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Advanced EU Situational Awareness System MSSAS: Tools and Functionalities

Friedrich Steinhäusler[1]
[1]*International Security Competence Centre GmbH, 2500 Baden, Austria*

Abstract: The Multi-stakeholder Standardized Situational Awareness System (MSSAS) is based on the situational awareness (SA) requirements of crisis managers, identified in two international surveys, four technical expert meetings, two public workshops and discussions with members of the Advisory Board and among consortium members. In addition, the results of the analysis of 23 EC-funded, pertinent projects with SA-relevance have been taken into account. MSSAS Concept consists of SA Reference Architecture, SA Functionalities and SA Tools. MSSAS integrates state-of-the art technologies, ranging from space-based observations to wearable detectors and computer-assisted decision support systems. Special MSSAS Modules have been developed for Law Enforcement, Firefighters, Paramedics and Technical Relief Organisations.
Keywords: Situational Awareness, Crisis Management,Technologies, Emergency Services

I. Introduction

Dealing with crisis often requires crisis management coordination within and between states. Since a crisis situation is trans-sectoral, the situation cannot be perceived as a whole without sharing information with the actors involved, creating Situational Awareness (SA). Current systems for sharing information in the context of SA are not adapted to operate in cross-border contexts and present several shortcomings related to interoperability, data management/processing, decision making, standardisation and procurement. This hinders a reliable sharing of SA-related information.The military refers to the infamous *Fog of War* to describe the difficulties a commander has in making far-reaching decisions, when there is only a mixture of erroneous data, half-truths and reliable information at hand. The situation is as troubling for a civilian incident commander as events spanning more than two decades have proven, i.e. sarin attack on the subway in Tokyo in 1995, synchronized distributed terrorist attacks of 9/11 in the US in 2001 and the nuclear accident in Fukushima in 2011. Each required the temporary assembly of members from multiple organizations to make speedy, efficient, and effective decisions. However, little has changed in terms of inadequate situational awareness (SA) in such large emergencies since then, i.e., multi-stakeholder crisis managers cooperating frequently still lack reliable information to assess the situation on scene. This applies to natural disasters (e.g., tsunami in Asia, 2004[1]), technical disasters (e.g., AZF explosion in Toulouse, 2001[2]), as well as urban terror attacks (e.g., train bombings in Madrid, 2004 [3], and the truck attack on a Christmas market in Berlin, 2016 [4]).

An adequate multi-stakeholder SA serves to both, (1) filter out information that is not goal-related, and (2) help people to understand how and why they should provide relevant information to crisis managers.Significant scientific and technical progress has been made regarding SA-related hard- and software over the past two decades. However, many of these functionalities and tools have not been integrated into SA systems used routinely by crisis managers in the European Union (EU). This deficit can contribute to erroneous decisions, leading to increased health hazards to first responders (FR)s and members of the public, and unnecessary high costs associated with the efforts of regaining control over a crisis situation. The importance of an adequate SA system has become even more prominent due to the emergence of new safety- and security threats in the EU, such as cyberattacks, attacks on National Critical Infrastructure (NCI), mass casualty events, extreme weather phenomena due to climatic change, transboundary mass migration and – possibly one of the biggest challenges for crisis management – deployment of a weapon of mass destruction (WMD) by terrorists.[5]

In the course of managing a crisis, far reaching decisions need to be made with regard to the protection of the public (sheltering versus evacuation), assessing health risks to first responders on scene (selection of the optimal Personal Protection Equipment (PPE)) and forecasting potential environmental hazards associated with the crisis (toxic plume dispersion). The complexity of predicting the potential impact of toxic chemicals, radioactivity and explosions on man, structures and the environment requires the use of advanced computer modelling.

At present, EU crisis response organisations routinely use relatively simple tools for SA with some exceptions. Accordingly, these legacy SA systems have a limited range of input- and output data formats. Modern Decision Support Systems (DSS) rapidly map the situation, enhance SA, coordinate staff in real-time, optimize traffic management and resources, reduce management costs and, thereby, assist emergency managers to make faster and better decisions. An essential component of DSS is the incorporation of geographic coordination technology, using mobile terminals, pocket-sized tracking devices, smartphone and tablet apps, mission control software and frequently, also third-party components (e.g., automated sensors or Unmanned Aerial Vehicles (UAV) and Unmanned Ground Vehicles (UGV)). Key to successful joint decision-making among the multiple stakeholders involved in crisis management (CM) is information sharing. This implies that the SA system is capable of shared communications and data-based SA for the commanders and actors on scene, in the air, on waterways and seas, depending on the location of the responders.

In full recognition of the current shortcomings in the area of SA the European Commission supported the development of the *Multi-stakeholder Situational Awareness System (MSSAS)*within the framework of the SAYSO project; project details at https://www.sayso-project.eu/.

II. MSSAS Requirements

Information on MSSAS requirements was obtained from a variety of sources: (1) Analysis of two international, questionnaire-based surveys; (2) Results obtained in four dedicated technical expert meetings; (3) Results obtained from two Public Workshops with First Responders (FR), different stakeholders and representatives of specialised industries, (4) Researching international Commercial-Off-The-Shelf (COTS) technical solutions related to SA, (5) Discussions with members of the SAYSO Advisory Board and among consortium members, and (6) Identifying 23 SA-related projects among EC-supported FP7- and H2020 projects, providing 38 SA-functionalities, respectively SA-tools; 58% of them at Technical Readiness Level (TRL) 7.[6]The following paragraph summarizes the findings:

- New SA functionalities and tools should represent added value, rather than replacing what is already available and working well. High level of maturity is mandatory for a high acceptance level. These tools should create primarily knowledge, not data only.
- SA tools should display information, e.g., on display units or maps, as simple graphics, easily understood and easy to use by all stakeholders. Information graphics represent a major SA tool. A key mapping feature is the display of what, where and when has happened. Maps (street maps, critical infrastructure, generic maps, static and dynamic maps, hot spot maps, etc.) should visualize events in 3D with a timeline (e.g., GeoTime).
- Extensive training programme for new tools should be foreseen to address the Human Factor, i.e., training should cover routine use and application in an actual major crisis.
- Interoperable technologies are needed that can be integrated and used together. Added value-assessment is needed before a new SA tool will be accepted by crisis managers. Purchases are made with long-term vision in mind (planning horizon: up to 15 years), favouring a holistic view.
- There is a significant gap between which SA tools are available in the US and EU and what is being used by EU crisis managers at present, based on the SAYSO SOTA and Gap Analysis. This gap can be narrowed by coordinated national programmes (e.g., introduced successfully in the United Kingdom (UK) after increased terror threats).
- An EU Directive is considered helpful in order to put more obligations on member states to introduce new SA technologies, i.e., top-down forcing is considered a high priority.
- It is cautioned, however, that access to modern SA equipment in itself does not necessarily mean it will actually be used, unless there is regular training and routine deployment.
- Experience by law enforcement, firefighters and paramedics indicates that they are interested increasingly to deploy new SA tools (e.g., drone, body cam, Smart CCTV). However, sharing of SA information among stakeholders from different organisations can still be problematic.
- The future MSSAS should be based on information derived from: (1) Space-based imagery, (2) Aircraft- and drone-based data, (3) Data derived from a system of special detectors, (4) Data derived from a system of special cameras; (5) Data obtained through land-based robots; (6) Information obtained with the use traffic management tools, and (7) Application of decision support tools.

