMPRESS Ontology includes the main concepts and the relationships between the concepts of the health emergency management domain, in the context of the IMPRESS Platform. The ontology thus represents the disastrous events, the resources, the activities and the agencies that are involved in a health emergency, as well as the relationships among them. The ontology was developed in the H2020 project of the same name. As the concepts represented in IMPRESS are closely related to Search and Rescue's workflows, this ontology can provide many reusable assets for this project's semantic model.

3.4.8 beAWARE

The beAWARE [10] ontology is an "all-around" lightweight crisis management ontology for climate-related natural disasters and represents the following key aspects:

- Information relevant to climate-related natural disasters.
- Analysis of data from multimodal sensors.
- Rescue team assignments.

4 Semantic Model Requirements and Objectives

In this section, the requirements gathered from all relevant deliverables, input and valuable feedback of Search and Rescue's consortium will be presented. These requirements are further divided into main categories to better address them. More specifically and based on the input that has been gathered from D3.1 "Requirements to knowledge management and SA Model" so far, the specific domains that cover the SA requirements have been identified. These domains are presented separately, due to the fact that each domain represents different kind of information. Right after the presentation of each domain the specific objectives that need to be fulfilled by the SA model will follow. Subsequently, the way that these objectives can be satisfied through the conceptualization of the aforementioned domains, along with the concepts that derived from each specific domain are also presented. The resulted concepts will constitute the main classes of the SA ontology.

4.1 Knowledge Management

One of the main goals of S&R is to support access to various sources in order for the necessary information to be collected. Based on this information, a knowledge base mechanism will identify the key resources for a variety of incidents and the emergency response along with the decision support mechanism will function properly. Moreover, the model needs to provide a proper and unified terminology for the components of the project, as the de facto representation of information they will be exchanging. First of all, the foundation of shared awareness can be observed in the following convergence points between first responder teams:

- Incidents and hazards
- Command, Control, Coordination, Communication sites (C4 sites)
- Assets
- Infrastructures
- Cordons, Zones and Areas

Apart from that, the model should properly represent the following core concepts for the purposes of Search and Rescue, as they were identified during the process of requirement analysis in the context of the Knowledge Management domain:

- **Actors and roles of actors**. A representation of every type of first responder involved in the operations.
- **Emergency incident**. Incidents should be properly represented, providing as much as detailed information as possible.
- **Patient**. The model should represent injured individuals throughout operations, focusing on providing detailed information about their status, blood pressure, location etc.
- **Resources**. Every actor involved in the operations requires resources. They are further divided into first responders', first receivers', supplies and equipment (assets such as devices, wearables, vehicles etc.). All types and subtypes of the resources should be properly represented, focusing on well-defined relations between resources and actors.
- **Data types**. The data types are very important when representing information. Numerical values should be able to accommodate arbitrary accuracy, while messages should conform to Emergency Data Exchange Language (EDXL) standards. Additionally, serialized information should be encoded as received in order to enhance performance (deserialization is much faster than field-to-field processing).

- **Communication**. Various means of communication will be encountered in operations, such as voice, image, GPS, Wi-Fi and Bluetooth. The model should properly represent those.
- **Location**. Geographical locations, positioning and coordinates are all very important factors for the success of an operation. They are even more important when involving multiple organizations, authorities and nations. The model will focus on encoding this information according to widely used standards.
- **Time**. This adds a challenge to the representation of information, since temporal data add yet another dimension in representing information. Extra care must be taken to ensure redundancy and non-verbosity of the model.
- **Country and incident place**. When multiple nations are involved, it is important to represent this information for all actors, assets and tools.
- **Incident types**. Due to the flexible nature of incidents, an incident could be classified into one or more main incident types. Subtyping relations will be provided by the model to address this.
- **Health impact, safety, triage types and classification levels**. The model should take into consideration critical information such as the effects the operation has/will have on health, safety hazards, triage types and classification levels indicating the amount of danger an incident poses. These concepts need to be properly represented.
- **Traffic, weather data and complexity of the environment**. This information is very useful metadata which can help actors determine the best course of action and assess the situation. The model should represent this information with as many details as possible.
- **Status of critical infrastructure**. The critical infrastructure defines the assets of the operation on which the entire success status hinges. Therefore, the model should provide detailed information about this status.
- **Notifications**. Notifications reach not only human actors, but also services and mechanical components. To that end, it is of utmost importance to uphold widely used standards in notification and message representation (e.g., EDXL messaging).

4.2 Information Awareness Concepts

Information awareness as it was described in D3.1, needs to meet specific goals such as the timely, relevant and effective use of available information, which will be delivered to the proper actors accordingly. To this end, CONCORDE[11] will act as the emergency communication app in the S&R project, in order for the aforementioned to be accomplished. Since CONCORDE must be extended to support the requirements of Search and Rescue, the semantic model should also address the following concepts:

- **Workspace**: PSAP, EMS en route, Incident Field, etc. In these spaces, there are specific actions that need to be performed i.e., Tasks.
- **Actor Group**: Bystanders, PSAP staff, EMS en route staff, Incident Field staff, Transport Staff, First Receiver staff. Actors undertake different tasks in an emergency response incident, according to their role. Moreover, roles will define different access rights to the content of the system.
- **Role**: Commander, operator, runner. Various actors may play various roles depending on the context i.e., conceptual space where they belong in a particular moment. Moreover, it should

be taken into account that specific types of incidents will introduce new actors in overarching the responder service in command such as police or military.

- **Task**: Triage, documentation, evacuation, assessment and treatments.
- **Profile**: It will be developed towards the decision support and the coordination function of the system such as profile to acquire, update and view incident information (type, level, timing, location, number of injured, etc.) to fill and monitor patients and access of available resources of actor's organizations such type of resources and their location.

