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Current military science research topics

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Abstract: Physical Sciences are of paramount importance in any higher military educational institution as they provide the basis for all military science courses. Especially weapons physics and chemistry are nowadays at the frontiers of science leading to new inventions and discoveries. This report summarizes in random order some very important topics of current military scientific research focusing in particular on arms control, defense and security science.

Keywords: *Military Science, Artificial Intelligence, Geographic Information Systems, Radiological Weapons, High Temperature Superconductors, Laser Guided Missiles, Explosives Detection, Chemical Weapons Detection, Military Construction Materials, Chemical Warfare Agents, Ballistic Trajectories, UAV, CBRN*
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I. Artificial Intelligence in Military Applications

Artificial Intelligence (AI) applications are increasing rapidly in civilian applications because of their cost-cutting potential and reliability. Because of their disruptive potential, militaries around the world have also entered the 'AI race' (Horowitz, 2018), (Work, 2015). Military applications have the extra attractiveness of potentially replacing –at least in part- humans, who find themselves in dangerous situations, by machines and are further generally characterized by requirements of very fast response (for example when faced with intercepting a large number of incoming missiles, even the best trained human operator can be easily overmatched) and very low error tolerances (for instance a friend identified as foe; the downing of an Iranian civilian Airbus in 1988 by a military system identifying it as a foe in 1988 is a well-known example). Error tolerances are also important because countermeasures can easily make large error rate solutions very uneconomical (e.g. the enemy may send a large number of projectiles with no payload for each one with a payload to exhaust the interceptor defenses). In very broad terms AI or any Data Analytics technique need to perform one or more of the following in military situations:

-classification (e.g. friend or foe, threat or no threat)
-deviation detection (from a 'normal' or expected behavior, e.g. a camouflaged object or radar trace)
-prediction or estimation (e.g. projectile trajectory)
-clustering, association or link analysis (for instance in cyberattacks)

AI generally learns from data, in a supervised or unsupervised method. Once sufficient knowledge is acquired, the AI can take decisions much like a human. General machine learning techniques involves 'eager learners', that is systems that try to incorporate all they have learned in a model: A simple familiar example is a linear regression model, though this is too simplistic for most realistic applications. More

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involved eager learners are, of course, Artificial Neural Networks (ANN) and Support Vector Machines (SVM).

ANNs essentially construct a highly complicated nonlinear function that best matches the data they have been trained with. For instance an ANN-based firewall has been given a large number of labelled sets of packet characteristics (labelled means someone else, typically a human, has analyzed them and 'labelled' that behavior as 'attacks' or 'normal behavior') and based on this knowledge has constructed a model that can decide in real time whether a new, unknown packet is 'normal' or 'an attack' and, in the latter case, block it. In a sense, an ANN is a complex interpolation scheme. SVMs are similar in that a 'demarcation line' is constructed between what is 'friend ' vs. 'foe', 'attack' vs. 'non-attack' etc. Other eager learners (Decision Trees), even in their most robust form (Random Forests), which try to create rules from the data, have usually error rates that are unacceptably high for military applications.

In contrast, 'lazy learners' are systems that only store known cases and will bother to classify or else make a decision only when asked to do so. This is similar to how doctors, engineers or lawyers deal with new cases: They try to relate a new case to a known case: For instance a doctor will try to relate the symptoms of a new case to a known disease pattern; if successful, this newly solved case will be store in his 'case' database, usually the doctor's memory. In the firewall example above this would mean searching the memory to find the closest case or cases to the one presently faced. This is commonly referred to Case Based Reasoning (CBR), or, in more jargon terms, 'k-NN' (meaning the search will be for the k nearest neighbors). CBR is attractive for humans, who want to *understand why* a specific decision is taken, the answer being 'because the present case is *close* to one or more known cases for which was dealt analogously'. However, CBR typically does not meet the timeliness requirements, e.g. blocking in *real time* without being vulnerable to an overload of information. For example, in the firewall case the attacker may send a large amount of legitimate traffic to overwhelm a CBR memory search. In addition, eager learners only need to store the model parameters (e.g. slope and intercept for simple linear regression), which is much less information than the entire list of cases. Other unsupervised learning AI techniques, such as clustering (i.e. automatically identifying groups with 'similar' behavior) may also have military applications.

A perhaps relatively less researched subject is countermeasures, e.g. trying to fool the AI so as to cause it to take the wrong decision. This could be a challenge both for the party trying to fool the AI and the party responsible for 'defending' the AI, especially for methods that are not easily understood in human terms. One possible attack is on the training set, i.e. a training set with mislabeled data, which are, however, presumed to be fully controlled by the AI programming party. For instance it is well-known that SVM relies quite heavily in data close to the 'demarcation line', hence a small mislabeling in only a small number of data in the training data sets can result in a wrong classification and hence decision. A second example would be to force the AI to interpret/classify data that are on the border or outside its interpolation knowledge base, effectively forcing an extrapolation by a model that has been constructed from an interpolation. Considerations such as the above emphasize the need for training data control as well as robustness safeguards.

II. Geographic Information System (GIS) technology in military operations

Geo-technologies have widened the use of location-based information in a military context (Lenagala and Stimers, 2017). Geographic Information System (GIS) is a computer-based tool that analyzes, stores, manipulates and visualizes geographic information in a map. Nowadays in order to effectively manage the warfare battlefields, which are changing rapidly, it is necessary to use dynamic and updated maps. GIS has become a useful tool in military operations that has further enhanced their effectiveness (Longley et al., 2016). The use of GIS not only provides far-superior accuracy in analyzing location-based information than the previously used techniques, but also supports easy information sharing in a very short time period (Lenagala and Stimers, 2017). GIS technology, by contributing to Military Decision- Making Processes (MDMP), has become a widely used tool for the militaries of developed countries. Many modern armies take advantage of

GIS in MDMP (all branches of the United States military have a military occupational specialty focused on geospatial data analysis - e.g. the U.S. Army's 12Y-Geospatial Engineering). In addition, commercial GIS software for military-specific applications has been developed and employed along with digital databases to provide customized digital maps of variable scale, content and symbolization designed for military units demands (Fleming et al., 2009). Military forces are using GIS in a variety of ways including cartography, battle field management, terrain analysis, remote sensing, military installation management and monitoring of possible terrorist activity (Satyanarayana and Yogendran 2009).

This short review demonstrates the importance of spatial information that offers GIS technology to MDMP for the field commander or the command headquarters for land, sea or air based operations. The spatial data are of crucial importance to the military commander in order to take well-informed decisions. GIS and digital mapping occupy military center stage in activities such as battlefield simulation, logistics management, command control, mission briefing and communications planning. Use of GIS in the management of military bases could reduce base operation and maintenance costs, improve mission effectiveness and provide rapid modeling capabilities for analyzing alternative strategies.

Weather plays a dominant role in the battlefield either on the land, or in the sea or in the air. Since at times, weather conditions may determine the success or the failure of a military operation, real time weather information is essential for field commanders. Thus, knowledge of information regarding cloud coverage, wind conditions, visibility, temperature and other related parameters are of high importance in any operation. The computer based GIS software systems can provide automated weather information to military forces along with other characteristics such as the terrain analysis (eg the Digital Elevation Model - DEM). (Satyanarayana and Yogendran 2009)**,**

In land based military operations, terrain conditions and elevation along with vegetation cover, road networks, and communication lines must be available for effectively guiding troops, restoring communication in the area of operations or sending back-ups. An open GIS approach allows limited access (e.g. geographic images, maps) to individual users, according to their rank and operational duties, for carrying out successfully the planned operations (Satyanarayana and Yogendran 2009)**.** In addition, effective GIS tools, for the army land managers, have been suggested to monitor environmental dynamics and plan military training activities (Singer et al., 2012).