III. MSSAS Design

The MSSAS Base for MSSAS (Figure1) is based on *SA Reference Architecture*, *SA Functionalities* and *SA Tools*, together with *additional tools* identified in the TRL)-analysis of 23 EU FP7- and H2020 projects addressing SA-related topics.

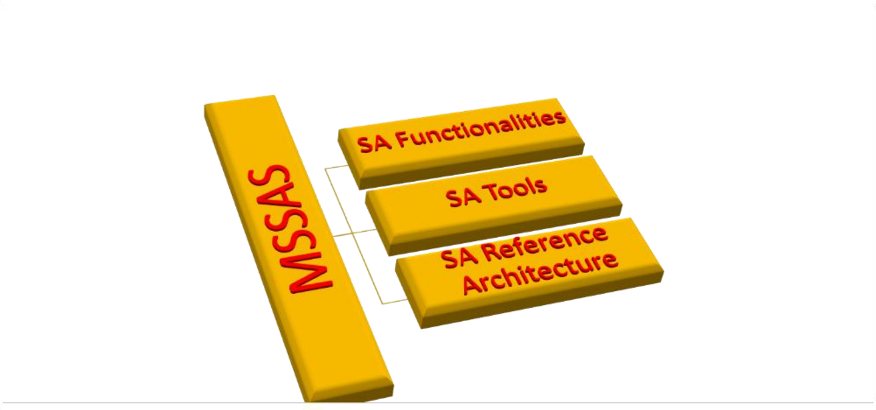

Fig. 1 MSSAS Conceptual Design

MSSAS has a modular structure, consisting of a *Base* and four *Practitioner-Modules* (Figure2).In addition to the SA-functionalities and SA-tools required by the practitioners, the MSSAS Base accounts for the newly developed SAYSO *Community Crisis Management Library* (CCM), which provides practitioners and researchers with a platform where they can share information. Its three key sections link to relevant external sites, the SAYSO Project and the Online Community Platform (OCP).

Besides, the MSSAS Base takes into consideration ethical/legal issues as addressed in the *General Data Protection Regulation* 2016/679 (GDPR). The GDPR is accounted for in three matrices. Each matrix schematically breaks down the GDPR into individual components relevant in the context of the SAYSO MSSAS. Furthermore, each matrix represents a different mode that the MSSAS specification should represent, i.e., Passive Mode, Active Mode and Learning Mode.

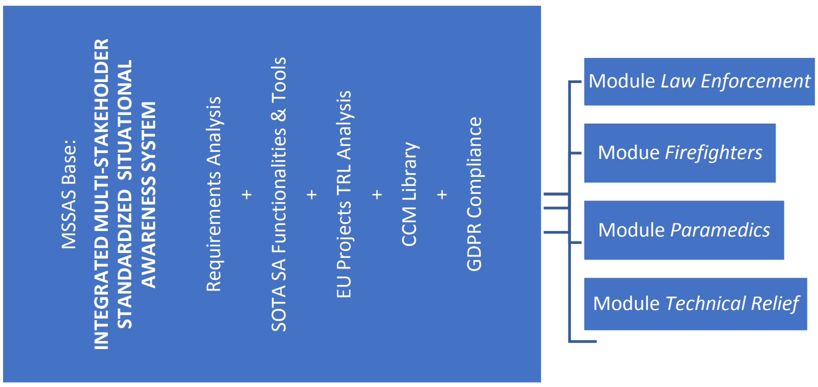

Fig. 2 MSSAS Base and modular structure of MSSAS

IV. MSSAS Functionalities and Tools

The design of the MSSAS accounts for the way SA is acquired and used. Typically, this process occurs in four phases:

a. *Observation*: Initially FRs seek and scan for critical clues. This observation phase consists of taking and noting observations. It places observations in context and assists in understanding the situation as a whole.
b. *Assessment*: Subsequently, these clues are used to assess (1) what will happen, if no action is taken by them, as compared to (2) the benefits by taking an appropriate action;
c. *Decision:*On the basis of this prediction a decision is taken by the crisis management and acted upon;
d. *Communication & Coordination*: The last step in this SA-based process is to communicate and coordinate with other FRs on scene and with all other organisations involved.

SA tools need to correspond to the special working environment of FRs on scene and in their attempt to regain control over a crisis situation, jointly with crisis managers, safely, quickly and cost effectively. FRs are multitasking experts. In order to create adequate SA, they use the available data and combine them with the extensive know-how from their working methods, competencies and their tacit knowledge. SA enables them to assess what is going on, respectively predict what might happen next. Therefore, SA functionalities and tools have to create an information profile for them that enables them to successfully manage four roles, i.e., (a) situation follower, (b) analyzer, (c) planner and (d) decision maker.

FRs face multiple threats, both visible and invisible, while on scene. Therefore, they need comprehensive SA, since subsequent decisions on which actions to take can determine their own health risk, as well as that of victims on scene or downwind. The special environment FRs typically operate in is characterized by high levels of stress. An FR must make quick decisions under high-pressure and high-stakes circumstances. Adding multiple distractions can further impact on their threat perception and risk assessment. SA tools need to assist them in this complex task of acquiring sufficient data to make a decision without causing information overload.

Note: In order to fulfil their demanding tasks crisis managers can benefit from commercial-off-the shelve (COTS) SOTA SA tools described in the following sections. Of the different SA approaches, only functionalities and tools specified by FRs and SA experts participating in this project as useful were considered in the design of the MSSAS presented in this report. The mentioning of a particular product or supplier does not represent an indorsement or recommendation by the author.