4.3 Decision Support System (DSS)

Emergency management requires an efficient Decision Support System and there is specific information that needs to be available in order for the DSS to function properly. To this end, in order for the functionalities of DSS to be covered, the model should represent the following inputs, as they described and categorized in D3.1:

- Operational Data:
  - First Responders
  - Commanders
  - Bystanders (callers & volunteers)
  - Social Media
  - GPS-location
  - Text data from the incident field (preprocessed data of video and audio)
  - Data from sensors, drones and other hardware devices
  - Triage Data (patient id, type of injury, more)
- Prediction Data:
  - Weather data (heat, rain, wind, temperature, etc.)
  - Resources' arrival prediction
  - Traffic data (prediction for traffic flow)
  - Earthquake prediction
  - Patient health evolution
- Infrastructure Data:
  - Nearest Hospital
  - Number of beds
  - First aids
  - Operational status
  - Available Ambulances
  - Logistics
  - Public Services
  - Accommodation suggestions (schools, shops, hotels)

4.4 User Needs

In the previous sections, the actors and their roles have been identified as core concepts of the Situation Awareness model. Due to the fact that the use cases of S&R involve several actors that need to receive different kind of information according to the incident and the S&R operation, the DSS will assist in this regard. Therefore, the several actors that will be involved in S&R operations should be identified and they will be represented as entities by the SA model and the respective ontology. This work will be documented in section 5 and it should be highlighted that depending on the updated version of the SA requirements, along with the technical workshops that are going to take place, this work will be altered accordingly.

Regardless of the actors and their roles or types, CONCORDE will support specific technical use cases, hence, the system should provide specific functionalities to users, which may also affect the SA model itself. In any case, this will be examined and ensured after the incorporation of the ontology, however, these core functionalities should be mentioned.

- Registration and access to the system: All actors need to be able to register and access the system in an efficient fashion.
- Viewing and sharing available information through the available resources: In order to execute successful S&R operations, this is paramount. The visualization support supports and complements textual information provided in operations.
- Create and update information on the field roles' responsibilities: As many such operations are very risky, it is entirely possible for first responders having to change field roles to adapt to the current situation.
- Notifications and signals: Real-time notification and signaling is important and alerting functionalities should contain concise and frugal messages.
- Check available resources: To maximize the chances of success in operations, it is necessary to be able to inspect the currently available resources in real-time at any given moment.
- Provide resources: If resources are insufficient and endanger the operation, the system should provide quick solutions to assist users in acquiring more resources.
- Documentation: In order to increase the system's usability, it is important to provide not only thorough documentation of its functionality, but also enable first responders to properly document standards procedures and training scenarios, so that the system can reproduce the documented instructions in order to help first responders.
- Communication: Communication channels provided by the system should function in real-time and ensure proper transmission of information.
- DSS: Decision support is the heart of SA and, as such, users should have as many DSS functionalities and tools available to them as possible.

4.5 Situation Awareness (SA) model Objectives and Means of Verification

As it was previously mentioned, in the frame of S&R project, specific objectives need to be fulfilled by the SA model. In this context, the model aims to:

- define the decisions that first responders (and other actors) make during the course of S&R operation;
- represent the types of critical information required in order to support the various actors with their tasks;
- represent the important information flows that potentially exist between involved actors, mediated by a knowledge management system in the form of notifications, alerts and timely information supply.

Taking into account the fact that the aforementioned objectives must be satisfied, Table 2 presents how this can be succeeded through the conceptualization of the domains that were previously described. Afterwards, the concepts that derived from each specific domain are also presented and the interconnection among them will constitute the actual semantic model, which will be documented in section 5.

Table 2: Objectives and Means of Verification

Objective	Domain of SA requirements	Concepts
Definition of the decisions that first responders (and other actors) make during the course of S&R operation	DSS	• Prediction • Resource
	User needs	• Role • Actor • ActorGroup
Representation of the types of critical information required in order to support the various actors with their tasks;	Knowledge Management	• EmergencyIncident • PatientState • Resource • Location • IncidentPlace • CommunicationMeans • Metadata (Traffic, Weather, Environmental Complexity)
	Information Awareness	• Workspace • Task • Profile
Representation of the important information flows that potentially exist between involved actors, mediated by a knowledge management system in the form of notifications, alerts and timely information supply.	User needs	• Role • Actor • ActorGroup
	Knowledge Management	• CommunicationMeans • Metadata (Traffic, Weather, Environmental Complexity) • Notification

5 Semantic Data Model Specification

5.1 Vocabularies and Ontologies

In general, an ontology describes a domain of interest in a formal manner. Typically, it consists of a finite list of concepts as well as the relationships between these concepts of a domain [12]. Other information that may be provided in an ontology is properties, constraints, as well as disjointed statements etc. Ontologies provide a common way to represent a specific domain, overcoming issues of terminology misinterpretation among the applications that might share information. The Search and Rescue Ontology includes the main concepts and the relationships between the concepts of actors in S&R situations, in the context of the Search and Rescue Platform. The ontology thus represents the disastrous events, the resources, the activities, the actors, the actions and the agencies that are involved in such situations, as well as the relationships among them. In order to define an ontology, it is imperative to define the central entities and data comprising the model. For our needs, we use the state-of-the-art models/ontologies of POLARISCO, IMPRESS, FOAF and GEONAMES as a basis, while we update and expand them for our needs.

Due to the nature of the information we wish to express and due to a need of representing additional sub-categories, actors and events, we augment the model with additional entities and properties. For maximum compatibility with widely used state-of-the-art, we map all entities and properties appearing in our model into their respective entities and properties in the state-of-the-art models we use as a basis, where applicable. This is achieved via the *owl:sameAs* property, which correlates two entities or properties representing the same piece of information.

5.2 Search and Rescue Model

Based on the semantic model requirement analysis, we are going to present the Search and Rescue model. It is important to note that, since the model addresses the needs of multiple multidisciplinary and heterogeneous datasets from various data sources, we should provide a model as simple as possible, grouping concepts and relations as much as possible, while also representing all relevant concepts.

There are three main concepts throughout the model:

- **Classes**, which represent the core entities of the model.
- **Object properties**, which conceptually link the model's classes, aiming to represent relations.
- **Data properties**, which accompany each class of the model. Each class is defined to have a specific set of properties correlated to it and this information is explicitly stated in the described ontology instead of it being implied by an inferencing engine.