Similar inputs are required in air operations along with precise height information for the targeting process. GIS and GPS (Global Positioning System) support military leaders by reducing uncertainty in decision-making. For example, pilots receive detailed data relayed to the location of the target, plus data of meteorological information, which enhance visibility, and pre- warns them about possible changes, which may occur during an aerial activity (Satyanarayana and Yogendran 2009).

At sea, when there is no visual aid, naval commanders depend largely on indirect methods, to navigate vessels. Global Positioning System (GPS) provides the means of determining vessel's position at sea. Electronic Chart Display and Information System (ECDIS), helps the navigator to navigate the ship safely in all weather conditions, while Electronic Navigation Chart (ENC) is a replacement of the conventional paper chart, which is used as tool for navigation, providing inputs for detailed information about depth, hazards and navigational aids within the area. ECDIS is the real time GIS application in marine environment and ENC is the database for GIS operations. In addition, ECDIS can be used to other naval operations using layers related to oceanographic and meteorological conditions to provide the means for anti-submarine or beach landing (of armed forces) operations (Satyanarayana and Yogendran 2009)**.**

In the present digital era, GIS is an excellent tool for military commanders and its use revolutionizes the way in which military forces operate and function. Although, the potential of some GIS applications has already been developed, the future of GIS in military will be determined by the way that the military units will accept GIS and utilize it in the battlefield operations**.**

III. Radiological weapons effects

Military Science has always been very concerned about the effects and defenses of radiological weapons. Radiological terrorism has been the focus of intense study (Ferguson, et al., 2003) due to widespread fears that nuclear materials could be used as radiological weapons (dirty bombs). As early as 1987, it became apparent that even medical radioactive devices could be used as radiological weapons, when scavengers broke into an abandoned cancer clinic in Goiânia (the capital of the central Brazilian state of Goiás) and stole a cancer treatment device which contained significant amounts of radioactive cesium-137 (Wikipedia - Goiânia Accident, n.d.). According to the IAEA report (IAEA, 1988), after removing a metal canister, which contained 1,375 curies of Cesium-137 from a teletherapy machine, the burglars broke open the canister revealing the Cs-137 source, despite the fact that it had been doubly sealed within two stainless steel capsules. The medical radioactive material in question was in the form of highly soluble Cesium Chloride salt (three times denser than water) which weighted 93 grams inside the canister. Handling the source resulted in distributing some radioactive material among friends and family members. Eventually, the canister and the source ended up in a junkyard, whose owner cut open the source selling the glowing Cesium Chloride powder to curious buyers. A portion of the radioactive powder was carried away by the wind contaminating the environment. According to the Brazilian Nuclear Energy Commission team (IAEA, 1988) 200 people were contaminated, 28 people suffered radiation burns, 4 people died and one person had his arm amputated. Decontamination operations generated some 3,500 cubic meters of radioactive waste which also included debris from building demolitions. Finally, about 87% of the radioactive material was recaptured while there were devastating effects on the local economy and quality of life. The Goiânia accident indicates that terrorist radiological weapons can result in widespread radiological contamination and many casualties. The Arms Control Center is particularly interested in the effects of radiological weapons presenting here briefly the parameters of the computer code HOTSPOT (Homann, 2015; Homann & Aluzzi, 2013) used in simulating radiological attacks (the material of this section is also included in a research proposal written by the Arms Control Center).

The Hotspot Health Physics codes, which are used by the Arms Control Center in the study of radiological weapons, were created to provide emergency response personnel and emergency planners with a fast, field-portable set of software tools for evaluating incidents involving radioactive material. The software is also used for safety-analysis of facilities handling nuclear material. Hotspot codes are a first-order approximation of the radiation effects associated with the atmospheric release of radioactive materials. Its mathematical model is a hybrid of the well-established Gaussian plume model, widely used for initial emergency assessment or safety-analysis planning. Virtual source terms are used to model the initial atmospheric distribution of source material following an explosion, fire, resuspension, or user-input geometry. Hotspot takes into account the following crucial parameters of the attack:

A. Wind speed

Wind speed a crucial parameter of a radiological attack. In fact, if we assume that all other meteorological parameters are constant and that the radiological material has a relatively large half-life then the dose received at a certain distance downwind from ground zero (GZ) is inversely proportional to wind speed while the area receiving a certain dose is also a rapidly decreasing function of speed.

B. Stability Category

Meteorologists distinguish several states of the local atmosphere: A, B, C, D, E, F. These states can be tabulated as a function of weather conditions, wind speed and time of day. According to the stability category the attack can result in a wide spectrum of lethal effects. Therefore the attacker will certainly take that into account, just as it happens by war-planners, so that the lethal effects are maximized.

C. Inversion Layer

At first sight, it seems perfectly reasonable that temperature should decrease with altitude. However, due to various atmospheric phenomena there is sometimes an altitude at which the temperature gradient is inverted (temperature begins to increase with increasing altitude). The inversion layer acts as a blanket that limits the vertical mixing of the released radioactive material. Inversions can spread over large areas or be quite localized, and can last for many days or be of only a few hours duration. The region below the inversion layer is also referred to as the mixing layer. The mixing layer height ranges typically from 100 m to 3,000 m and can significantly increase or decrease air-concentration values and the respective lethal probabilities.

D. Source term

According to the Gaussian plume model, after a radiological explosion, the air concentration, as well as the dose received by an individual downwind, is directly proportional to the source term (i.e. the quantity of the radioactive material). Therefore, all the results of this proposal will scale linearly with the mass (or the activity) of the source.

E. Deposition Velocity

The heat and smoke of a radiological dispersion device (RDD) will lift small particles of radioactive material up into the air which, according to their nature, will settle to the ground as they are carried along by the wind contaminating the ground surface. Large particles will contaminate the immediate vicinity of the explosion while smaller (fine and mostly respirable) ones will travel large distances or will rise up at high altitudes until they are deposited on the ground. The velocity at which this deposition takes place is called deposition velocity. Obviously, non-respirable material will have a much larger deposition velocity than respirable ones.

F. Altitude of Explosion (Height of Burst)

The effect of altitude is clear and predictable. All relevant simulations indicate that radioactive plumes resulting from ground explosions yield higher doses than those resulting from high altitude ones. All simulations show perfectly clear that a ground explosion is by far the most lethal choice of a terrorist and we will focus our study on it.

G. Explosive Energy

The geometry of the radioactive plume as well as its granularity depend on the energy of the explosion. The more energetic the explosion the larger the temperatures attained by the radioactive material and thus the finer the particles generated by the explosion (molecular bonds break more easily at high temperatures). Moreover, the more energetic the explosion the larger the dimensions of the initial cloud and, thus the smaller the concentrations of the radioactive particles in the air and on the ground.

H. Timing

The time of attack is indeed a very decisive parameter, which needs special attention. During daytime many people will be in the streets and the radioactive plume will be easily mixed with other gases which form the usual urban pollution. The cloud will not be easily detected but this is not the case with the explosion itself. Early detection can help since it may provide some warning to the public which can avoid inhalation of the cloud by finding shelter in nearby buildings (or staying indoors if are not caught in the streets). At nighttime a radiological attack against urban targets would cause fewer casualties as most people will be indoors during the plume passage and the population density in the streets will be very small.