The sections below describe examples of COTS-, respectively cost-free technological solutions, representing SOTA with regard to SA. Such functionalities and tools provide operational assistance to the FRs with visual- and numerical information in different formats.

4.1 Computerized Maps

Critical decisions during emergencies rely on accurate georeferenced information and accurate mapping technology. Visual information and spatial awareness lead to making faster decisions and better management. With the increasingly easier access to *Geographical Information System* (GIS)-technology, combining geographic data with on scene information and displaying the information on a map is an effective way to assist crisis managers in obtaining SA.[1] Such a tool uses dynamic, georeferenced, interactive mapping with an integrated map editor. Thereby, it can be deployed to inform officers of incident location(s), improve decisions on resource allocation, evaluate effectiveness of interventions, and inform residents about an ongoing crisis management-related activity. Mobile app enables officers to do offline mapping, navigation and data sharing in remote locations. Such a system works 100% offline, requiring the officer only to locate himself using GPS. Thereby, an officer on scene can collect data in remote areas without needing to rely on a network connection. These data can be organized into customized schemes, exported and shared with the team. Maps can be imported in several formats, such as *PDF*, *GeoTIFF* and *JPG*. Example shown in Figure3.

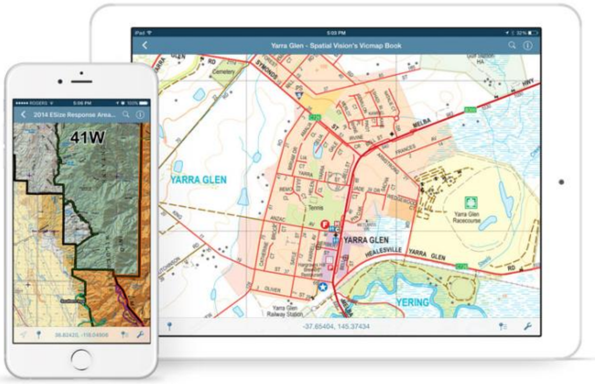

Fig. 3 Example for a GIS-based off line computerized maps displayed on Smartphone and Tablet (http://www.avenzamaps.com; last accessed 25 August 2018)

4.2 Information Exchange

Emergency response is highly time-critical work and timely access to information is key. This applies basically to all FRs, who need to respond rapidly to a crisis. In addition, they require an information exchange system with high reliability. With the development of location-based services, COTS emergency response systems have improved with regard to information exchange.

During the operation aimed at regaining control over a fast-developing situation, the situation can be subject to fragmentation in terms of information exchange procedures and systems across different stakeholders. This is exacerbated by a widespread prevalence of ad-hoc measures and practices in a crisis, particularly when security-related or even classified information is involved.

An important component in this context is related to *Call Taking (CT)*. Modern technological solutions regarding *Call Incoming* and *Location of Incident* improve the dispatch decision progress, e.g., data concerning location make it convenient to track one or more vehicles simultaneously. COTS CT systems offer crisis managers:

(a) *Automatic call distribution*, i.e., configurable call queues reduce transfers by delivering specific call types to call-takers who have defined roles, skill, and ability to handle them;
(b) *Optimized call handling*, i.e., a call taker is able to receive, process, and complete emergency calls and texts, whilst information pertinent to the task is displayed;
(c) *Telephony Private Branch Exchange (PBX) support*, integrating office personnel and phone systems into the total emergency call taking solution and offering multiple call control functions, such as call answer/release, call transfers, call hold, call mute, call parking, conference calling, auto-attendant, intercom and paging;
(d) *Integration of text to an emergency phone number*, i.e., SMS text is delivered to the call taker screen, text calls ring and are answered in the same format as voice calls. Thereby, a call-taker is able to handle multiple text calls as well as voice calls at the same time;
(e) *Map viewer displaying calls*, i.e., using local ESRI GIS data emergency calls and text can be displayed on the viewer prior to answer. In this manner, the call-taker can answer a call based on geographic location. Precise handset location is possible from all different sensors on modern devices, such as GPS, WiFi Access Points, cell towers, *Bluetooth* beacons and barometric pressure sensors.

An important component of advanced information exchange via digital two-way radios is *Radio over Internet Protocol* (RoIP), linking two or more radios using an internet-based connection, where it effectively transmits/receives audio communications over Internet Protocol (IP).With the advancement of mobile phones as a low-cost mass product, *mobile smart phone application* for communication, navigation, and incident reporting have become valuable functionalities in information exchange. Example shown in Figure 4.

Fig. 4 Reporting through mobile phone (text, visual and geographic information); http://www.qognify.com (last accessed 25 August 2018)).

4.3 Modelling

An important functionality for advanced SA in crisis management is modelling. In this process GIS image/data processing, 3D building modeler, interactive visualization, and dynamic scene-update are integrated into a 3D model, e.g., of an office building. Taking real-time positional measurements of people and resources within a structure, even a multi-story building and its users can be visualized for the incident commanders as 3D SA. This approach can increase the speed and effectiveness of an emergency response, thus saving lives and decreasing costs.

Science-based technical modelling can be used for industrial plant siting analysis involving multiple potential vapor cloud explosion scenarios, urban multi-story building external high explosive scenario, large-scale city/residential high explosive scenario, and small-scale IED terrorism events (e.g., subway bombing). Structural damage in a building affected by an explosion and associated victims can be colour-coded to describe the extent of damage, respectively injury.

Photorealistic 3D modelling of areas or structures can be achieved by using drone-based photogrammetry, preferably in automatic swarm-mode in order to save time and reduce operational cost. A special methodology for creating 3D map-based models from mobile devices uses a mobile portal and location-based information in cities to perform textual searches, navigate using 2D maps assisted by a GPS, and leave messages to the environment, or recognize the environment from a 3D map. Target platforms include laptops, Personal Digital Assistant (PDA) devices and smart phones. This method can be applied to modelling large urban areas. 2D modelling assists crisis management in the prognosis of the characteristics and trajectory of gaseous or liquid HAZMAT plumes (toxic chemical, radioactive fallout). Thereby, FRs can be advised on what Personal Protective Equipment (PPE) to use; the population living near the site of uncontrolled HAZMAT release can be warned appropriately whether to take shelter, prepare for evacuation or take precautionary measures before using drinking water. Example shown in Figure 5.