5.2.1 Model representation in OWL

In this subsection, we are going to justify the reasons which led us to designing the provided model/ontology in its current state. More specifically:

- We will showcase subtyping relations and the need for additional entities insertion in the ontology.
- We will showcase subtyping relations between object properties, as well as which semantic attributes they should have (functional, inverse functional, reflexive, irreflexive, transitive, symmetric, asymmetric).

- We will discuss data properties which have a complex range type.

Further on, we will describe attributes which carry semantic elements and meaning, as well as terminology used throughout the ontology's description. The main elements defining an (our) ontology are described in the next subsections, alongside respective data and object properties.

More specifically, we should take into consideration the following properties attributes:

- **Functional**: An object property is defined as functional if for each instance x of a specific class, there can only exist at most one individual instance y of another class, such that x is linked to y via this object property.
- **Inverse functional**: An object property is defined as inverse functional if for each instance x of a specific class, there can be at most one individual y of another class, such that y is linked to x via this object property.
- **Reflexive**: An object property is defined as reflexive if an instance is linked to itself via the object property.
- **Irreflexive**: An object property is defined as irreflexive when no instance is linked to itself via the object property.
- **Transitive**: If an instance x of a specific class is linked to an instance y of another class, which in turn is linked to an instance z of yet another class (both links have the same object property), x is also linked to z via the same object property. In this case, the property is a transitive one.
- **Symmetric**: If an instance x of a class is linked to an instance y of another class via this object property, then y is also linked to x via the same property. In this case, the property is a symmetric one.
- **Asymmetric**: If an instance x of a class is linked to an instance y of another class via this object property, then y cannot be linked to x via the same property. In this case, the property is an asymmetric one.

5.2.1.1 Entity classes

In order to supplement the understanding of our proposed ontology, the entities/classes of the model, as well as their object property relations are presented in a grid illustrating their hierarchy (left to right indicates topmost to bottom classes) and are displayed in Figure 2.

The main/core entities of the model are the following:

- **AccessRights**: The rights granted by a system. These are closely correlated with actor groups and roles.
- **Actor**: An agent participating in operations.
- **ActorGroup**: A conceptual group one or more actors belong to.
- **ClassificationLevel**: The classification level of the danger of the incident.
- **CommunicationMeans**: The means of communication in a Search and Rescue operation.
- **CriticalInfrastructureStatus**: The status of the critical infrastructure throughout an operation.
- **Datatype**: The datatype of data. Necessary when upholding standards in data exchange between services and components.
- **EmergencyIncident**: An emergency incident.
- **HealthImpact**: The health impact which can be caused by a specific operation.
- **IncidentPlace**: The place an incident has occurred.

- **IncidentType**: The type of incident which has occurred.
- **Location**: An entity representing a location. Correlated with entities such as resources, actors and incidents.
- **Metadata**: An entity representing metadata. Metadata is a top-level entity, which further divides into:
    - **EnvironmentComplexity**: This entity represents metadata expressing the complexity of the environment throughout an operation. It divides into:
        - **EmergencyScene**: This represents metadata about the scene of an incident.
        - **EMS**: This represents information about emergency medical services involved in an incident.
        - **PreArrival**: This represents metadata on pre-arrival to an incident.
    - **TrafficData**: This entity represents traffic metadata throughout an operation.
    - **WeatherData**: This entity represents weather metadata throughout an operation.
- **Notification**: An entity representing a notification sent from one actor to another.
- **PatientState**: An entity representing the state of a victim.
- **Prediction**: An entity representing prediction data for DSS services in the project.
- **Resource**: An entity representing resources used throughout operations. Further divided into:
    - **Equipment**: This entity represents equipment (usually for actors). It is further divided into:
        - **CommunicationEquipment**: Equipment used by actors to communicate.
        - **Service**: A service utilized in operations.
        - **TransportVehicle**: A transport vehicle involved in an operation.
        - **UtilityTools**: Utility tools and extras involved in operations.
        - **Wearable**: A wearable device such as a helmet, VR glasses etc.
    - **FirstResponderResource**: This entity represents a first responder resource.
    - **FirstReceiverResource**: This entity represents a first receiver resource.
    - **Supplies**: This entity represents general supplies.
- **Role**: An entity representing a role. Closely correlated with actor groups and actors. The role can be conceptual throughout operations, or for granting access rights to specific system functionalities.
- **SafetyHazard**: An entity representing a safety hazard.
- **Task**: This represents a task to be executed. Correlated with actors.
- **Triage**: This represents a triage entity.
- **Workspace**: This entity represents a workspace throughout operations. The workspace involves entities such as actors, locations and resources.