I. Target Conditions

It is common sense that the terrorists will choose a densely populated metropolitan area so that the lethal effects of their attack are maximized. Once we have estimated the lethal areas then we can simply multiply the population density by that area to estimate the number of casualties. Warning is an extremely effective countermeasure. If the public has early enough warning it can simply evacuate the area thus avoiding any exposure to the lethal effects of the attack. Even on a very short notice the public can simply remain indoors, have recourse to shelters or avoid being in the streets at the time of attack.

All the above parameters are taken into account by HOTSPOT simulations conducted at the Arms Control Center to estimate doses and ground contamination (surface concentrations) after a radiological attack. The importance of such military scientific studies cannot be overestimated as they can predict the destructive effects or RDDs and suggest possible mitigation measures (e.g. evacuation and decontamination procedures).

IV.MILITARY APPLICATIONS OF HIGH TEMPERATURE SUPERCONDUCTORS

A. Introduction

Superconducting materials' unique properties enable significant improvements in commercial as well as military applications compared to conventional systems in electronic warfare equipment and high power applications. These properties include (Kolli, et al., 2017):

- Zero resistance to direct current
- Extremely high current carrying density
- Extremely low resistance at high frequencies
- Extremely low signal dispersion
- High sensitivity to magnetic field
- Exclusion of externally applied magnetic field
- Rapid single flux quantum transfer
- Close to speed of light signal transmission

Superconductivity brings sensitivity, accuracy and performance advantages. Superconducting wires, tapes and coils can be used in magnets, generators, magnetic energy storage, AC transmission lines, etc. During the 1970s and until the end of 1990s there were several important achievements in the superconducting technology. Some of the main applications in the electric power sector which were accomplished using liquid helium, i.e. low-temperature superconductors (LTS) technology, are: AC generators, motors, AC transmission lines, Magnetic Energy Storage (SMES), transformers, etc. During this period, USA were reluctant to invest in new technology, but other countries had pushed forward programs for the development of superconducting generators and other electrical power applications.

In 1986, the discovery of high temperature superconductors (HTS), i.e. oxide based ceramic materials demonstrating superconductivity above 35K, and the following announcement, in 1987, of cuprate superconductors functioning above 77K, brought a sharp revitalizing interest in the applications of superconductivity. USA took a leading role in the research and development of power systems with Department of Energy (DoE) and Defense Advanced Research Agency (DARPA) programs to facilitate military applications of superconductivity, aiming at prevailing in the field of superconducting military applications as they had fallen far behind in comparison with Japan and USSR (Anon, 1988)

HTS can provide solutions to specific challenges related to military/space environment (US Congress Office of Technology Assessment , 1990):

- Light weight: eliminating bulky liquid helium refrigeration systems reduce the size and weight of superconducting equipment providing flexibility and mission capability of the vehicles on which they are deployed.
- Ruggedness: the military superconducting equipment should continue to operate during battle conditions, and to be rugged enough to withstand vibration, acceleration and other stresses.
- Radiation hardness: space craft do not have the protective layer of the Earth's atmosphere to absorb the radiation from solar flares and cosmic rays.
- Low power consumption.

In the following section some of the main military applications of HTS so far are discussed.

B. HTS military applications

1. HTS cables, wires and tapes.

Due to higher transmission capacity, lower losses, and reduced weight and operating costs, HTS cables are superior to conventional copper wires for almost all applications. Electrical losses (including those of cryogenic systems) are reduced to one tenth when compared to losses in the AC- copper cables and to zero when compared to the DC- copper cables. American Superconductor Corporation (AMSC) has scaled up the cost-effective production of Yttrium-based 2nd generation superconducting wires with nominal performance nearing 100 A (Fleshler, et al., 2009). 2G wires present improved performance and are used in the production of HTS electrical power devices (Curcic & Wolf, S.A. , 2005).

2. HTS motors and generators

Large capacity HTS motors can be used on warships and merchant vessels for electric propulsion (Jun, Z., et al., 2012) as well as aircraft propulsion (Masson, et al., 2005). In 2009, the US Navy announced the successful power- test of a superconducting motor producing 49,000 hp. The motor was jointly developed by Northrop Grumman and AMSC. Incorporating coils of HTS wire, the motor weighs about 75 tons compared to 300 tons for a tradition copper wound electric motor and is able to carry 150 times the current of similar-sized conventional motors used on the first two DDG-1000 series destroyers. This technology will make ships more fuel-efficient and free up space for additional war-fighting capability (Patel, 2009; Pearson, 2009). The advantages of HTS generators make them promising for applications on military platforms. These advantages include: ability to carry high electrical current densities; low noise; excellent stability in transient phenomena; high performance under partial load; minimum maintenance requirements (Oberly, 2006).

3. Mine protection

Moving through the magnetic field of the earth, steel ships develop a low level magnetic charge which can be detected by magnetic sensors and magnetically activated underwater mines. For this reason, most naval ships are equipped with large copper degaussing coil systems to "neutralize" their magnetic signature. In July 2008, the U.S. Navy launched a revolutionary technology as a counter-mine tool. Utilizing HTS materials, a degaussing coil was produced and installed on the USS Higgins (DDG 76). The new system is cooled by a cryogenic compressor and can carry high current densities (at a factor of 100-200 times higher than that of traditional conductors) at lower voltage. This results into smaller footprints and improved efficiency. In addition, HTS degaussing systems are 50-80% lighter than copper based systems, which translates into fuel saving or opportunities to add different payloads (Vietti, 2009; AMSC, 2008).

4. Communications

HTS unique features make superconducting electronics most promising for satellite communications as they offer the advantages of ultra-low signal dissipation and distortion along with intrinsic (quantum) accuracy. Superconducting devices present inherent tolerance to high radiation environments which is a requirement for satellites and battlefield systems. Superconductor RF filters with superior interference cancellation have been employed in U.S. cellular base stations, enabling wider range and fewer dropped calls. For defense applications, 4th generation All-Digital Receivers (ADRs) take advantage of the HTS ability of analog-to-digital conversion and present flexibility in the signal processing that detects, characterizes and decodes incoming RF signals (Hole, 2006; CCAS, n.d.).

C. Conclusion

Years of research and a number of successful projects have proved that HTS can bring a lot of benefits to military applications. Nonetheless, R&D in this field is ongoing to exploit the numerous capabilities of this technology. Superconducting distribution grids on ships, Integrated Power Systems and Next Generation Electric Machines, are some examples of current research programs (Hebner, et al., 2017; Miller, et al., 2013; AMSC, 2017)

V. Laser technology in laser guided missiles

Laser technology has observed a great advancement over the last few decades. This technology is used for a wide range of applications including medical sciences, military, industrial manufacturing, electronics, holography, spectroscopy, astronomy and much more.

Military officials have indubitably always been interested in laser technology, even before the first laser was invented. Especially, since these devices can bring technological revolution in warfare, when used as rangefinders, target designation, sensors, active illumination, data relay devices, directed energy weapons, weather modifier and much more (Kaushal, 2017).

In case of global military conflict, the role of anti-missile defense becomes very important. Although anti-missile defense with a hundred percent reliability was not reached by any country, huge efforts are put into this area. In addition, in the battlefield environment, the timelines between identifying, tracking and shooting are very critical to ensure the continued success of the warfighters. This requires improved pointing, targeting and designating capabilities during military operations. For those purposes, early attack detection systems, controllable rockets, high power lasers are used.