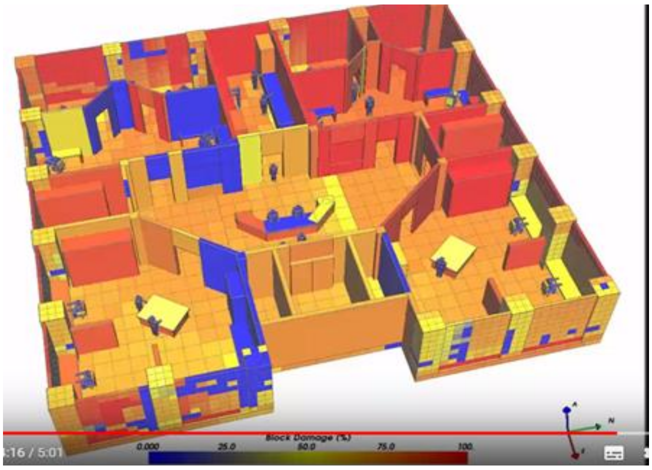

Fig. 5 Detailed damages on second building floor due to VBIED blast (red: total destruction; blue: undamaged); BREEZE ExDam explosion modelling; https://www.youtube.com/watch?v=MEEN1htmnkE

4.4 Information Technology and Technical Infrastructure

To encourage stakeholders to make information available to each other and while controlling the cost, a service-oriented architecture, with common standards for information sharing is recommended.

This architecture requires different stakeholders to only adapt their technical interfaces to an environment where they communicate with other actors. Thereby, stakeholders can exchange information using agreed upon standard formats, not just with specific stakeholders, but with all contracted clients. All actors remain in full control of their own local systems and resources. Any service (e.g., a traffic mapping service) provided to external peers, would expose an open API based on common standard data formats, whereas its internal implementation is hidden from external clients. Example MSSAS functions thus provided range from shared traffic maps and UAV imaging services, to external cloud data storage services.

When considering the design, implementation, and maintenance of APIs, one of the most important factors to consider are data formats - i.e., how the API handles the interaction between data generation and data request. Representational State Transfer (REST) is a well-established architectural style that defines a set of constraints to be used for creating web services. Web Services that conform to the REST architectural style, or RESTful web services, provide interoperability between applications using Internet protocol technology. REST-compliant web services allow the requesting systems to access and manipulate textual representations of web resources by using a uniform and predefined set of stateless operations. REST services are independent from specific data formats, however, currently most REST applications are based on domain specific (possibly standardized) adaptations of the XML and JSON notations.

Complimentary to the above is the expected rapid proliferation of new European wireless networking infrastructure. These will enable new automatic multi-sensor solutions that will have a major impact on the architecture of beyond state-of-the-art SA Systems. Also, the critical nature of SA requires mobile system access and the ability to share information efficiently and effectively via all kinds of devices. However, current state-of-the art COTS MSSA do not yet leverage the new emerging wireless infrastructures. The EU GALILEO satellite network will enable spoofing-proof geographical location services with precision down to decimetres. This next generation navigational satellite system will enable services,such as intelligent distress alarms and new UAV-applications. Secure autonomous rapid response surveillance drones are technically feasible and will therefore be an important cost-effective component in the state-of-the art MSSAS system.

4.5 Space-based Imagery

Satellite networks underpin many voice, data and mobile networks, providing them with a means to carry traffic across land borders and continents, when other alternatives like undersea cables are absent or in the event of terrestrial communications failure. Worldwide Government agencies use satellites as a safety net and for critical communications and data distribution, relying on precise timing information received by satellite. This approach is highly efficient for distribution of large amounts of data, whenever lower network quality of service or high bandwidth service costs pose limitations to crisis management. Space-based imagery provides information on natural or technological disasters, particularly in cases where national infrastructures are damaged (example shown in Figure 6):

- Giving a picture of inaccessible, flooded or damaged areas;
- Visualizing the geographical extent of flooded regions even under cloudy conditions;
- Enabling communication in emergency situations;
- Permitting the identification of precise locations of response teams, shelters, disaster areas or vulnerable populations;
- Anticipating disasters such as floods, landslides, fires or tsunamis;
- Tracking the path of tropical storms, including typhoons, cyclones and hurricanes;
- Identifying the changing morphology of volcanic domes in case of eruptions;
- Visualizing the atmospheric dispersion of ash emitted during volcanic eruptions;
- Visualizing the extent of forest fires and oil spills;
- Allowing for disaster risk reduction by guiding urban planners.

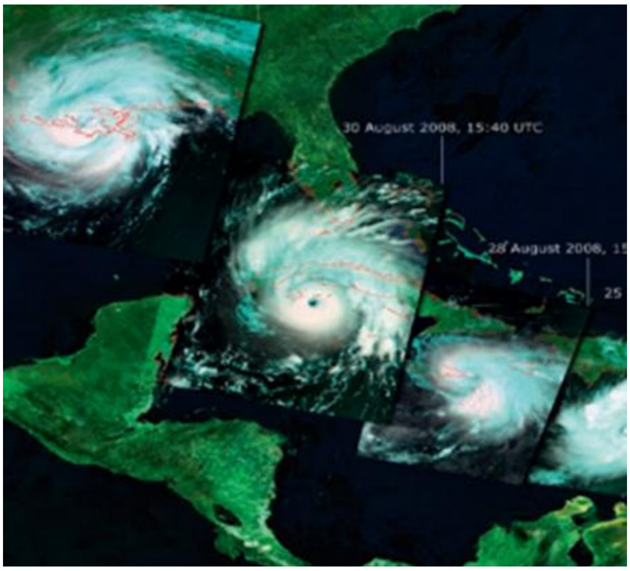

Fig. 6 Time-series of images of Hurricane *Gustav* approaching the US main land (2008, ESA)

4.6 Aircraft and Unmanned Aerial Vehicles

Aircraft – often in coordination with satellite surveillance – can be used in multiple ways to provide SA-related information, such as: (a) Helicopter, equipped with visible light-still and video cameras and Infra-red camera, provides visual information on the target area; (b) LiDAR (Light Detection and Ranging) laser scanner mounted on a fixed-wing aircraft or helicopter, scanning the target area, provides data for 3D modelling of the target area, predicting flash floods or determining changes in shoreline.

The coordinated use of satellite maps – identifying where local survey teams need to focus their efforts – and aircraft (e.g., after the passing of a storm), complete aerial views of the target area. Contrary to satellites, area-specific data from aircraft can usually be obtained on shorter notice as compared to requesting equivalent satellite data.