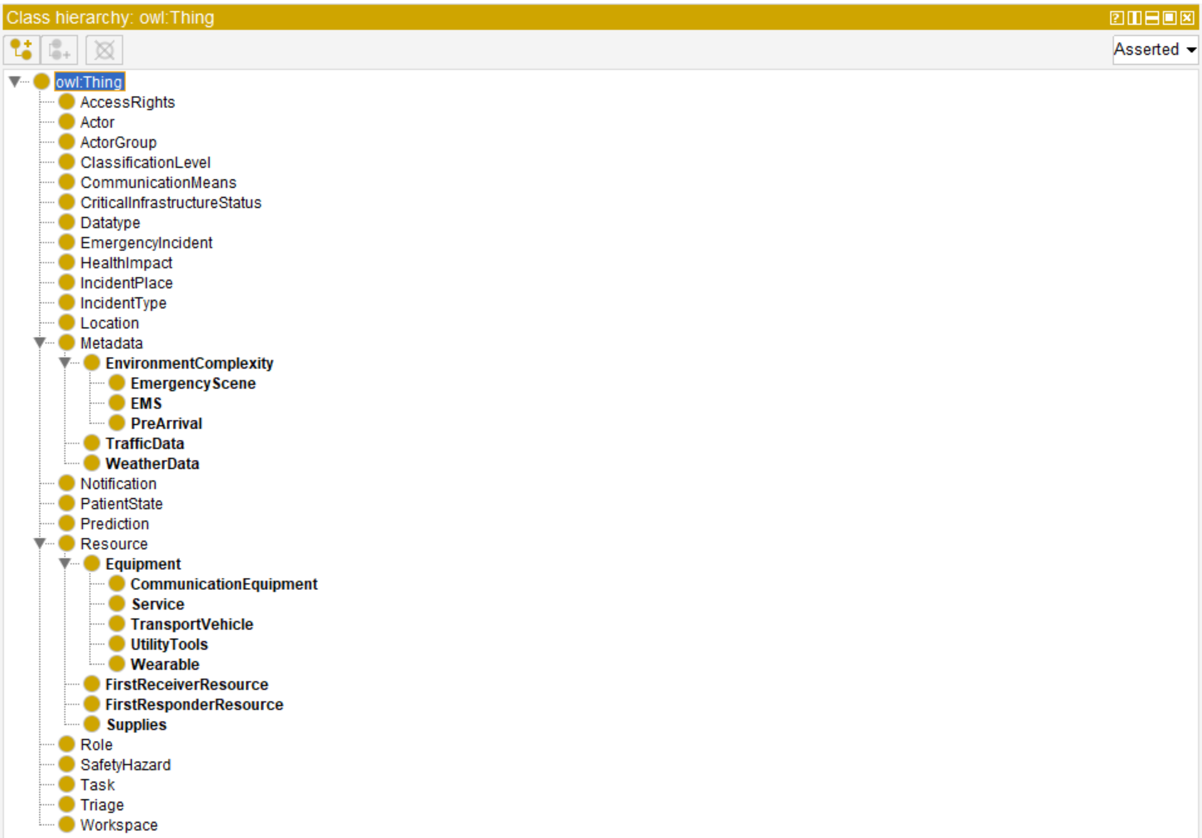

Figure 2: Search and Rescue ontology's classes.

5.2.1.2 Object properties

Leveraging subtyping relations among the ontology's entities, the defined object properties are as flexible as possible with respect to the entity type of their domain and range. This means that each object property tries to link higher-level classes as much as possible, since this implies that lower-level classes having the same parents can also utilize these properties themselves.

For the most part, the object properties of the ontology carry the following attributes:

- They are non-functional and non-inverse functional, because in most cases there are many to many relations between entities.
- They are not transitive, because in general the properties comprising the model do not carry any transitive semantics conceptually.
- They are irreflexive, because their domain and range differ.

The object properties of the model are the following:

- **actorBelongsToActorGroup**: A relation representing the fact that an actor belongs to an actor group.
- **actorGroupHasAccessRights**: A relation representing the fact that an actor group has access rights.
- **actorHasCommunicationMeans**: A relation representing the fact that an actor has a means of communication available.
- **actorHasHealthImpact**: A relation representing the fact that an actor is related to health impact.
- **actorHasLocation**: A relation representing the fact that an actor has a specific location.

- **actorHasPatientState**: A relation representing the fact that an actor has a patient state (i.e., they are a victim).
- **actorHasRole**: A relation representing the fact that an actor has a role.
- **actorHasTask**: A relation representing the fact that an actor has a task.
- **actorHasTrafficData**: A relation representing the fact that an actor has traffic data.
- **actorReceivesNotification**: A relation representing the fact that an actor receives a notification.
- **actorRequiresSafety**: A relation representing the fact that an actor requires safety from a safety hazard.
- **actorSituatedInLocation**: A relation representing the fact that an actor operates in a location.
- **actorUtilizesResources**: A relation representing the fact that an actor makes use of a specific resource.
- **emergencyIncidentHasIncidentType**: A relation representing the fact that an emergency incident has a specific incident type.
- **emergencyIncidentHasMetadata**: A relation representing the fact that an emergency incident has metadata describing the situation.
- **emergencyIncidentHasResource**: A relation representing the fact that an emergency incident includes a resource.
- **emergencyIncidentInvolvesActor**: A relation representing the fact that an emergency incident involves an actor.
- **emergencyIncidentInvolvesIncidentPlace**: A relation representing the fact that an emergency incident takes place in an incident place.
- **incidentHasCriticalInfrastructureStatus**: A relation representing the fact that an incident place or emergency incident has status for critical infrastructure.
- **incidentInvolvesClassificationLevel**: A relation representing the fact that an incident place or emergency incident has a specified classification level.
- **incidentPlaceHasIncidentType**: A relation representing the fact that an incident has an incident type.
- **incidentPlaceHasLocation**: A relation representing the fact that an incident has a specific location happening.
- **incidentPlaceInvolvesActor**: A relation representing the fact that an incident involves an actor.
- **incidentTypeInvolvesActor**: A relation representing the fact that an incident type involves an actor. Useful when representing which actors are required for specific incident types.
- **incidentTypeInvolvesResource**: relation representing the fact that an incident type involves a resource. Useful when representing which resources are required for specific incident types.
- **involvedInPrediction**: relation representing the fact that a prediction includes metadata, patient state or resources.
- **involvedInWorkspace**: relation representing the fact that a workspace includes a task, an emergency incident, an incident place, an actor, a resource or a location.
- **involvesSafetyHazard**: relation representing the fact that a safety hazard is correlated with an incident place, a location or an emergency incident.

- **involvesTriage**: relation representing the fact that a patient state or health impact involves a triage.
- **locationIsNearLocation**: relation representing the fact that a location is near location. Useful to represent neighboring locations and relations for DSS.
- **metadataHasDatatype**: relation representing the fact that metadata has a specific datatype.
- **notificationCarriesMetadata**: relation representing the fact that a notification carries metadata.
- **notificationHasDatatype**: relation representing the fact that a notification has a datatype. Very important to uphold standards when data is exchanged between services.
- **notificationInvolvesActor**: relation representing the fact that a notification involves an actor.
- **resourceHasTrafficData**: relation representing the fact that a resource carries traffic data.
- **resourceRequiresSafety**: relation representing the fact that a resource is correlated with a safety hazard.