Missiles or bombs can be guided and controllable via a laser designator device (LTD), which calculates relative position to a highlighted target. One of the earliest successful smart bombs developed and operationally used were the Laser Guided Bombs (LGBs). Laser designators used in LGBs give the precise marking of ground based or airborne targets especially for small-sized and well-defended targets. LGBs proved to offer a much higher degree of accuracy than unguided weapons, but without the expense, complexity, and limitations of guided air-to-ground missiles

Laser-guided weapons (LGWs) were first developed in the United Kingdom and United States in the early 1960s. They made their practical debut in Vietnam (Spencer C.T, 2011). In the wake of this success, other nations, specifically the Soviet Union, France, and Great Britain, began developing similar weapons in the late 1960s and early 1970s, while US weapons were refined based on combat experience. During the 1982 Falklands War LGWs were used, though not on a large scale, by the British forces (Hempstead, 2005). The first large scale use of smart weapons came in the early 1990s during Operation Desert Storm, while later there were used in large numbers during the 1999 Kosovo War (Spencer, 2015). Current laser guided missiles work in one of two ways:

A) *Beam rid*ing is based on a signal that is pointed towards the target. The signal does not have to be powerful, as it is not necessary to use it for tracking as well. First, an aiming station in the launching area directs a laser beam at the enemy aircraft or tank. Then, the missile is launched and at some point after launch is "gathered" by the laser beam when it flies into it. From this stage onwards, the missile attempts to keep itself inside the beam with the help of a sensor at missile's tail, while the aiming station keeps the beam pointing at the target. The missile, controlled by a computer inside it, "rides" the beam to the target (Maini A. K., 2013).

B) The second type uses a laser for guidance is technically called the *semi active homing* (Maini A. K., 2013). Somebody, it could be the pilot or a soldier on the ground, shines a laser beam on the target.

B1) A pulse repetition frequency code is used for the laser designator, the laser spot tracker, and the laser guided weapon. Each must use the same pulse pattern (same code) when operating together. Before dropping the bomb, the bomber aircraft computer tells the missile's control system the specific pulse pattern. Once the bomb is in the air, the control system is only interested in laser energy with this pulse pattern. The laser pulses are encoded to reduce the risk of jamming or spoofing.

B2) The reflected and scattered target's light is captured by a special system and sensors installed on the weapon that computes the necessary flight path corrections and sends back the control signal to focus the weapon on the target.

Most of the LTDs used in LGWs are based on Nd: YAG that emits short coded pulses at 1.06 μm wavelength (Kaushal, 2017). The advantage of using solid state lasers is that their power levels can be increased substantially when Q-switching is used to achieve short pulse lengths.

Thriving to protect the soldier's eye in a battlefield, lasers with a wavelength greater than 1.4 μm is preferred as these radiations are absorbed in the cornea of the eye and consequently, cannot reach sensitive retina. Therefore, eye-safe laser such as Er:glass solid state laser, operating at 1.5 μm or CO_2 operating at 10.6 μm with a pulse energy less than 10 mJ are a preferred choice for day or night-time operations (Kaushal, 2017). Other eye-safe lasers are Raman-shifted Nd:YAG lasers and Er:fiber lasers whose operating wavelength is in the range of 1.53 to 1.55 μm.

Several types of LGWs are: Maverick (Maini A. K., 2013), Hellfire (Aftergood S., 2011), Laser-Guided Bombs (GBU-12 Paveway II, GBU-16 Paveway II, Paveway III) (Kopp C. 2007), AGM-123 Skipper II, and the Griffin Laser Guided Bomb (Maini A. K., 2013).

Precision accuracy depends upon target size, laser beam divergence and designation range. In order to improve the accuracy of LTDs, laser beam divergence has to be chosen very carefully so as to avoid beam divergence losses along the path, between the laser source and the target.

Although LGWs offers high precision operational flexibility and remarkable capability of effective lock-on after launch targeting, there are some disadvantages, resulting the missiles to veer off course and potentially causing costly damage to unintended targets:

- The primary limitation is that the detector of the LGWs needs to be able to see the laser spot at most of the times and definitely short of hitting the target
- They are no good in the rain, fog, dust, smoke or in weather conditions where there is sufficient cloud cover.
- The laser guidance is not useful against targets that do not reflect much laser energy, including those coated in special paint which absorbs laser energy.

Special GPS-guided bombs are designed by using a system (JDAM) based on high-precision gyroscopes to monitor the speed and direction of the bomb and an inertial guidance system**.** This system can take control of the bomb if the GPS signal is lost for any reason (Kopp C, 2014).

VI. Detection of Explosives and Dangerous Chemical Agents Using Animals and Technology

Detection and identification of chemicals that can pose a threat is pivotal for the security of personnel, material and installations. Concern regarding illegal trafficking of hidden explosive material, dangerous chemicals or narcotics on commercial airlines has become more and more intense. On-site explosives detection is major issue for operational security in regions with military activities -currently or in the past- in order to prepare efficient decontamination. Terrorist or criminal attacks against civilian or military targets using chemical and explosive materials pose a significant threat in every country, leading to an urgency to increase the capacity of agencies involved in counter-terrorism activities and infrastructure protection to identify chemicals of particular risk of diversion and misuse by criminals and terrorist groups.

The issue of detection of dangerous chemicals has been an active area of research. Chemical explosives, agents of chemical warfare and narcotics are the main targets of detection practices during war or peace. Despite their differences from the point of view of their chemical structure, all these compounds can be traced through their vapors or as traces -solid or liquid particles- on air or surfaces (Bogue, 2015). This article reviews the different approaches, the use of trained animals or the use of detector devices built for that purpose. Traditional and modern practices are presented as well as future possibilities and technologies.

A. Using animals

1. Dogs

Traditional detection of narcotics and explosive vapors and traces relies on the olfactory system of highly trained dogs (*Canis familiaris*) and it is still the most effective and efficient method. Used ubiquitously by law enforcement, national security and private agencies for detection, sniffing dogs do not just react to a particular chemical smell, but to a combination of odors that make up an explosive or narcotic (Johnston, et al., 1998). Canines combine selectivity with mobility and independent thinking, qualities that rank them as the current best method for real-time detection of explosives, narcotics and other potentially hazardous substances. Their extraordinary ability to smell inspired the development of numerous detection techniques that are available today.

The use of dogs as detectors is based on the well-established reliability and the impressive selectivity and sensitivity of their sense of smell. The olfactory capabilities of the canines stem from the high number of olfactory receptors they possess, the large number of specific neurons in the brain, anatomical structures resulting in unique nasal airflow patterns and fluid dynamics that increase air retention while sniffing (Tomsic, 2013). These attributes combined with the high intelligence and ability to receive training and the positive attitude to coexist and work with humans, render the dogs 'the tool of choice' when it comes to detection of any kind. On the negative side, the cost for a special canine unit is high, even with high operational standards. The purchase of a single trained dog costs between 8000 to 15000 $ in addition to medical expenses, continuous training in specific training camps, acquisition and handling of the chemical agents for the training, transportation of K-9 units for a 10-year service. To this, one should add the cost of hiring and training of specialists such as dog handlers, trainers and vets. Another negative point is the fact that dogs can get tired or bored and when that happens the effectiveness of their detection output is diminished (Gazit & Terkel, 2003).

There are several animal species that possess especially sensitive olfactory systems and are capable of detecting minute concentrations of chemicals. Properly trained and motivated, individuals of these species can become valuable allies in the fight of detecting dangerous substances in a variety of circumstances. Two species that show promising potential are rats and bees. Even if they seem unlikely candidates for the task, given their completely different -compared with dogs- relationship to humans and their cognitive capacities and intelligence, these animals have extremely acute sense of smell, in many cases surpassing canines. Further, their small size and availability can be an advantage in a number of cases.