Unmanned Aerial Vehicles (UAVs; drones) fill a gap in times of disaster, when airport runways may be crippled thus denying conventional aircraft in the area from taking off; communication- and energy networks may be out of order. Also, the time required to schedule a satellite fly-by may delay first response efforts. In contrast, a man-backpackable UAV can be carried close to the disaster site and flown to capture aerial images. UAVs come in a variety of sizes from a small, hand-size platform, to a large platform that is capable of operations at high altitudes with a flight duration of several hours or even days. Due to UAV system cost, size, operational and support considerations, it is the smaller UAVs that provide FR with platforms of high utility at relatively low cost. The small physical size, ease of assembly and employment, and relatively low cost are attributes that make the Micro and Mini UAVs ideal platforms prime candidates for use by FR (example shown in Figure 7).

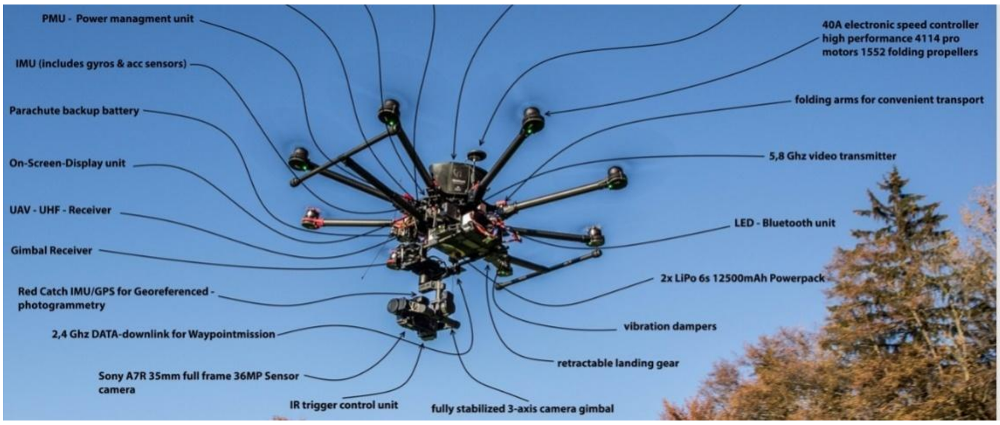

Fig. 7 Unmanned Aerial Vehicle with high-resolution camera

Aircraft require a minimum logistical infrastructure for operating in a target area: pilot(s), specialist maintenance personnel, airport, airfield, energy supply, communication infrastructure, meteorological service, aviation safety- and security services. Micro- and Mini UAVs for the most part require almost no logistics support base. As the platforms are small, they can be easily dis-assembled, transported to the launch site and re-assembled using hand-held tools.Manned and unmanned aircraft require a Mission Planning System (MPS). MPS provides complex functions in support to the flight crew, respectively UAV operator, during preparation of assigned missions (e.g., Search & Rescue operation; forest fire fighting), pre-flight study of mission feasibility, and mission debrief with post-flight mission analysis after mission accomplishment in order to assess the result and share the lesson learned. Examples for practical application on-scene are listed below:

- Infrared data serve to locate zones that feature increased temperatures as compared to their surroundings. Such a signal source can be a glow nest after forest fire, or body heat of a person hidden in undergrowth;
- Data from the visual camera provides additional visual information, correlating the optical information with location details of the site by using GPS data;
- Radiological data determine alternatively the location of a radiological source, its activity or assess whether the source is dispersed into the air. Data pairs on activity value/GPS position enable the user to assess a radiological source and create a radiation map;
- Chemical data provide information on the release of hazardous gases into the atmosphere. Different gas sensors can be installed on the flying platform;
- Aerosol data assist in the selection of adequate respiratory protective equipment for the FR by measuring the particle size distribution, indicative of the hazard potential of the aerosol.

4.7Unmanned Ground Vehicle

Crisis management uses Unmanned Ground Vehicles (UGV) to deploy sensors and collect information (e.g., sampling) in hazardous environments, even if they are to operate in confined spaces and close-in scenarios. Low center of gravity and high ground clearance enable a UGV to climb stairs and across rocks, move along gravel roads and forest paths, climb up cables and cross snow-covered areas. UGVs offer the inherent advantage that FRs need not be exposed to toxic chemicals, radiation, or Improvised Explosive Device (IED). Many UGV-systems are ruggedized, i.e., a UGV can be thrown through windows or down stairways. Equipped with a lightweight arm a UGV can manipulate and lift objects. Adding an adjustable mast, a UGV can illuminate the operational area.

Furthermore, a UGV can be equipped with specialized cameras, thermal imagers, and HAZMAT sensors.Cameras mounted on the UGV, suitable for VIS light and near-infrared (NIR) light, provide all-round SA in multiple directions. Jointly with an additional laser, a UGV can negotiate its way around obstacles. Built-in mesh radio and digital radio provide communication channels from the UGV to the crisis manager.UGV, specially designed for urban search & rescue missions, can operate on four-wheel drive or caterpillar track drive or climb cables. Modular structure design enables crisis manager to choose from an array of sensors and interchangeable payloads. Ergonomically designed operator console accounts for the inherent handicap of FR frequently wearing full-face mask and multiple layers of gloves on scene (example shown in Figure 8).

Fig. 8 Lightweight, throwable Unmanned Ground Vehicle (IRobot 110 First Look; https://www.robotcenter.co.uk/products/irobot-110-firstlook (last accessed 30 August 2018).

4.8Special Cameras

Body Cam can integrate with an in-car vehicle system and can be triggered by vehicle sensors (e.g., car door). Such body cams can provide real-time SA with features like Bluetooth®, WiFi (4G LTE, WCDMA), GPS, push-to-talk (PTT), multi-user video and imbedded biometric access. Use of SOTA secure wireless network supports live streaming video transmissions.

Demonstrations, terror attacks, hostage-taking and other high-profile police actions have focused attention on the need to equip law enforcement officers with cameras worn on the body. Thereby, officer safety is improved, transparency is enhanced and community relations and accountability during policing activities are improved. These systems can be configured either solely as a video transmission layer, as a complete private FR communications network, or as a disaster response/recovery system to provide fill-in coverage, when public cellular systems become congested or inaccessible.

Thermal Imaging (TI) Camera detects and displays small differences in heat, since all objects radiate a heat signature. This includes people, whose typical body temperature creates thermal radiation with a wavelength in the region of 10 µm. It makes a TI camera sensitive to radiation at this wavelength. FRs use thermal imaging (TI) cameras in situations of obscured vision due to smoke, fog, dust and lack of visible light, respectively in situations of discomfort due to heat. A frequent application is in firefighting, where a TI camera can assist in mitigating risks by protecting FRs from excessive temperatures, preventing injuries and reducing time spent fighting a fire. A large area of TI application is search and rescue missions at sea during nighttime, or in adverse weather conditions, such as during SCUBA operations, on harbour safety patrols, and assisting disabled boaters. Further SA applications on the water are collision avoidance, as well as vessel security.