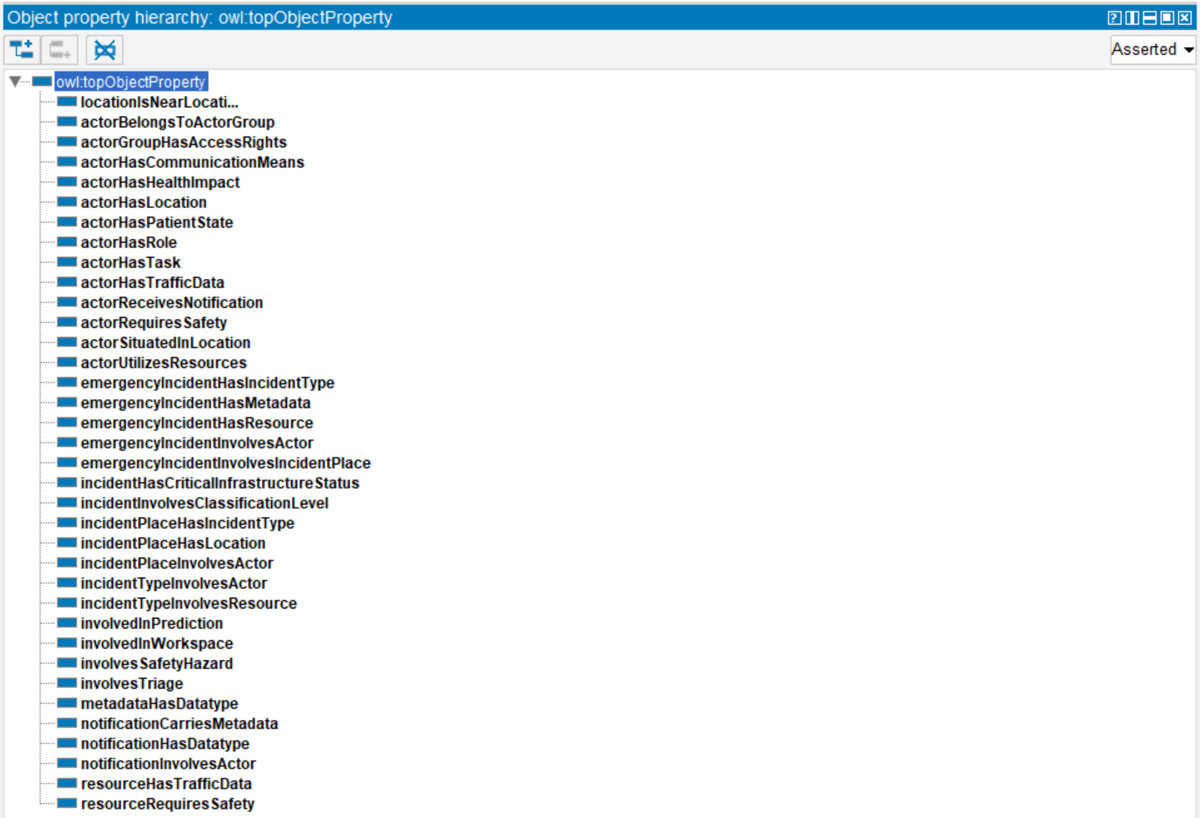

Figure 3: Search and Rescue ontology's object properties.

5.2.1.3 Data properties

Regarding data properties, the vast majority have an intuitive data type. However, some have a more complex datatype, such as xsd:XMLLiteral. The reason for this is to keep structured information in a serialized format, in order to better assist services consuming such information from the system. For example, services might need to store into the model a structured JSON message indicating a plan of action to be taken by first responders and then, another service will get this information from the system in order to forward it to the first responders directly. If the two services have already agreed upon the message's representation, then they can just deserialize this information and use it directly, instead of being forced to reconstruct it manually by parsing each field individually. In other words, at certain parts of the ontology we compromise the details/expressivity of the model in favor of assisting services in utilizing important information. Naturally, throughout Search and Rescue's development, this design is subject to change, in order to better facilitate the needs of the components and the end users.

It should also be noted that we will take into consideration the EDXL standards, when representing messages. EDXL is a suite of XML-based messaging standards that facilitate emergency information sharing between government entities and the full range of emergency-related organizations. EDXL standardizes messaging formats for communications between these parties. It was developed as a royalty-free standard by the OASIS International Open Standards Consortium, while it was designed to enable information about life-saving resources to be shared across local, state, tribal, national and non-governmental organizations. Implementation of EDXL standards aims to improve the speed and quality of coordinated response activities by allowing the exchange of information in real time.

The data properties of the model are the following:

- **hasActorGroupName**: Property of **ActorGroup**. The name of the actor group.
- **hasActorName**: Property of **Actor**. The name of the actor.
- **hasAltitude**: Property of **Location**. The measured altitude of the location.
- **hasColor**: Property of **ClassificationLevel**. The color of the classification.
- **hasCommunicationMeansName**: Property of **CommunicationMeans**. The name of the means of communication.
- **hasCriticalInfrastructureStatusName**: Property of **CriticalInfrastructureStatus**. The name of the critical infrastructure status.
- **hasData**: Property of **Notification** and **Metadata**. The data carried by a notification or metadata.
- **hasDatatypeName**: Property of **Datatype**. The name of the datatype.
- **hasEmergencyIncidentName**: Property of **EmergencyIncident**. The name of the emergency incident.
- **hasEmergencyIncidentSituationDescription**: Property of **EmergencyIncident**. The description of the emergency incident, encoded and serialized in XML format.
- **hasGroup**: Property of **ClassificationLevel**. The group of the classification level.
- **hasHealthImpactName**: Property of **HealthImpact**. The name of the health impact danger.
- **hasID**: Property of **Role**, **Actor**, **ActorGroup**, **HealthImpact**, **Notification**, **EmergencyIncident**, **Task**, **IncidentPlace**, **ClassificationLevel**, **IncidentType**, Resource. The unique id of a role, actor, actor group, health impact, notification, emergency incident, task, incident place, classification level, incident type or resource.
- **hasIncidentPlaceName**: Property of **IncidentPlace**. The name of the incident place.
- **hasIncidentTypeName**: Property of **IncidentType**. The name of the incident type.
- **hasLocation**: Property of **Location**. The well-known text representation of the location (i.e., a proper geometry such as a polygon or point).
- **hasLocationName**: Property of **Location**. The name of the location.
- **hasMetadataName**: Property of **Metadata**. The name of the metadata.
- **hasObjectives**: Property of **Triage**. The objectives of the triage.

- **hasPatientStateBloodPressure**: Property of **PatientState.** The blood pressure of the patient state.
- **hasPatientStateName**: Property of **PatientState.** The name of the patient state.
- **hasResourceInfo**: Property of **Resource.** The information the resource carries, encoded and serialized in XML format.
- **hasResourceName**: Property of **Resource.** The name of the Resource.
- **hasRoleName**: Property of **Role.** The name of the role.
- **hasSafetyHazardName**: Property of **SafetyHazard.** The name of the safety hazard.
- **hasStatus**: Property of **CriticalInfrastructureStatus.** The critical infrastructure status description, encoded and serialized in XML format.
- **hasTaskDescription**: Property of **Task.** The description of the task.
- **hasTaskName**: Property of **Task.** The name of the task.
- **hasTime**: Property of **SafetyHazard**, **PatientState**, **IncidentPlace**, **EmergencyIncident**, **Notification**, **Prediction** and **Task.** The timestamp representing the state of an instance of a safety hazard, patient state, incident place, emergency incident, notification, prediction or task.
- **hasType**: Property of **Triage.** The type of the triage.
- **hasTypeOfInjuries**: Property of **ClassificationLevel.** The type of injuries of the classification level.
- **representsAccessRight**: Property of **AccessRights.** The name of the rights granted.

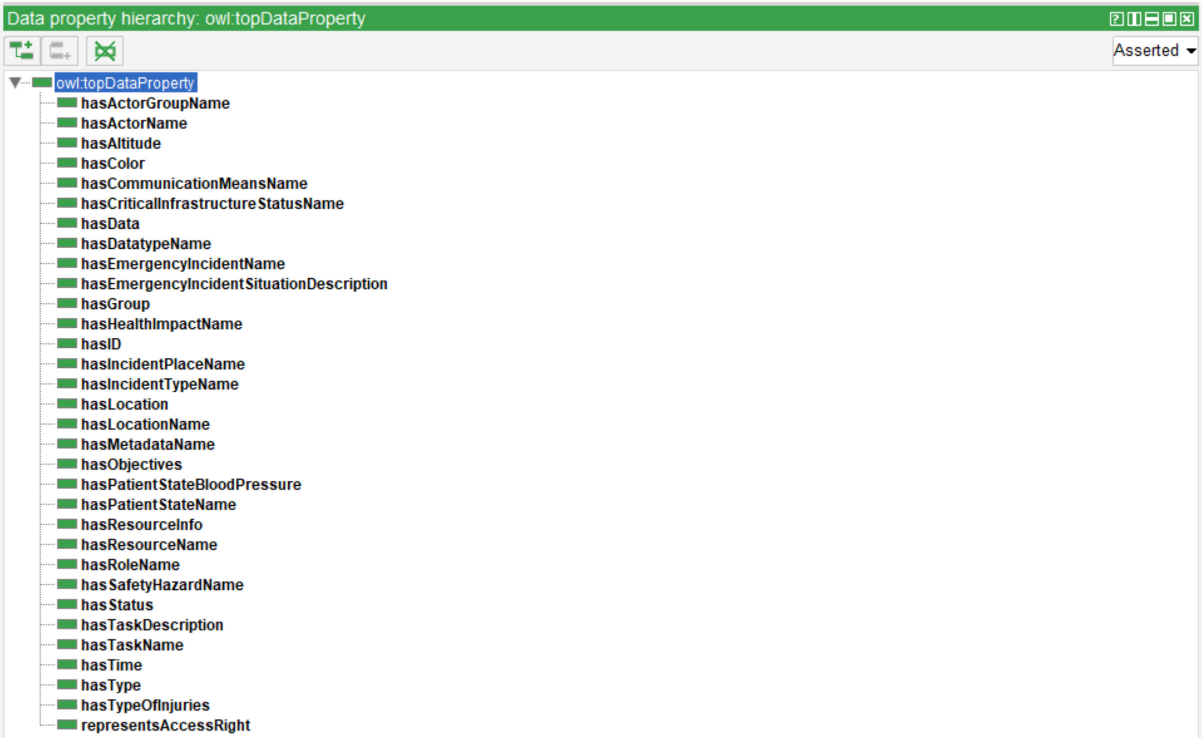

Figure 4: Search and Rescue ontology's data properties.

5.2.1.4 Interlinking with state-of-the-art ontologies

In this section, we are going to present the semantic linking to other ontologies which are considered state-of-the-art and which have been already presented in this document (see Section 3.4). It should be noted that some central ontologies like SKOS, Geonames and foaf are already included in bigger ontologies such as IMPRESS. For the sake of simplicity, we will discuss the links towards bigger ontologies which might have already incorporated smaller ones and we will provide this information explicitly, where applicable.

5.2.1.4.1 POLARISCO

- **Classes**:
  - http://www.ontologylibrary.mil/CommonCore/Mid/AgentOntology#Agent: This entity corresponds to the Actor class represented in our ontology.
  - http://purl.obolibrary.org/obo/BFO_0000023: This entity corresponds to the Role class represented in our ontology. More specifically, it is part of POLARISCO's BFO (Basic Formal Ontology).
  - http://purl.obolibrary.org/obo/BFO_0000011: This entity corresponds to the IncidentPlace class represented in our ontology. More specifically, it is part of POLARISCO's BFO (Basic Formal Ontology).
- **Object Properties**:
  - http://www.ontologylibrary.mil/CommonCore/Mid/AgentOntology#uses: This property corresponds to the actorUtilizesResources object property of our ontology. Part of POLARISCO's CCO (Common Core Ontology).
  - http://wwww.obofoundry.org/ro/ro.owl#located_in: This property corresponds to the incidentPlaceHasLocation object property of our ontology.
  - http://www.ontologylibrary.mil/CommonCore/Domain/SpaceObjectOntology#has_payload: This property corresponds to the notificationCarriesMetadata object property of our ontology. Part of POLARISCO's CCO (Common Core Ontology) and, more specifically, of the Space Object Ontology.

5.2.1.4.2 IMPRESS

- **Classes**:
  - http://fp7-impress.eu/EOPHC/Incidents: This property corresponds to the EmergencyIncident class of our ontology.
  - http://xmlns.com/foaf/0.1/Agent: This property corresponds to the Actor class of our ontology. Part of foaf ontology.
  - http://fp7-impress.eu/Activity/Communication: This property corresponds to the CommunicationMeans class of our ontology.
  - http://fp7-impress.eu/Person/HealthStatus: This property corresponds to the PatientState class of our ontology.
  - http://fp7-impress.eu/Resource/Equipment: This property corresponds to the Equipment class of our ontology.
  - http://fp7-impress.eu/Resource/Vehicles: This property corresponds to the TransportVehicle class of our ontology.
  - https://www.auto.tuwien.ac.at/downloads/thinkhome/ontology/WeatherOntology.owl#WeatherPhenomenon: This property corresponds to the WeatherData class of our ontology.
  - http://www.w3.org/2003/01/geo/wgs84_pos#SpatialThing: This property corresponds to the Location class of our ontology. Part of Geonames ontology.

- **Object Properties:**
  - http://www.purl.org/wai#plays: This property corresponds to the actorHasRole object property of our ontology.
  - http://www.xmlns.com/foaf/0.1/based_near: This property corresponds to the locationIsNearLocation object property of our ontology. Part of foaf ontology.
- **Data Properties:**
  - http://www.w3.org/2003/01/geo/wgs84_pos#alt: This property corresponds to the hasAltitude data property of our ontology. Part of Geonames ontology.

5.2.1.5 Ontology classes as a graph

In order to supplement the understanding of our proposed ontology, the entities/classes of the model, as well as their object property relations are presented in a grid illustrating their hierarchy (left to right indicates topmost to bottom classes) and are displayed in Figure 2.

For the sake of completeness, we provide how the classes of the ontology are connected together to form the model’s semantic graph, in Figure 6.

- actorBelongsToActorGroup (Domain>Range)
- actorGroupHasAccessRights (Domain>Range)
- actorHasCommunicationMeans (Domain>Range)
- actorHasHealthImpact (Domain>Range)
- actorHasLocation (Domain>Range)
- actorHasPatientState (Domain>Range)
- actorHasRole (Domain>Range)
- actorHasTask (Domain>Range)
- actorHasTrafficData (Domain>Range)
- actorReceivesNotification (Domain>Range)
- actorRequiresSafety (Domain>Range)
- actorSituatedInLocation (Domain>Range)
- actorUtilizesResources (Domain>Range)
- emergencyIncidentHasIncidentType (Domain>Range)
- emergencyIncidentHasMetadata (Domain>Range)
- emergencyIncidentHasResource (Domain>Range)
- emergencyIncidentInvolvesActor (Domain>Range)
- emergencyIncidentInvolvesIncidentPlace (Domain>Range)
- has individual
- has subclass
- incidentHasCriticalInfrastructureStatus (Domain>Range)
- incidentInvolvesClassificationLevel (Domain>Range)
- incidentPlaceHasIncidentType (Domain>Range)
- incidentPlaceHasLocation (Domain>Range)
- incidentPlaceInvolvesActor (Domain>Range)
- incidentTypeInvolvesActor (Domain>Range)
- incidentTypeInvolvesResource (Domain>Range)
- involvedInPrediction (Domain>Range)
- involvedInWorkspace (Domain>Range)
- involvesSafetyHazard (Domain>Range)
- involvesTriage (Domain>Range)
- locationIsNearLocation (Domain>Range)
- metadataHasDatatype (Domain>Range)
- notificationCarriesMetadata (Domain>Range)
- notificationHasDatatype (Domain>Range)
- notificationInvolvesActor (Domain>Range)
- resourceHasTrafficData (Domain>Range)
- resourceRequiresSafety (Domain>Range)

Figure 5: Search and Rescue's ontology in semantic graph representation's memo.

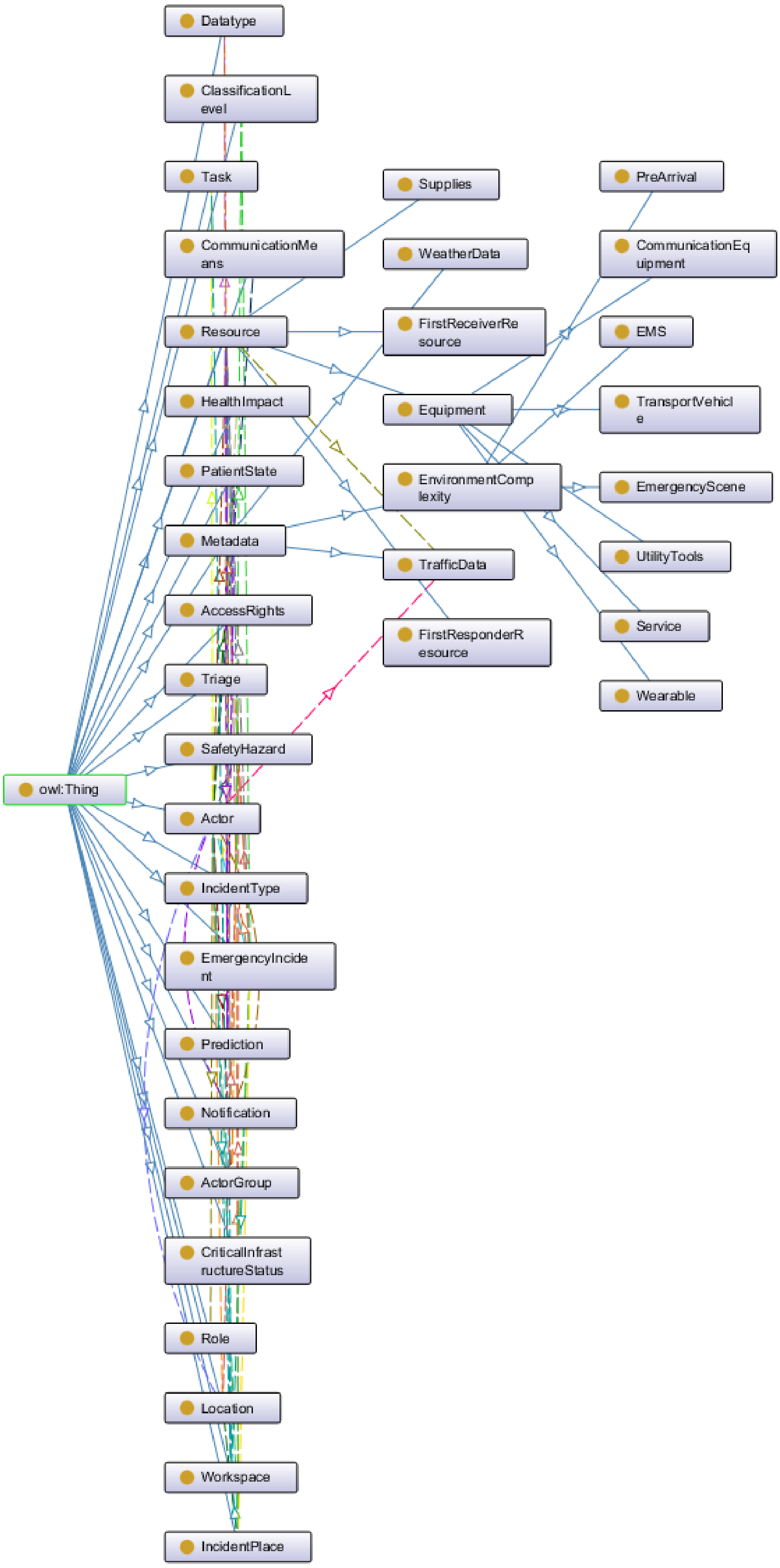

Figure 6: Search and Rescue's ontology in semantic graph representation.

6 Conclusions and Plan for the Final Release

6.1 Future work

While the desirable outcome of the current documentation is to provide a mature enough version of the model, SA model will be continuously monitored in terms of the project's needs and it will rely on their satisfaction. Furthermore, other techniques on how to best augment SA model with other existing and state-of-the-art approaches will be considered. The main goal would be to maximize utility, usability and compatibility of the model with standards and improve the credibility of Search and Rescue as a whole. Finally, the second version of the SA model, not only will represent the information of use cases that is related to the SA domain in detail, but also it will take under consideration the specifications of D8.1 "S&R Pilot guidelines and User's Handbook". All these key points for future work in order for the model to be further enhanced and extended will result in its second and final iteration at M18.

6.2 Conclusion

The current deliverable documents the first iteration of the semantic model that will constitute the Situation Awareness model of Search and Rescue. In this context, the working methodology in designing the provided ontology was described, while existing state-of-the-art approaches to situation awareness models as a whole were presented. Furthermore, the document focused on the requirements that should be covered by the model, both regarding knowledge management and decision support systems, as well as those that derived from user needs. Subsequently, a thorough specification of the model, vocabulary, entities and properties linking the entities was provided, while the important concepts involving the attributes accompanying properties of the model were also briefly explained. Finally, future steps on how to better improve the model during Search and Rescue's development were presented.

Annex I: References

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Annex II: Interlinking triples

In this Annex section, we are going to provide the interlinking of our ontology with state-of-the-art-ontologies.

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#Actor>
<http://www.w3.org/2002/07/owl#sameAs>
<http://www.ontologylibrary.mil/CommonCore/Mid/AgentOntology#Agent> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#Role>
<http://www.w3.org/2002/07/owl#sameAs> <http://purl.obolibrary.org/obo/BFO_0000023> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#IncidentPlace>
<http://www.w3.org/2002/07/owl#sameAs> <http://purl.obolibrary.org/obo/BFO_0000011> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#EmergencyIncident>
<http://www.w3.org/2002/07/owl#sameAs> <http://fp7-impress.eu/EOPHC/Incidents> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#Actor>
<http://www.w3.org/2002/07/owl#sameAs> <http://xmlns.com/foaf/0.1/Agent> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#CommunicationMeans>
<http://www.w3.org/2002/07/owl#sameAs> <http://fp7-impress.eu/Activity/Communication> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#PatientState>
<http://www.w3.org/2002/07/owl#sameAs> <http://fp7-impress.eu/Person/HealthStatus> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#Equipment>
<http://www.w3.org/2002/07/owl#sameAs> <http://fp7-impress.eu/Resource/Equipment> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#TransportVehicle>
<http://www.w3.org/2002/07/owl#sameAs> <http://fp7-impress.eu/Resource/Vehicles> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#WeatherData>
<http://www.w3.org/2002/07/owl#sameAs>
<https://www.auto.tuwien.ac.at/downloads/thinkhome/ontology/WeatherOntology.owl#WeatherPhenomenon> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#Location>
<http://www.w3.org/2002/07/owl#sameAs>
<http://www.w3.org/2003/01/geo/wgs84_pos#SpatialThing> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#actorUtilizesResources>
<http://www.w3.org/2002/07/owl#sameAs>
<http://www.ontologylibrary.mil/CommonCore/Mid/AgentOntology#uses> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#incidentPlaceHasLocation>
<http://www.w3.org/2002/07/owl#sameAs> <http://wwww.obofoundry.org/ro/ro.owl#located_in> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#notificationCarriesMetadata>
<http://www.w3.org/2002/07/owl#sameAs>
<http://www.ontologylibrary.mil/CommonCore/Domain/SpaceObjectOntology#has_payload> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#locationIsNearLocation>
<http://www.w3.org/2002/07/owl#sameAs> <http://www.xmlns.com/foaf/0.1/based_near> .

<http://www.semanticweb.org/iangelidis/ontologies/2021/1/snr#actorHasRole>
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<http://www.w3.org/2002/07/owl#sameAs> <http://www.w3.org/2003/01/geo/wgs84_pos#alt> .