2. Rats

Giant African pouched rat (*Cricetomys gambianus*) is the largest of the muroids. Within the past decade, giant pouched rats have been used successfully to detect landmines. In Mozambique, an African country littered with land mines, trained rats were used to search for explosives (Poling, et al., 2011). The project was designed and directed by APOPO, a Belgian nongovernmental organization based in Tanzania. The main advantage of using rats instead of dogs is the cost. For the same decontamination mission, it is cheaper to utilize rats. The rodents are easier to maintain, to feed and to transport, are available in high numbers and can reach in places where dogs cannot due to their smaller size. A rat weight is too low to trigger an anti-personnel land-mine.

3. Bees

During the 20th century, there was scientific debate regarding the olfactory ability of honey bees (*Apis mellifera*). Supporters of Dance Language Theory suggested that bee foraging is a socially coordinated behavior (Von Frisch, 1974). The Dance Language was the mainstream paradigm, leading to an underestimate of the true olfactory capability of bees. It is now known that bees can be trained through sent (Wells & Wenner, 1973). This fact offers the opportunity to harness the olfactory chemosensory ability of bees. Bees are able to recognize a vast array of different compounds at vapor concentrations on the scale of parts per trillion, even parts per quadrillion (MacDonald, 2003). Training bees is similar to training dogs and involves conditioning so that the insect would associate an odor, such as explosive materials or other chemical substances, with a reward, such as sugar.

Bees may be used as living chemical biosensors in two ways: constrained in a laboratory-based assay termed the Proboscis Extension Reflex system (PERs) or as traceable, free-flying biosensors in the field (Bromenshenk, et al., 2015).

As an assay, a number of bees are constrained inside an apparatus, immobilized in situ, actually glued on the spot on stable cassette and bee-holder. The apparatus contains motion devices or simply a camera and image processing to monitor the motion of every insect's tongue. A trained bee would present a Proboscis Extension Response (PER) when it smells a predetermined odor (e.g. TNT). PER is a response due to conditioning. The insect is reacting to smell by extending its tongue in order to receive the expected reward, commonly sugar water. That motion of the proboscis is detected from the imaging sensor inside the apparatus and it gives a positive signal. The apparatus, benchtop or portable, can be used as a field detector, since the presence of target vapors in detectable concentration would elicit PER (Bromenshenk, et al., 2015).

The use of free-flying honey bees is suited for open field detection and it is based on the monitoring of the flying pattern of a swarm of trained bees. University of Montana researchers in Missoula have trained honeybees as an efficient and low-cost means to screen large areas for hidden explosives. Landmines and buried unexploded ordnance leak chemicals into the environment (Carlsten, et al., 2011). Trained honeybees swarm areas where explosive residue is present. The location of the residue can be mapped to provide a picture of the extent, location, and density of bomb-contaminated areas.

A hive of 40,000 to 65,000 bees costs around U.S. $100 and can be trained in as little as two hours (MacDonald, 2003). Bees are indigenous to a wide range of climates and beekeeping is a world-wide practice. Training a hive is a straight forward process. A sugar-water feeder and traces of explosives are set up near a colony. As the bees feed, they begin to associate the explosive's odor with the food source. Bees also train each other. The main expense of such an endeavor would be the cost required for setting up a monitoring system, by means of laser-guided motion detectors LIDAR (Light Detection And Ranging) combined with digital imaging analysis or even Harmonic radar technology. The monitoring system would follow the swarm's movements. The location of the residue can be mapped to provide a picture of the extent, location, and density of bomb-contaminated areas.

B. Purpose-built sensor device Technology

Operational requirements for chemical detection established the need for state of the art, portable chemical agent detectors. In wartime, the use of animals is impractical in situations where units or individuals operate in enemy territory. A soldier or a unit cannot have its own bee hive sentinels. The same applies for routine everyday check of installations, where the use of dogs would disrupt the function of the operation or it might cause harm to the animal and the handler, for example during the examination of a building that is a suspected site of a nerve agent attack. In similar situations, portable detector devices would be the tool of choice. Such devices should be able to detect the target substances directly, by means of their chemical nature, or through a characteristic property, such as their electromagnetic response to an external stimulus or their spectrum. Sensitivity, selectivity, miniaturization and ruggedization are necessary qualities for a military purpose detector device.

Technology-based detection of chemicals includes vapor and trace detection techniques (chemiluminescence, mass spectrometry, ion mobility spectrometry, electrochemical methods and micromechanical sensors, such as microcantilevers) and bulk detection techniques (neutron techniques, nuclear quadrupole resonance, x-ray diffraction imaging, millimeter-wave imaging, terahertz imaging and laser techniques).

1. *Spectroscopic approaches for the detection of explosives*

a) Ion mobility spectrometry (IMS)

The molecules of the air sample are ionized and passed to a detector. The period of time the ion flies in the tube, termed drift time is a function of its mass and its charge. The mass to charge ratio is determined. By determining the mass-to-charge ratio, it is possible to identify components within the sample through comparison with known standards. An IMS spectrum is a plot of ion current versus time, with different peaks representing different specific ions.

b) Mass spectrometry (MS)

Samples are drawn from the air into a mass spectrometer where molecules are first ionized and then passed through a magnetic filter, which allows ions to be identified based on their charge-to-mass (m/z) ratio. In some systems, the MS is connected to a front-end gas chromatograph. There are several types of mass spectrometers with different principles of operation (Gross, 2017). In time of flight mass spectrometry, the determination of m/z is achieved thought the value of time the ionized molecule spent across the tube of the spectrometer. In Gas Chromatography-MS chemical species are separated in the column of the chromatographer and then identified in the mass spectrometer. Electrospray ionization MS, usually coupled with an HPLC front-end separator, is similar to GS-MS but more sensitive. Several instruments allow another step of process, tandem MS or MS/MS, where the ions produced during the ionization of the initial sample are filtered based on their m/z value. The selected, user-defined ions are passed to a collision cell. Within the collision cell the precursor ions also known as "Parent ions" are bombarded with an inert gas (Xe, Ar) and are further broken down into different charged and mass product or daughter ions due to Collision Induced Dissociation. These product ions are then run through an additional quadrupole to further separate the ions which is set to monitor specific ion fragments. This process can be repeated several times in order to get highly specific readings.

Mass spectrometers have excellent specificity for identifying different ions, and some systems have sub-attomole sensitivity. However, they are bulky, non-portable and they need power supply and laboratory grade installation along with various additional equipment in order to operate such as inert gas supply, pumps and dedicated computer interface. As a method, is quite an expensive one and requires maintenance and university-trained operators. As a detector system, it is valuable only for screening high profile installations.

c) Old factory type sensors

There is potential in a biomimetic approach, in which research inspired from nature lead to the development of man-made systems that copy olfactory mechanisms. Of special interest is the mimicking of biological olfaction for the construction of biosensors based on animal olfactory macromolecules - such as odorant-binding proteins - for chemical molecular sensing. Olfactory receptor neurons of the fly *Drosophila melanogaster* were probed against a number of chemical substances (Marshall, et al., 2010). Detection of explosives by means of direct stimulation of olfactory sensory neurons has been reported previously (Corcellia, et al., 2010). A biomimetic odorant sensor which co-expresses olfactory receptor genes and a companion receptor Or83b in living cells was constructed (Liu, et al., 2013), in order to classify unknown volatile chemicals and detect specific types of illicit substances. Goldsmith and co-workers (Goldsmith, et al., 2011) reported the manufacture of a nanoelectronic interface comprising of mouse olfactory receptor proteins (ORs) coupled with carbon nanotube transistors. The resulting device transduce signals associated with odorant binding to ORs in the gas phase under ambient conditions. Proteins and neurons from different species can be employed (pig, worm, wasp, dog).

d) Micro-electro-mechanical systems (MEMS)

These are miniature detecting devices allowing the measurement of minute difference of several physical properties of the system by means of optical or electrical detection. The change in the property under examination is caused by the adsorption of target molecules on the appropriately coated surface of a cantilever. Subsequently, identification and quantification of the alteration lead to the identification and quantification of the target chemical compound.

(1) Surface acoustic wave sensors

Surface acoustic wave (SAW) sensors detect a chemical by measuring the disturbance it causes in sound waves across a tiny quartz crystal. The SAW sensor is a small, piezoelectric quartz crystal that is coated with a thin film of a proprietary polymer which selectively absorbs the gas or gases of interest. An acoustic wave is generated on the surface of the piezoelectric substrate material. If a vapor is absorbed, the properties of the wave alter (e.g. amplitude, phase, harmonic content, etc.). The measurement of changes in the surface wave characteristics is indicative of the vapor and thus can be used for the substance identification. Currently a device named Joint Chemical Agent Detector (JCAD) uses surface acoustic wave technology to detect the chemical warfare agents. Eight SAW crystals, each coated with a different polymer, form the chemical sensor array in the detector unit. Each polymer is specifically designed to attract nerve, blister, or blood CW agents. The base frequencies for the SAWs are 275 MHz. The property measured in this case is the resonant frequency of the SAWs. The frequency changes from the SAW array are processed by a neural network algorithm to determine the type and concentration of the chemical agent (Laljer & Owen, 2002).

(2) Microcantilever Sensors

The detection method is based on monitoring the changes in surface stress, bulk stress and mass of micro-cantilever (MC), which are caused by the adsorption of target molecules on the chemically modified surface of the cantilever. The change in cantilever deflection or change in vibrational amplitude is most commonly measured by a laser reflected off the backside of the cantilever and onto a position sensitive quadrant photodiode. Deflection can also be measured by the change of capacitance or resistance of the cantilever. A more complex device that combines MEMS with the capacitance of CMOS (complementary metal-oxide semiconductor) is presented by Tomsic (Tomsic, 2013). The apparatus is subsequently compared to a sniffer dog.

C. Conclusions

The diversity of cases that require accurate and quick detection of potentially dangerous chemicals has led to the conception and development of a variety of techniques, all of whom are useful, depending on the circumstances. The combination of several approaches increases reliability. The use of traditional practices, such as the use of detector canines have historically proven its value and they will continue for the foreseeable future. Continues study on the field ensures the optimization of the security capabilities by means of new applications and technologies. Increase demand can only lead to cost reducing practices, leaving space for the development of more exotic and imaginative methods such as the use of trained insects for monitoring potential security and environmental threats. Further, the development of portable detector devices will allow the extended use of the relevant technology leading to real-time accurate chemical detection to an individual level. To that direction, the biomimicry of the olfactory tools from several animal species seems very promising. As a closure note, the advance on the field of chemical detection may also play a role in health care, environmental monitoring and industrial health and safety.

VII. CONSTRUCTION MATERIALS FOR MILITARY APPLICATIONS

Nowadays, the Armed Forces of the majority of developed countries are facing challenges that include construction and protection of infrastructure in several military operations. Changes on the battlefield conditions result to intensifying threats in the case of an attack that require increased protection levels (such as ballistic and blast protection for temporary or constructed military facilities, radiation shielding etc.) concerning all types of facilities, infrastructure and above all military personnel. This introductory article aims to review the progress that has been achieved in the field of civil engineering materials used for military protective structures, with emphasis in different types of concrete used in radiation shielding buildings.

a) Types of military buildings

Military sites are both offensive and defensive and do not have to be in the front line to be of the foremost significance. They include fortifications designed to withstand assaults and bases from which operations could be launched. To these the 20th century added buildings designed to protect civilians from various forms of air-attack.

The category of military buildings is a particularly broad one, and overlaps are inevitable with others. Broadly speaking, military buildings can be divided into the operational and the ancillary (commonly known in the military as 'the teeth and the tail'): buildings for fighting, and buildings for living and working. The following operational structures can be distinguished:

- Army buildings: Those range from permanent barracks and officers' messes, to temporary structures.
- Aviation sites: Perhaps the largest category of modern military buildings in most countries. Military airfields are typically large and complex sites that were built in great numbers after World War II. Airfields were increasingly given concrete runways for all-weather flying. The component elements range from station headquarters and guard houses, to more functional technical blocks, hangars and control towers.
- Bombing decoys: Intricate systems of deception, laid out away from urban areas to draw enemy raiders away from their intended targets. Dummy systems of lighting, and street grids, simulating cities under aerial assault, were laid out on less vulnerable sites.
- Pillboxes: Strong-points, generally of reinforced concrete, placed at strategic locations, such as at river crossings, or along coastal and inland antiinvasion 'stop lines' which were intended to slow down the progress of an attacking force. Some were designed for machine guns; others, more unusually, housed artillery.
- Air raid shelters
- Military bridges
- Military hospitals
- Military Academies
- Naval buildings
- Industrial Military Buildings
- Communications centers

Although personal protection measures for soldiers mainly involve high performance light armor materials that are normally rather expensive, for the protection of buildings, shelters and critical infrastructure facilities, the aspect of weight seems to be not so critical. Contrary to this, the logistic aspect is crucial especially for missions abroad were in such cases it is preferred to use local materials as much as possible.

b) Construction materials used for military infrastructure

The rapid development of building and civil engineering after World War II is characterized by wide application of concrete as the basic material in all branches of infrastructure, including those for military purposes. Concrete is one of the most common construction materials widely used that fulfils most of the above criteria and is by far the most widely used material for radiation shielding due to its cheapness, satisfactory mechanical properties and durability. In its most basic form, concrete is a multiphase-multicomponent mixture that typically consists of Portland cement, fine and coarse aggregates, water, mineral additives and chemical admixtures. The principle cementitious material is Portland cement. Portland cement has high energy quantities and emissions associated with its production, which is conserved or decreased when the amount used in concrete is reduced. Today, most concrete mixtures contain supplementary cementitious materials, sometimes referred to as mineral additives, for improved concrete performance in both its fresh and hardened state. Furthermore, supplementary cementitious materials reduce the consumption of Portland cement per unit volume of concrete. Supplementary cementitious materials such as fly ash, granule blast furnace slag and silica fume enable the concrete industry to use hundreds of millions of tons of by product materials that would otherwise be used as land-filled as in the west.

New types of structures and new technologies in building, structural and civil engineering created more difficult requirements for this material. The classification of concrete types is based on the basic feature of concrete, which is its compressive strength. According to Kmita (Kmita, 2000), the following cement-based concrete classification is made, taking into account the latest achievements in concrete ingredients and the technology of production: (i) conventional concrete (CC), up to grade 60 MPa; (ii) high strength concrete (HSC), grades 60-90 MPa; (iii) very high strength concrete (VHSC), grades 90-130 MPa; (iv) reactive powder concrete (RPC), grades 200-800 MPa; (v) high performance lightweight concrete (HPLC) greater than 55 MPa.

c) Concrete with radiation shielding properties

Ionizing radiations such as energetic photons and charged particles such as electrons take place in nuclear technology applications (nuclear reactors, nuclear power plants, nuclear medicine etc.). However, wherever the energetic photons or electrons take place in an application, there is always a safety issue coming down due to their health hazard potential. Therefore, proper shield design is of vital importance not only for protection of military and other personnel working in places where radiation is involved but also protection of military or laboratory equipment from radiation hazard.

The performance requirements of the concrete of containment structures are mainly radiological protection, structural integrity and durability. For this purpose, high-performance heavy density concrete with special attributes can be used (Ouda, 2015). The density of heavyweight concrete is based on the specific gravity of the aggregate and the properties of the other components of concrete. Concretes with specific gravities higher than 2600 kg/m^3 are called heavyweight concrete and aggregates with specific gravities higher than 3000 kg/m^3 are called heavyweight aggregate. The aggregates and other components are based upon the exact application of the high density concrete. Some of the natural minerals used as aggregates in high density concrete are hematite, magnetite, limonite, barite and some of the artificial aggregates including materials like steel punchings and iron shot. Especially for barites ($BaSO_4$), their potential use in building construction was considered to be ideal to radiation protection, but this is not feasible as global barite reserves are not enough. However, other researchers (Akkurt, I. & El-Khayatt, A. M., 2013) report that for concrete that contained barites as aggregates, although improved concrete shielding properties against gamma-rays were recorded, it is not an ideal material to improve shielding properties against neutron radiation. If a high barite proportion is required for concrete used against both neutron and gamma-ray it is recommended to back up it by hydrogen absorber. Examples of such materials are water-bearing concrete, magnesium oxychloride concrete and water, masonite, moist earths, etc.

Minerals like bauxite, hydrous iron ore or serpentine, all slightly heavier than normal weight concrete can be used when high fixed water content is required. It is essential that heavy weight aggregates are inert with respect to alkalis and free of oil, and foreign coatings which may have undesired effects on bonding of the paste to the aggregate particles or on cement hydration.

Presently, heavyweight concrete is extensively used as a shield in nuclear plants and radio therapy rooms, and for transporting, storing and disposal of radioactive wastes. For this purpose, concrete must have high strength and high density. Heavyweight and high strength concrete can be used for shielding purposes if it meets the strength and radiation shielding properties. Such concrete that normally utilizes magnetite aggregate can have a density in the range of 3200-4000 kg/m^3, which is significantly higher than the density of concrete made with normal aggregates. Concrete aggregates play an essential role in modifying concrete properties since the physico-mechanical properties affect significantly its shielding properties.

Another factor that needs to be assessed is the resistance of concrete to radiation that may cause losses in mechanical strength. Gamma radiation from different sources that range from special military equipment, arms and ammunition or even radioactive wastes, requires further investigation because of its ability to deeply penetrate and degrade materials (Soo & Milian, 2001). Early studies indicated that damage to concrete will only occur for gamma doses on the order of 10^8 grays, Gy. A detailed explanation for the strength losses is not known. Possibly, the losses on compressive strength could be connected with the radiolysis of the water of hydration in the cement, as well as pore water. If hydrogen and oxygen radiolytic species are lost during radiation, this would decrease the level of cement hydration, and it may be postulated that the strength would also decrease (Soo & Milian, 2001).

Experimental work by Soo & Milian (Soo & Milian, 2001) showed that for Portland cement mortars the decreased compressive strength could occur at gamma doses that are much less than the threshold dose of about 10^8 Gy cited by other workers. The curing time during the radiation is an important factor in quantifying the amount of strength loss. It is proposed that for a dose rate on the order of 31 Gy/hr, losses in strength may occur for relatively low doses of the 10^5 Gy range.

The concrete shielding properties may vary and is dependent on the composition of the concrete (Kharita, Yousef & AlNassar, 2011). Different types of special concretes have been developed by changing the aggregates used in mix design, depending on the available natural and artificial local materials (Akkurt et al., 2005; Kharita et al., 2008; Kaplan, 1989; Ibrahim and Rashed, 1998). Since hydrogen, iron, and carbon have suitable scattering cross-sections they can be used for moderating fast neutrons making concrete produced by carbonate aggregates or iron ores (hematite) very attractive to be used for neutron shielding. The resultant slow or thermal neutrons should be captured using materials with suitable capture cross-section, like boron and cadmium. The capture of thermal neutrons usually results in the production of hard or penetrating gamma radiations called capture gamma rays. To reduce or suppress the production of this secondary-capture gamma radiation, elements may be introduced which have two characteristics; large neutron capture cross section, and causing the emission of soft capture gamma rays which are much less penetrating and, are readily absorbed within radiation shield. The boron isotope B-10 has a high capture cross-section for thermal neutrons. In this regard, boron is far more effective than other elements such as hydrogen and silicon in capturing thermal neurons (Kharita, Yousef & AlNassar, 2011, Kaplan, 1989).

Boron could increase the neutron shielding effectiveness of concretes, since it works as a suppressor of secondary-capture gamma rays. According to Jaeger et al., (Jaeger et al., 1975) boron can be added to concrete in three different ways:

i) as aggregates: some boron containing natural minerals and boron containing industrial materials have been used as aggregates for radiation shielding concrete. Commercially important boron materials are listed in American standard specifications for aggregates for radiation shielding concrete (ASTM C638, 1998).

ii) using special boron cements (Kharita, Yousef & AlNassar, 2011, Kaplan, 1989, Kolovos, 2003).

iii) addition of boron to the water used in the concrete in the form of soluble compounds.

The first method has been used in special type of very heavy concretes, boron containing, and scrap based (Jaeger et al., 1975). Boron frit, boron carbide, and calcium boride have been mentioned as potential source materials for such purposes (Kharita, Yousef & AlNassar, 2011). Very little accurate information has been reported on the effects of using some of the most commercially available soluble compounds of boron such boric acid and borax. However the addition of boric acid and its pure frit is not suitable for enhancement of the shielding properties of concrete, because of the deleterious effects on the setting process of cement (Kolovos, 2003, Kolovos et al., 2001, Kolovos et al., 2002, Kolovos et al., 2005).

Recent studies by Rezaei-Ochbelagh et al. (Rezaei-Ochbelagh et al., 2012), showed that if silica fume with up to 45% w/w Pb is added to concrete it can partially increase the flux of gamma rays emitting from it. Increased silica fume addition leads to increased resistive strength of concrete specimens. Therefore, in order to reduce costs and increase the resistance of concrete used as a shield against gamma rays, silica fume can be used as a partial cement replacement and for this purpose, a proportion of 15% is suggested that exhibited an increase on the compressive strength of the concrete by about 22%.

d) Conclusions

It is concluded from this work that as long as radiation shielding protection is required, different types of concrete are available that consist of various specialized aggregates, cements or mineral additives with reduced cost that potentially can be used for military construction purposes, when protection of infrastructure in several military operations is required.

VIII. TOXICITY ASSESSMENT OF CHEMICAL WARFARE AGENTS

Chemicals can potentially cause adverse effects on human health and the environment and thus determining the toxicity of chemicals prior to their use or release is of paramount importance. Toxicity assessment is a key step in drug discovery when a specific substance is designed to enter the human body but is also extremely important for chemicals of industrial use or for the unexpected or uncontrolled, accidental or deliberate release of chemicals (Rajes and Bajic, 2016). The latter case applies also to the release of Chemical Warfare Agents (CWAs) that are highly toxic chemicals that can have lethal or incapacitating effects on humans and animals through their toxicological effects.

CWAs have rather simple structures, are characterized by high toxicity and can be divided in different categories based on their effects in human including: nerve agents such as sarin (GB), Tabun (GA) and V-agent (VX), blistering agents such as sulfur mustard (HD) and lewisite (L), blood agents such as hydrogen cyanide (AC) and cyanogen chloride (CK) and choking agents such as phosgene (CG) and chlorine (CL) (Ganesan et al., 2010). Decontamination after the release of such chemicals, as a consequence of a terrorist attack or as part of a neutralization process of disposed amounts of CWAs, demands, among others, the knowledge of the toxicity of the substances involved.

Hazard assessment can be based on *in vitro* or *in vivo* experimental procedures that include different toxicity endpoints. Toxicity can be measured quantitatively, in example as the lethal dose to the 50% of the tested individuals (LD_{50}) or the lethal concentration to the 50% of the tested individuals for a time period (LCt_{50}), or even qualitatively by assigning a class to each tested compound (i.e. toxic/nontoxic or high/medium/low toxicity). *In vitro* toxicity experimental testing gained significant ground in toxicity assessment due to the development of the effective high throughput screening (HTS) methods that allow the fast evaluation of thousands of compounds. *In vivo* animal testing has also been used but due to significant time and cost limitations as well as ethical considerations the use of such methods is declining.

Along with toxicity evaluation, the physicochemical characteristics of compounds are equally important as these are crucial factors that affect environmental fate and transport as well as exposure potential. Among these, octanol−water partition coefficient (logP), water solubility (logS) melting point (MP), boiling point (BP), vapor pressure (VP), and bioconcentration factor (BCF) significantly affect bioavailability, permeability, absorption, transport and persistence of chemicals in the organisms and the environment (Zang et al., 2017).

Experimental testing procedures are often expensive, labor intensive and time consuming and as such, alternative or complimentary methods to assess toxicity are highly desired. Within this context, the effective use of computational resources (including data, algorithms, methods and tools) has emerged in the toxicity assessment scheme, allowing for a fast and inexpensive toxicity estimation even before the actual synthesis of a given chemical. Advanced *in silico* methods and tools can significantly contribute in the long-desired goal of reducing animal testing by organizing, analyzing, modeling, simulating, visualizing and finally predicting chemical toxicity and physicochemical properties (Melagraki, 2006). A broad range of computational methods and tools have been already developed within this *in silico* toxicology framework including advanced modeling techniques for the generation of predictive models, simulation tools for studying chemical-biological interactions and web based or stand-alone decision support systems (Melagraki et al., 2006a; Melagraki et al., 2006b).

Large organizations such as the Organization of Economic Cooperation and Development (OECD), the European Chemicals Agency (ECHA) and the U.S. Environmental Protection Agency (EPA) as well as research centers including the military US Army Laboratory highly recommend and extensively use the above-mentioned concepts and *in silico* methods and tools in exposure, toxicological hazard, and risk assessments of chemicals (Hardy et al., 2010).

These *in silico* methods are underpinned by recent advances in artificial intelligence and machine learning methods that support the development of the classical quantitative structure – activity relationship models (QSARs) and result in an increased accuracy of predictions. New concepts such as the Adverse Outcome Pathways (AOPs) that describe linked events at different levels of biological organisation that lead to an adverse effect on human health and the environment have emerged and are currently developed to enhance the mechanistic understanding of toxicity. Overall, the availability of a variety of *in silico* methods and tools renders the development of a decision support system necessary to combine results and guide decision making.

Conclusions

Toxicity assessment of chemicals prior to their synthesis and use is a challenging task and towards this goal *in silico* toxicology is significantly contributing in replacing expensive and time-consuming experimental methods. Compounds of military interest, including chemical warfare agents, are also studied within a computational toxicology context. Customized models based on transparent data and methods, with well-defined domains of applicability can lead to accurate predictions and thus can be systematically developed and used to effectively assess chemicals' toxicity as well as critical physicochemical properties and guide decision making.

IX. Numerical and analytical determination of the envelope curve for realistic ballistic trajectories

The importance of the envelope curve of the ballistic trajectories of a given weapons system has been demonstrated repeatedly in the past (Budikov 2015), (Hart 1998). Various aspects of the trajectory characteristics under perturbations can be derived from the envelope, making this a widely applicable technique for a variety of related issues.
The analytical determination of the envelope curve is transformed from a relatively trivial problem (Vorvolakos 2016) to a far more involved one as increasingly more realistic ballistic trajectories are considered. As air resistance effects are taken into account the analytical determination of the envelope curve is possible in certain cases (Vorvolakos 2017) but not in general.
For the domain of modern artillery ballistic trajectories, the particulars of the projectile motion (aerodynamic profile as well as extended body dynamics - as opposed to point particle dynamics) necessitate the application of numerical approximation and techniques as well as analytical methods.
The problem becomes more involved when long range ballistics are taken into consideration, in which case the rotation of the Earth as well as its curvature need to be taken into account transforming the shape of the calculated trajectories.
In principle, the techniques developed could be applied to the determination of the accessible spatial domains of realistic military long range ballistics of both projectiles and missiles. In the case of missiles, two most generic cases need to be identified:

- The 'fire and forget' variety, where the study of motion essentially follows the same steps as those of the generic projectile
- The 'guided' variety, where the study of motion through the envelope curve analysis only applies to the unguided portions of the trajectory.

The aim is to develop a flexible yet powerful technique that can be applied on-the-fly to determine the safety domain as well as other needed aspects of the ballistic trajectories of modern weapons systems that can increase the accuracy of the shot and the safety of the personnel involved.

X. The use of small commercial UAV's as detector carriers for CBRN threat assessment

The typical association of flying drones (UAV's) with risk assessment mostly refers to the risk these flyers present to manned aerial vehicles as well as structure and the general population in general (Plioutsias 2018). There is however another interesting aspect of the association of drones with risk assessment. This is based on the ability of UAV's, equipped with the appropriate measuring devices to survey remote, dangerous, or contaminated terrain in a safe manner and to assess the dangers this terrain could present to potential personnel involvement. As an added benefit, if personnel has been exposed to environmental threats, drones, due to their mobility and the out of the box availability of high definition cameras, have been effectively utilized in numerous search and rescue operations.
It has been recently been brought to the attention of the public media in Greece, that the local municipalities have requested the assistance of drone operators for the location of the remains of a lost fisherman in lake Volvi just north of the city of Thessaloniki, in January 2018 (Polychronos 2018) . The use of drones in missions to either detect danger, or to help

people already in danger has been proven repeatedly in the near past.

The aim of the study would be to illustrate the usefulness of a readymade UAV, which can follow a pre-programmed flight path to perform a survey of a control area and detect any traces of ionizing radiation present (typically γ radiation). To achieve such a goal, a commercially available, simple to use, radiation detection system of ionizing radiation would be required. The detection system must include the ability to perform and store measurements over a time period that would enable the full coverage of the area under consideration. Other important parameters of the detection system include its physical dimensions and especially the weight as these can impose constraints on the UAV's capabilities and cost (Vorvolakos 2018). The analysis of the data collected, would take place offline, at which time the actual risk assessment would also take place. In principle, online data analysis could also take place provided a reliable communication set up extending the visual communication typically available in commercial drones can be realized. Following the realization of the concept using an ionizing radiation detector, an extension to cover other types of threats (including chemical or biological agents) can be realized. Each particular type of threat presents unique challenges and characteristics that need to be addressed according to the detection technologies available as well as the contamination threats presented.

The goal is to assemble and test an ionizing radiation UAV surveying system with a total cost of the order of 2 to 3 thousand Euros, making this readily accessible to local civil authorities. Such a system could easily be scaled up to provide wider area of coverage and further capabilities at a relatively low cost.

XI.

Appendix

There is no appendix to this study

Acknowledgment

Conflict of Interest Statement

The authors of this work certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest (e.g. political, religious etc.) in the subject matter or materials discussed in this manuscript.

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Biographies

Due to the large number of authors biographies are omitted in this report

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