Camera Ball technology – about the size of a small football – enables FRs to see in all directions simultaneously. A series of LEDs in the 850 nm spectrum illuminate the area for the cameras. Because the frequency is just barely within the visible light spectrum, it is not visible to anyone around the corner. One user is able to look left, another user can look right, and if they both can miss something behind them, they can scroll back in time and replay the video from that perspective. The system maintains vertical and horizontal video stability, even as the system rolls, bounces, or hangs on a rope. It is specifically designed for emergency response by being coated in a thick rubber shell to provide durability. Six lenses, connected to a single camera module within it, provide 360° coverage.

Image stitching software eliminates noise in the resulting photo. The camera ball can be tossed or rolled into dangerous areas to take panoramic photos that are then wirelessly transmitted through its own WiFi hotspot to an Android or IOS device. It can send the data from user's phone over secure 256-AES encryption to authorized users anywhere. FRs can mount their smartphones on their wrist to quickly take in what the camera ball sees, and act accordingly (example shown in Figure 9).

Fig. 9 Camera ball with six-lenses for 360 degree coverage (Bounce Imaging Explorer, https://www.bounceimaging.com/; last accessed 30 August 2018)

4.9Special Detectors

*Wearable detectors (*e.g., wrist watch-radiation detector; smart phone-thermal detector) can deliver measurement data, video and audio data back to crisis management in real-time. Integrating location and biometrics data from devices provides personnel tracking, two-way text communication and video sharing to crisis managers. Major progress has been achieved by embedding body-worn detectors and integrated voice- and data communications within Personal Protective Equipment (PPE), capable of communicating measurement data to crisis management.

Detectors with interactive GIS user interface provide continuous, real-time operative SA of the event and measurement data. Using the detector data, management software integrated into the detection system can provide incident scenario simulation (e.g., CBRN threat scenarios), analysis and forecasting. Interchangeable sensors for monitoring gamma radiation, VOCs, combustibles, toxics and oxygen, together with a local weather station for tracking toxic plumes, can send real-time data to command station up to several kilometres away. Thereby, forecasts of HAZMAT dispersion and analysis can be obtained from the sensor system on a map interface, based on GIS information, together with surveillance and sensor data, as well as different dispersion and plume calculation models.

Detectors configured with networking options (Ethernet, WiFi, mesh) offer a wide range of applications, such as: man-down alarms for individual team members; GPS tracking capabilities; establishing a continuously monitored perimeter around an incident; seamless wireless connectivity to provide centralized visibility; fast mobile access to levels and toxicity data via PC, smartphone, or tablet (example shown in Figure 10).

Fig. 10 Wrist watches as gamma dosimeter (left) and warning device (right; POLIMASTER, Gamma Radiation Dosimeter; http://shop.polimaster.us/pm1208m-wrist-gamma-indicator-radiation-detector/)

4.10Traffic Management Software

Intelligent Transport System (ITS) in the context of SA encompasses planning, monitoring and control or influencing of traffic. ITS advises the command-control and signaling system and receives for this purpose information about the current traffic situation and future demand and disturbances from other systems. The overall aim is to maximize the effectiveness of the use of existing infrastructure for transporting FRs to/off the scene, transporting victims in need of hospital care to trauma centres, and provide evacuation routes for the population under threat. This necessitates fair allocation of road space among competing users.

ITS address traffic congestion, avoiding it through the exchange of real-time information on infrastructure and traffic conditions. In order to achieve this goal, ITS simulates vehicles, pedestrians, traffic lights and multimodal mobility. ITS applies computers and electronic communication to improve transport services and road usage, consisting mainly in driver information and navigation services, transit user information, transit priority systems, re-routing using Video Management Software (VMS), lane control, dynamic use of the hard shoulder on motorways or access control measures, electronic tolling, dynamic traffic management with variable speed limits (VSL) and automated enforcement.

Modern approaches to traffic management can be adapted to requirements originating from the special needs of crisis management (e.g., priority access routes for FR vehicles; identification of safe and secure evacuation routes). Providing different stakeholders with specific traffic information for access to and egress from the incident scene (police patrol cars, fire fighter trucks, paramedic ambulance cars) can improve SA significantly.

Typically, ITS are map-centric and provide real-time SA solutions for an individual vehicle or optionally for a fleet of vehicles with a live streaming feed of what's happening, when it's happening, from anywhere with a network connection. It can operate through the fleets' in-car video, incorporating geographic coordination technology.

Using mobile terminals, pocket-sized tracking devices, smartphone and tablet apps, mission control software and possibly also third-party components (e.g., automated sensors or UAV system), ITS can provide vehicle location, GPS monitoring tools, and emergency situation alerts. 3G/4G/5G network-connected devices, including LAN/WAN-connected office PCs, dispatch monitors, smartphones and tablets, can be used by the crisis manager to access the live scene from anywhere (example shown in Figure 11).

Fig. 11 Managing traffic with map-centric and video-centric views with real-time SA application (L3 Mobile Vision Inc., http://www.mobile-vision.com/products/patrolscout/; last accessed 30 August 2018).

4.12Decision Support System

Computer-based *Decision Support System* (DSS) has been a major breakthrough with regard to SA and crisis management. Successfully supporting crisis management decision-making requires the availability of integrated, high quality information about the events on scene and related consequences. This information is organized and presented in a timely and easily understood manner by a DSS. A DSS provides access to actionable resources, such as an integrated repository for internal and external data, plus incorporated intelligence for understanding and evaluating the data within its environmental context. With the addition of models, analytic tools, and user interfaces, a DSS has the potential to provide multiple actionable information resources.

A fundamental requirement for successful DSS application is the realization of an organization responsible for managing a crisis that it may be rich in data describing the crisis situation but poor in information. The solution is *Data Warehousing* (DW), which is the central prerequisite of DSS-related information architecture. DW addresses crisis data management challenges, such as multiple entry points to data, lack of integrated systems, ambiguous and multiple definitions, and most importantly, the need for analytical processing without disturbing operational systems. SOTA data extraction tools enable cleansing and transformation, thereby reducing substantially the work associated with loading a DW. Also, COTS tools are available for moving, building and managing meta data repositories.

Since a DSS is basically a computer programme application that *analyzes* data and presents it so that crisis manager can make decisions more easily, DSS designs reflect an "informational application" as compared to an "operational application" that only *collects* data in the course of an operation.

A DSS has three basic components: (1) relational database, (2) modelling algorithms, and (3) user interface. SOTA designs of DSS systems have profited from powerful data mining techniques and relational online analytical processing (ROLAP), enabling multi-dimensional views from relational databases. Web-based information systems have been used for DSS applications and are well established today. Over the past few years, service-oriented DSS (DSS in CLOUD) has become one of the major trends in order to gain more agility. DSS in CLOUD enables advances in scale, scope and speed concerning the large amount of data, information and analytics associated with advanced SA. In addition, neural networks and fuzzy logic software tools are being designed for DSS applications.

DSS supports effective identification of problems and opportunities, critical decision-making, formulation of a strategy, its implementation, and evaluation of its success and failure. DSS can be applied in SA-related crisis management addressing widely differing topic areas, such as *security* (e.g., counterterrorism action), *environment* (e.g., floods), *critical infrastructure* (e.g., electric power black-out) and *society* (e.g., migration).

With the advancement of *Big Data* capabilities, DSS can incorporate a multiplicity of data sources, such as real-time spatiotemporal data (e.g., GPS data), data originating from the public (e.g., Volunteer Geographic Information and social media), small satellites, UAVs, Call Data Records (CDR), Internet of Things (IoT), crowd sourcing and sensing data (physical sensing devices and remote sensing) (example shown in Figure 12).

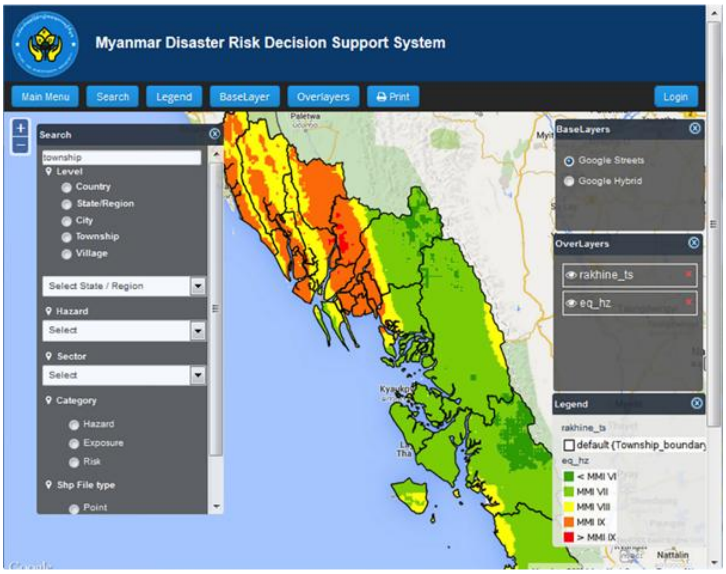

Fig.12 Managing Disaster Risk Reduction Decision Support System enabling crisis managers to access risk assessment data in Rakhine State (Asian Disaster Preparedness Center; http://isepei.org/case-studies/effective-communication-flood-risk-information-improved-decision-making-rakhine-state; last accessed 30 August 2018)

V. EU Project Results

Among theresearch projects sponsored by the European Commission (EC) within the Framework Programme 7 (FP7) and Horizon 2020 (H2020) 23 projects were identified related to SA. 58% of these project results had reached a relatively high maturity of Technical Readiness Level (TRL) 7 on the scale 1 to 9; 32% had provided SA-related results at TRL 6. SA-functionalities, respectively SA-tools listed below (categorized as TRL = 7) were considered for specifications of the operational MSSAS in addition to COTS:

(a) Decision Support Systems
- Advanced Situation Awareness System
- Buried victim localization tools
- Resource management;

- Advanced Situation Awareness System using UAV-based Expert System
- SA using machine vision, virtual reality, simulation and geographical mapping technologies
- Situational awareness application of hands-free communication in Personal Protection Equipment

(b) Networks and Communications
- Communication and vision under adverse conditions
- Communication and person-localisation system in tunnel and metro
- Space-based information supporting forest fire management
- Multi-hazard satellite service platform

(c) 3D Positioning/Localization/Tracking Systems
- Tracking and positioning functionalities indoors and in urban canyons

(d) Sensors and Sensor Platforms
- Dynamic tagging
- Unmanned air-, ground- and sea vehicles as platform for multiple sensors
- Unmanned Aerial Systems for increased situational awareness
- Airborne sensor network for information communication
- Imaging system using aerial platforms for mission management
- Mixed ground- and aerial robotic platform
- Onboard sensor technologies
- Spatial information on area of interest using drone-based orthophotos

(e) Modelling and Simulations
- 2D/3D modelling of hazards and effects
- Simulation platform
- Symbology for maps.

VI. MSSAS Module Law Enforcement

Law enforcement will ensure that the firefighters, ambulance services and technical relief organizations can fulfil their tasks on scene. In order to achieve this goal, they will cordon off the disaster area, direct traffic and sometimes set up a safety zone around the disaster area. If victims are difficult to identify, the police will deploy the disaster identification team, consisting of experts convened on an ad hoc basis. A key feature of law enforcement teams is that they perform their work in consultation with one another.The following SA functionalities and SA toolsare recommended for the *MSSAS Module Law Enforcement*:

Modelling, UAV, UGV, thermal imaging camera, camera ball, wearable detectors, traffic management, decision support system, hand-held detector, information exchange, information technology, technical infrastructure; robust and resilient communication; resource management; SA using machine vision, virtual reality, simulation and geographical mapping technologies; Situational awareness application of hands-free communication in PPE; Advanced Situational Awareness by 2D/3D visualization; communication and person-localization system in tunnels and metro systems; tracking and positioning functionalities indoors and in urban canyons; electronic tagging; unmanned air-, ground- and sea vehicles as platform for multiple sensors; airborne sensor network for information communication; spatial information on area of interest using drone-based orthophotos; simulation platform; symbology for maps.

VII. MSSAS Module Firefighters

Firefighters represent the key component in many disasters. In the disaster area, the fire service's first duty is to save people and animals. Naturally, firefighters extinguish fires, and in addition conduct tests to find out whether any hazardous substances have been released. Usually the fire chief is in charge of the operational management of the response effort on scene. As a member of the disaster management team on scene, the fire chief puts the team's decisions into practice and coordinates the work of the emergency services.The following SA functionalities and SA tools are recommended for the *MSSAS Module Firefighters*:

Modelling, UAV, UGV, thermal imaging camera, camera ball, wearable detectors, traffic management, decision support system, hand-held detector, information exchange, information technology, technical infrastructure; robust and resilient communication; resource management; SA using machine vision, virtual reality, simulation and geographical mapping technologies; situational awareness application of hands-free communication in PPE; communication and vision under adverse conditions; Communication and person-localisation system in tunnel and metro systems; space-based information supporting forest fire management; multi-hazard satellite service platform; tracking and positioning functionalities indoors and in urban canyons; electronic tagging; unmanned air- and ground- vehicles as platform for multiple sensors; unmanned Aerial Systems for increased situational awareness; airborne sensor network for information communication; imaging system using aerial platforms for mission management; mixed ground and aerial robotic platform; onboard sensor technologies; spatial information on area of interest using drone-based orthophotos; 2D/3D modelling of hazards and effects; simulation platform; symbology for maps.

VIII. MSSAS Module Paramedics

Anyone injured in a disaster will require medical assistance as soon as possible. Ambulance paramedics will usually provide first aid and stabilise the injured so that they can be taken to hospital. The paramedic is a highly trained and skilled medical professional who is educated to carry out some of the duties of a physician, i.e., a paramedic can examine, evaluate and treat patients with equipment and medications usually only found in the
emergency department of a hospital. They act typically as emergency care practitioners on ambulances or on first response emergency vehicles.The following SA functionalities and SA tools are recommended for the *MSSAS Module Paramedics*:

Modelling, UAV, UGV, thermal imaging camera, wearable detectors, traffic management, decision support system, information technology, technical infrastructure; Decision Support Systems; resource management; geographical mapping technologies; robust and resilient communication; communication and person-localization system in tunnel and metro systems; tracking and positioning functionalities indoors and in urban canyons; electronic tagging; airborne sensor network for information communication; symbology for maps.

IX. MSSAS Module Technical Relief Organisation

In times of crisis, a Technical Relief Organisation provides technical and logistical support for other Government Organisations, Non-Governmental Organisations or other authorities, like firefighters and law enforcement. This support is part of national civil protection measures, addressing inter alia: Technical support (electric power supply, drinking water supply, waste water treatment, building bridges), search & rescue operations, clearing roads of obstacles, assistance in floods, provision of emergency lighting, temporary telecommunication system, operation of logistics centre, food supply for FRs, repair of equipment, environmental protection (oil barriers, water analysis), emergency sheltering for general public, temporary road construction, etc. The wide spectrum of tasks and capabilities of Technical Relief Organisations also reflects on the multiplicity of SA-related requirements. The following SA functionalities and SA tools are recommended for *Technical Relief Organisations:*

Modelling, UAV, UGV, thermal imaging camera, camera ball, wearable detectors, traffic management, decision support system, hand-held detector, information exchange, information technology, technical infrastructure, geo-referenced detector data; Advanced Situation Awareness System using DSS; Resource management; Advanced Situation Awareness System using UAV-based Expert System; SA using machine vision, virtual reality, simulation and geographical mapping technologies;

Robust and resilient communication; Communication and vision under adverse conditions; communication and person-localization system in tunnel and metro; space-based information supporting forest fire management; multi-hazard satellite service platform; Tracking and positioning functionalities indoors and in urban canyons; Electronic tagging; Unmanned air- and ground- vehicles as platform for multiple sensors; Unmanned Aerial Systems for increased situational awareness; airborne sensor network for information communication; imaging system using aerial platforms for mission management; mixed ground and aerial robotic platform; spatial information on area of interest using drone-based orthophotos; 2D/3D modelling of hazards and effects; symbology for maps.

X. Conclusions

SAYSO MSSAS focuses on the needs of crisis managers, integrating technical solutions from the current SOTA and COTS SA systemsoperating in space, air and on the ground. Practical application of the SAYSO MSSAS has the following advantages:

(a) Since the SA requirements differ for Law Enforcement, Firefighters, Paramedics and Technical Relief Organisations, specific *MSSAS Modules* have been developed and applied in different threat scenarios. However, some of the same COTS SA functionalities and tools are needed by Law Enforcement, Firefighters, Paramedics and Technical Relief Organisations, such as: Modelling, UAV, UGV, thermal imaging camera, camera ball, wearable detectors, traffic management, decision support system, hand-held detector, information exchange, information technology, technical infrastructure. This reduces cost significantly for upgrading current levels of SA hard- and software in different crisis management organisations.

(b) Additional hardware, identified in this study as supportive tools for FRs in obtaining adequate SA, does not place an undue physical burden on FRs, i.e., new SA technological tools are typically light weight and have small geometrical dimensions.Additional such SA-relevant software is end-user friendly in terms of operating it in stressful situations.

(c) MSSAS can create reports and dashboards, thereby rapidly converting information into knowledge. In this manner

(d)

(e) MSSAS provides crisis management with the ability to gather and disseminate end user-oriented information with FRs on-scene, as well as providing comprehensive information to decision makers among other public safety and government officials.

MSSAS brings as much data as possible to crisis management and then synthesises it into the most meaningful and complete assessment of the situation at the time and its potential development in the future, without risking information overload. If needed, this picture can be shared with other organisations involved in regaining control over the situation (common operational picture (COP)), be it at the local, national or international level.

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References

[1]. The Editors of Encyclopaedia Britannica, Indian Ocean tsunami of 2004, LAST UPDATED: 19 December 2018; https://www.britannica.com/event/Indian-Ocean-tsunami-of-2004 (last visited 15 February 2019)

[2]. Georges Guiochon and Laurent Jacob, On the Catastrophic Explosion of the AZF plant in Toulouse (September 21, 2001), AIChE Spring Meeting and Global Congress on Process Safety, 4 April 2012; https://www.aiche.org/academy/videos/conference-presentations/on-catastrophic-explosion-azf-plant-toulouse-september-21-2001

[3]. F. Javier Barroso, Thirteen years after deadly Madrid train bombings, memorial in disrepair, El Pais, 13 March 2017; https://elpais.com/elpais/2017/03/13/inenglish/1489396094_806567.html

[4]. Melissa Eddy, A Year After the Berlin Market Attack, Germany Admits Mistakes, New York Times, 19 December 2017;https://www.nytimes.com/2017/12/19/world/europe/berlin-attack-memorial.html

[5]. Kelsey Davenport, WMD Terrorism, Arms Control Association, January/February 2019;https://www.armscontrol.org/taxonomy/term/27

[6]. EU TRL Definition for H2020, Extract from Part 19 - Commission Decision C(2014)4995 https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf