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Application of Explosive Detection Systems Steps for Fielding

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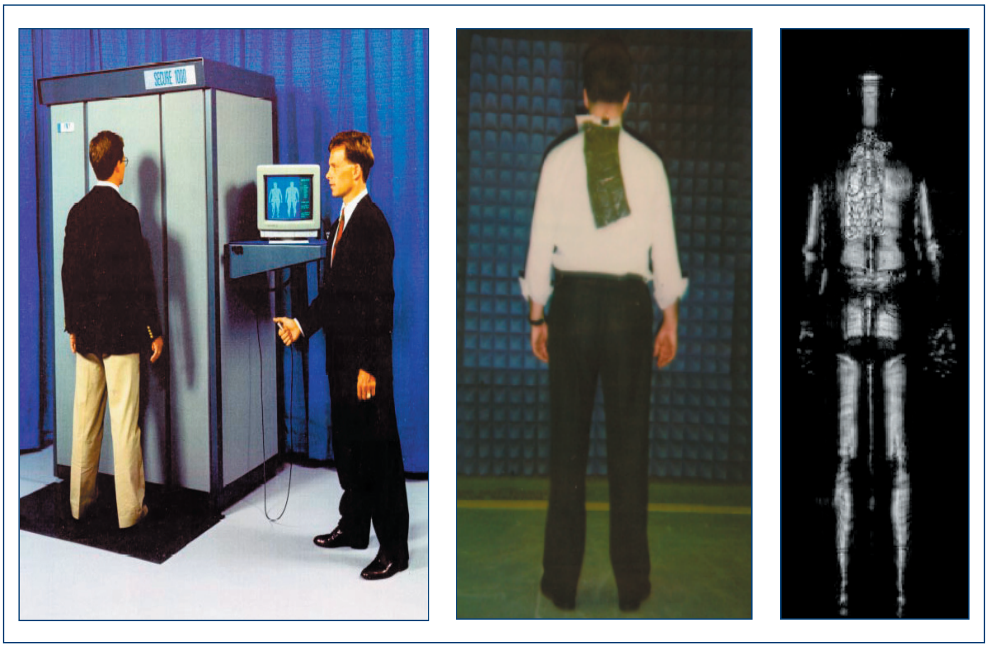

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BORDER SECURITY PROGRAMME

SENSORS, RADAR TECHNOLOGIES AND CYBERSECURITY UNIT

INSTITUTE FOR THE PROTECTION AND SECURITY OF THE CITIZEN

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1. Introduction

A wide range of activities is involved in the application of Explosive Detection Systems (EDS) and the fielded use of such instruments. The right steps must be taken to bring an instrument into operation if it is to be of value. A reconsideration of the process is needed because terrorist methods and types of target are changing. Aviation has, for a long time, been regarded as especially vulnerable, since a small bomb can down an aircraft carrying hundreds of people. There are many examples of terrorist attacks on aircraft and airports and this makes aviation security a priority of most governments. It is in the airport that one is most likely to see an EDS in use. Of recent years, attacks on other forms of mass transportation have been seen, such as in Madrid on 11 March 2004 and in London on 7 July 2005, and on non-transportation targets such as government buildings, places of entertainment, restaurants, shopping centres and open-air markets. Each of these environments has different characteristics, such as throughput, number of alighting and joining points, baggage handling methods, shape of facilities and feasible geometrical configuration for inspection. Methods traditionally used for aviation will have to be completely changed to be applicable to such targets and a major R and D effort is likely to be needed.

To analyze the application process, we can first list some of the processes and steps that are involved. The key processes are:

risk assessments, threats analyses, characterization of system type, statement of performance and quality requirements, test and evaluation, choice of instrument and calibration.

A well-organized procurement and commissioning process might consist of the following steps

1. Identify the threat.
2. Select the sensitive place /process.
3. Evaluate the data (throughput, size, etc.)
4. Find the right technology.
5. Decide the technical requirements (sensitivity, minimum detection level etc.)
6. Choose one or more EDS meeting the requirements and obtain samples for evaluation
7. Evaluate, test and accept or reject the EDS
8. Operation, calibrate and maintain the EDS

In this document we will review some general points, regarding the application steps mentioned above, and describe risk assessment and risk management, including some of the methods used. We discuss some formal aspects of procurement: the performance parameters of EDS which must be specified in the agreed documentation and the main characterization that must be take into account during the definition process.

Next, we outline the basic quality assurance required of the supplier of EDS and some of international and national standards which may apply. We then describe the important test and evaluation step, which must be taken during the procurement process. Finally, we discuss the new threats which must nowadays be considered, together with some improvements of the current methods and equipment and technologies which are required to counter these threats.

2. Risk management

Risk Management related to security is a systematic, analytical process to consider the likelihood that a threat will harm an asset or individuals and to identify actions that reduce the risk and mitigate the consequences of an attack or event [6]. The process must be systematic and methodological to identify the highest-probability threats and those with the most serious consequences, and to evaluate and choose the right system and specification for the particular threat faced. Risk management is of key importance for focusing the effort of prevention. A decision to deploy EDS should only be taken after a comprehensive analysis, as described in this section.

The process may be considered in two parts: Risk Assessment and Action Plan

2.1 Risk Assessment

To establish a formal system for Risk Assessment, first, there is a need to define the key terms:

Threat - an event or occurrence that can potentially cause harm to an individual (person) systems or assets. (A threat is not harmful unless/until the potential is realised).

Risks - the probability that potential for harm from a threat will be realized, considered together with the level of the consequences.

Vulnerabilities - the weaknesses of a system that must be examined. They may be related to personnel, protection systems, processes, physical structures. In our paper it can be points that could be exploited by terrorists to carry out an attack.

There are some established methods and techniques for collecting and analyzing data to perform risk assessment.

2.1.1 Basic Risk Management Method

One simple method contains the following steps:

- **Risk assessment & intelligence** - Threat Assessment; Intelligence collection, gathering and dissemination; Data mining.

- **Protection (site & transport)** - Protection from explosives and weapons; Physical protection of sensitive sites; Transportation protection; Access control systems; Protection from CBRN threats

- **Detection, identification & localization** - Detection and identification of the threatening device or object (explosives, weapons, CBRN, drugs, other dangerous goods or whatever it is) ; Scanning; Intrusion detection; People identification (biometrics); Detection of sick people, Localization of people, vehicles and containers; Detection of abnormal situations and behaviour.

2.1.2 The GAO-DCM Method

The second method of risk management that we describe has been advocated [6] by the Defense Capabilities and Management department of the US Government Accountability Office. It contains the following categories:

- Threat Assessment
- Vulnerability Assessment
- Criticality Assessment.

For comprehensive risk management, all these assessments have to be done for air, ground, and sea scenarios. They may be described in more detail as follows:

- Threat assessment
  A threat assessment is used to evaluate the likelihood of activity against a given asset. It helps to establish and prioritize security-program requirements, planning, and resource allocations. A threat assessment can be identifies and evaluates each threat on the basis of various factors, including capability, intention, and impact of an attack.

- Vulnerability assessment
  Vulnerability assessment is a process that identifies weaknesses in physical structures, personnel protection systems, processes, or other areas that may be exploited by a hostile organization. It may be applied to security systems, computer networks, , infrastructure etc. These assessments are conducted by teams of experts skilled in such areas as engineering, intelligence, security, information systems, finance, and other disciplines.

- Criticality assessment
  Prioritize for all vulnerable assets which are most important and thus would get the highest level of protection, the factor that have to take into account are basically: mission and significance of a target importance to community security (computer networks), economic activity (Plants, bridges) some facilities might be critical at certain times, like large sports stadiums, shopping malls.

2.1.3 ISO-AGS Method

The following general structure for security analyses was introduced by the ISO Advisory Group on Security [10] and has been adopted by CEN BT/WG 161, the CEN Working Group on Protection and Security of the Citizen. It is based on a threedimensional model as follows:

- TARGETS
- THREATS
- COUNTERMEASURES.

2.1.4 The 4P's Method

A risk management approach can guide preparedness efforts related to every component of the threats that have been defined. The outputs of such systematic work are wide plans of action. The 4P's Method is a classification used in framing an action plan.

Prevent - threat related,
Pursue - person related,
Protect - target related,
Prepare - operation related.
This categorization originated in the UK [10] and has been recommended for use across Europe [5]. The explosive threats that we are dealing with in this report, must be detected and identified in wide scenarios, starting with human (suicide bombing), material transfer, and end item carrying, in baggage, mail, containers and vehicles. In most of these scenarios, application of explosive detection instruments is part of the Prevent topic, as a horizontal activity applied to most categories of targets.

2.1.5 European Union Counter Terrorism Strategy

Later in 2005 , the Council of the European Union defined its Counter Terrorism Strategy on the basis of a slightly different four pillar structure:
Prevent, Protect, Pursue, Respond.
In this structure, Explosives detection is considered to be part of the "Protect" pillar, which is defined to consist of actions to "protect citizens and infrastructure and reduce our vulnerability to attack, including through improved security of borders, transport and critical infrastructure" "Prevent" in the Counter Terrorism Strategy refers to political and sociological measures to prevent people turning to terrorism.

As may be seen from the above descriptions, the various systems for Risk Management are all quite similar in concept, each seeking to break down the problem into categories into which all the required actions can be placed. The question of the relative merits of the different approaches is of secondary importance. The key point is that some systematic method should be adopted.

2.2 Threat Probability and Threat Consequence

During the process of risk assessment we have to consider and identify all the threats. The next step is Risk Analysis and Threat Classification, in which we check the likelihood of occurrence of every threat and classify them by their consequence and the probability of occurrence. The action priority must be given to those with the most probability of occurring and the most catastrophic consequence. The threat probability is simply the likelihood (or perceived likelihood) that a particular threat will actually take place. The threat consequence is the damage that the event would be expected to cause if it did occur, including loss of life, injuries, and damage to Property. Both of these aspects have to take into consideration, and they are largely independent.

The important thing in any risk management method is that it needs to be a process in which we try to identify and mitigate the highest likelihood threats with the most serious consequences, which we call the "Unacceptable Risks". One approach is to divide each of the two aspects into three categories to produce five overall categories of risk as in Table 1.

Table 1: Risk level determination

	Minor damage	Major damage	Catastrophic damage
Low probability	Trivial risk	Tolerable Risk	Medium Risk
Medium probability	Tolerable Risk	Medium Risk	Major Risk
High probability	Medium Risk	Major Risk	Unacceptable Risk

3. System Performance & Characterization

3.1 Performance Parameters

A detection system is characterized by certain key properties: descriptive statement which define what type of system it is and performance statistics which measure how well it does its job. Explosives-detection equipment uses qualitative and quantitative information extracted from objects within e.g. baggage to determine the presence of an explosive threat. If the information extracted was combined to represent a single physical parameter, the physical parameter can be thought of as a decision variable. The paradigm presupposes a population of explosive threat and normal bags that generates a position and spread (or distribution) of the physical parameter for each population. The overlap of the two populations determines the performance of the equipment. To classify the information obtained from the equipment, a threshold value of the physical parameter is adopted on which to base a decision on the presence of an explosive threat. The threshold value of this physical parameter establishes the detection (true-positive fraction) and false-alarm (false-positive fraction) rates (see table 2). The primary focus of a test and evaluation plan should be those aspects of the explosives-detection equipment that affect the value of the physical parameters that establish the decision threshold.

Table 2: Definitions of true and false positives and negatives

		(T) Truth	
		Yes (explosive present)	No (explosive absent)
(D) Detector reading	Yes	a	b
	No	c	d

1) a + b + c + d represents total tests.

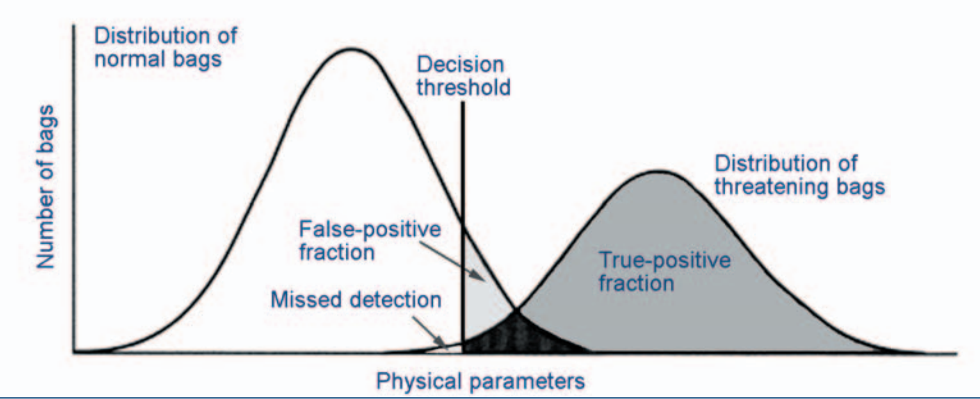
2) a represents true positives,
   b represents false positives,
   c represents false negatives,
   d represents true negatives.

3) a + c tests run with explosives present.

4) b + d tests run with explosives absent.

True positive rate (sensitivity): = Pr(D = Yes | T = Yes) = a/(a + c).
False positive rate: = Pr(D = Yes | T = No)= b/(b + d).
Specificity: Pr(D = No|T = No) = d/(b + d).
Operating point: b+d >> a+c in realistic scenarios.

Figure 1: Probability density functions of test measurement in the threatening bags (gray curve) and normal bag (line curve). The overlap of the two populations determines the performance of the equipment.



There are several factors that may contribute to the position and breadth of the distribution of a physical parameter, ultimately determining a detection and false-alarm rate. These contributors include random fluctuations due to statistical processes inherent to data acquisition, artificial clutter (noise) resulting from the type and orientation of objects within test object, mechanical drifts, physical and electronics drifts.

3.2 Main factors to be weighed for a given application

Having conducted the Risk Assessment and concluded that EDS is needed, we have to define the technical specification required for the instrument, including the quantitative data. The three main factors which must be considered are: type of explosive involved, probability of detection and cost of the EDS. In most cases, all these elements must be taken into account to get the maximum security with reasonable price. In addition factors of health and safety, public perception, privacy and throughput are important.

3.2.1 The explosives & taggants to be detected and the desired sensitivity levels

The ideal EDS would be able to detect any type of explosive. Real EDS are designed to detect a limited list of specific substances known to be explosive. Even a system able to indicate all known explosives, were it to exist, could still be defeated by a novel one. There is no detector available which indicates the specific properties of high energy release, instability and emission of gaseous reaction products.

We can categorize the explosive types by looking at the historical involvement of explosives in terrorist events, taking into account the targets and trying to identify the requirements to protect our own vulnerable targets. But variation of the chemical behavior is another factor that forces us to make a very systematic risk management process to find the changes and improvements of the material (threats) we looking for and to consider how they affect the EDS/s we use.

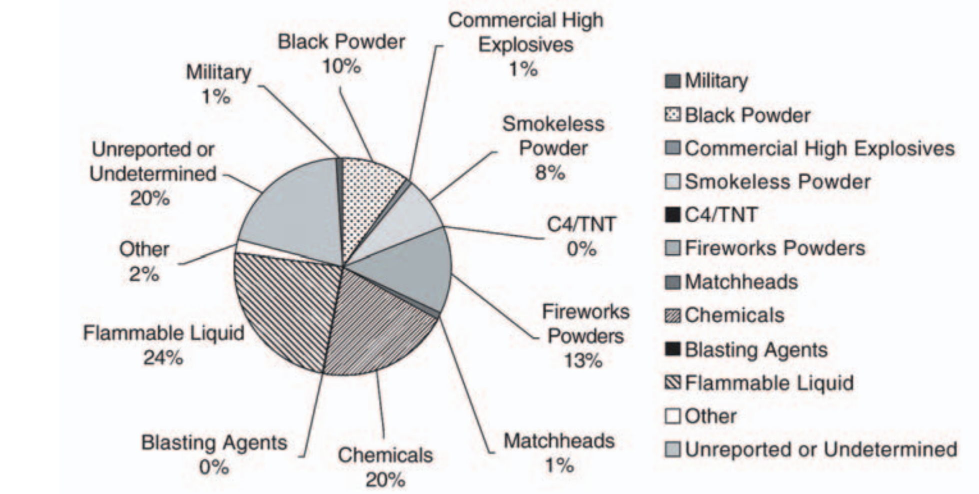


Figure 2:
Summary of explosives used in the past (1) (SOURCE: U.S. Department of Treasury, 1996)

If we consider the vapor pressure as a single example of a parameter affecting the EDS, then it is evident that there is very big variation between explosives in this characteristic. In addition to detection of explosives themselves, also important is the ability to detect explosives which have been tagged to make them easier to find. Table 3 lists some examples.

Table 3:
Detection agents used in plastic explosives

Explosive Marker	Chemical Name	Minimum Concentration (percent mass)	Vapor Pressure (ppb)
EGDN	Ethylene glycol dinitrate	0.2	60,000
DMNB	2,3-dimethyl-2,3 dinitrobutane	0.1	27,000
p-MNT	Para-mononitrotoluene	0.5	>50,000
o-MNT	Ortho-mononitrotoluene	0.5	>200,000

[13] (Sources: The Convention on the Marking of Plastic Explosives for the Purpose of Detection, signed in Montreal in 1991, available from the International Civil Aviation Organization, Committee on Marking, Rendering Inert, and Licensing of Explosives et al., 1998).

3.2.2 System cost

System cost is often a major factor in determining what sort of explosives detection system to purchase. Depending on the type of system and the degree of sophistication that is desired, commercial detection systems can range from approximately $20,000 to greater than $1 million in cost. It is often necessary to choose between the purchase of one very sophisticated system and the purchase of several cheaper and less sophisticated ones. Maintenance costs must be factored in when determining total system cost. Several maintenance plans are available from the various detection systems manufacturers, ranging from a per call to a scheduled preventative maintenance option. Maintenance costs can vary depending upon the complexity of the system, number of systems at a particular location, and the specific plan chosen. These costs can be as high as 10 percent of the original system cost on a yearly basis.

3.2.3 Health/public safety issues

If the application will involve screening people for explosives, then the potential health effects of the screening process need to be taken into account. Even if it is demonstrable that there is no real hazard to human health, the public perception that there is a problem may present a significant barrier to the use of a technology. The prototypical example is the use of personnel screening systems that use low-dose X-ray technology to detect bombs and other contraband items. While the X-ray dosages involved are trivial, the general public dread of X-rays has thus far limited the use of such systems. In some places in the world these systems have been restricted primarily to use in correctional facilities, where the inmates or persons visiting inmates are screened. In these applications, there is essentially a captive audience that has little choice but to submit to the screening process. For wider applications, extensive education of the public may be necessary before the technology can be applied.

3.2.4 Privacy & Detection Process

Equipment for detection of explosives may give rise to issues of privacy because of the connection between innocuous true positives and passenger medical status (presence of prostheses, implants, pharmaceutical nitroglycerine etc.), the second issue that may cause privacy problems is that some new methods and technologies give "naked" pictures of the passenger that is being checked, (low dose x –ray, acoustic & millimeter wave technologies).

Figure 3: X-ray explosives detection system for personnel (Rapiscan Secure 1000)

Figure 4: Wideband (27 - 33 GHz) image of a man with a thin sheet of simulated plastic explosive between his shoulder blades. (a) Optical picture (b) Millimetres-wave image.[8]

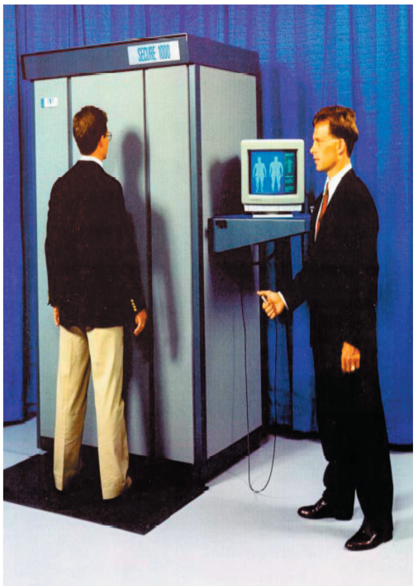


Figure 3

Figure 4a

Figure 4b

3.2.5 System speed (throughput rate)

One high-volume application is inspection of passengers in aviation and mass transportation stations. Achieving adequate throughput rate is, in fact, one of the most important problems that need to be solved by using EDS i.e. the EDS is useful if it is faster than hand-search. We can define throughput as the rate that the objects pass the screen such as passengers per hour through a portal (gate) or number of luggage items per hour in an X-ray machine. When the required throughput rate is very high, two or more systems with different characteristic may be employed together to achieve the rate overall, but reducing the performance at some points.

Example: luggage can be speed-screened in a high-rate X-ray machine which we allow to have a relatively high false alarm rate, and only suspect luggage from the first stage undergoes inspection in a high resolution low-rate X-ray machine or other EDS, with low false alarm rate. The same approach could be applied to a trace machine for passengers in the aviation application.

3.3 Defining System Characterizations

Once the application of explosives detection has been identified, there are a number of factors that need to be weighed in determining what sort of detection system to acquire. One of these is, of course the cost, which is assessed in relation to the qualities of the system. Trace systems may cost anything between $5,000-$100,000, depending on the technology and the sensitivity, the average cost being between $40.000 and $75.000.

Defining the characterization is a basic step for the overall specification before we can choose and evaluate the candidate EDS. For example, we can categorize the characterization of a trace system according to the following groups [3]:

Mechanical	Operational	Maintenance and Calibration	Legal issues	Safety
System Size	Explosives Detected	Maintenance	Admissibility	Radioactivity
Weight	Nuisance Alarm Rate	Calibration		
	Detection Limits			
	Probability of Detection			
	Ruggedness			
	Field Power Operation			
	Start-up Time			
	Sample Collection Mode			
	Sample Collection Time			
	Sample Analysis Time			
	Ease of Use			
	Alarm andUser Notification			
	False Positive Rate			
	Data storage and transfer			
	Drug Detection			

3.3.1 Mechanical

These characteristics need to be defined on a quantative basis because definitions like "easy carrying by one person" are open to misunderstanding.

(1) System Size: L* W* H limits the capability of the system to be handled

(2) System Weight: For example, an instrument consisting of one piece with a weight of about 10kg (or two pieces of 5 kg) could generally be feasibly carried by one operator without risk of dropping.

3.3.2 Operational

(1) Explosives Detected: The system can detect all the type of explosive as described at section 3.2, explosive and taggant. Of course, this is a wide definition and, when we need to give the specification, it should be refined to take into account the level of security in the area and any other measures specific to the problem at hand that need to be taken care of. The explosives that are most often stated in specifications as being required to be detected are : TNT, RDX, PETN, NG, EGDN, DNT, ANFO (ammonium nitrate), double base smokeless and black powders, and common taggants such as DMDNB and mononitrotoluenes. It is important to remember that, not all the explosives will be detected at the same sensitivities by the same EDS, because their chemical properties vary.

(2) Nuisance Alarm Rate: is when the EDS gives a true alarm, but because of innocuous contamination of the operator, who handles or works with ammunition or explosive before starting the work with the EDS. The recommended acceptable alarm rate could be, for example, between 1 percent and 5 percent, depend on the contamination level of the operator before using the EDS. This can be defined in the specification.

(3) Detection Limits: these should specify the minimum quantity of explosive or taggant that we would like to find, with a certain level of confidence, usually limited to 95-99 percent. A typical minimum would be the amount that can be found in fingerprints: 70-100 μ gram. The surface of the object that it is planned to check may also come in to the picture.

(4) Probability of Detection: the requirement should be specified as a percentage, usually expected to be between 95 percent 99 percent for a swiped fingerprint or other swipe from hard or soft surfaces. (See par.3.1).

(5) Ruggedness: the specification should include the environmental conditions that the EDS can withstand during its life cycle. It should include at least the following:
- Transportation – both in its packing case and out, and the kind of case.
- Shocks- definition of the condition depends on the use of the EDS.
- Temperature-range for continuous use and max. and min. for short-time peaks.
- Dust and humidity – definition depending on the planned use

(6) Field Power Operation: Mains, depending on country (220 v 50 Hz./ 110v 60 Hz) and, if necessary, battery operation and 12/24 DC for use in a car, with or without a converter.. All these options can be carefully reviewed for the best (and minimum needed) requirements, according to the planned use of the instrument .

(7) Start-up Time: this characteristic depends on the operational method of use of the EDS and the place of operation. The time to start from both cold and warm states should be considered. If it is too long, a lot of time can be wasted in operation. This requirement can force us to consider the full plan for operation during a very early stage of the specification process,

(8) Sample Collection Mode: Swipe methods can be used for most types of explosive on most surfaces.Vacuum collection is useful for surfaces such as clothing.

(9) Sample Collection Time: the time needed to collect the sample varies between seconds and a few minutes, depending how many samples are needed and the object being checked.

(10) Sample Analysis Time: after the sample collection , the time for the system to analyze the sample and give its result, typically between 30s and 2 minutes. It is usually short compared to the sample collection time and so not the bottleneck.

(11) Ease of Use: The operation of a particular system can sometimes need the manufacturer's involvement for a period of training before use. If this is unacceptable in the context, this should be stated in the specification that the operator will not have any training and an average person should easily be able to operate the system.

(12) Alarm and User Notification of Detection: systems are designed to give an indication of a detection event that can be audio, visual alarm, spectrum detail or other. The explosive type or general information about the type is shown by some systems.

(13) False Positive Rate: The rate is generally less than 5 percent during test in the laboratory. Two kinds of false positive need to be distinguished: those intrinsic to the instrument and those caused by response to innocuous but explosive-like materials.

(14) Data Storage and transfer: the data of the system can be printed and/or logged electronically. In defining the specification, consideration should be given to how convenient it will be to transfer the EDS data to other systems in use by the organization.

(15) Drug Detection: Some types of EDS also have a capability to detect narcotics. A requirement for this feature depends on the general management and context of the security system. It will vary from a minimum of no need for any capability to detect drugs to a maximum of a need for a capability of detection of all the common kinds, such as cocaine, heroine and marijuana.

3.3.3 Maintenance

(1) Maintenance interval: systems need maintenance; the interval for preventive treatment should be defined, including down time and the time to obtain spares if needed.

(2) System Calibration: the calibration process should be defined by the manufacturer with a written procedure that can be performed by trained staff. The

need for calibration may be due to specific events like: change of weather, cases of contamination with explosive, change of location, or another environmental condition. A minimum of once a day calibration can be a reasonable requirement of such an instrument.

3.3.4 Legal issues

Admissibility: the system should have the ability to provide admissible evidence in court. This ability can probably be achieved by a few conditions: certification of the method and procedures with an international or national calibration system or certification system (ISO 17025 or similar). Data records of the validation process have to kept and presented when needed as a basis for validating the results of the instrument.

3.3.5 Safety

Radioactivity: the presence of radioactive material in some types of explosive detection device is a serious concern, because of possible risk to the public, the environment and especially the operator who works continuously with it. The instrument must comply with relevant national regulations and there may be some legal paperwork required during the life cycle of the instrument to document this.

4. Standards & Quality

During the life cycle of EDS the requirements for standardization are very important and include at least the following steps:

First: Quality assurance system of the industry involved.
Second: Specification and R&D process.
Third: Evaluation and qualification specification.
Fourth: Requirements for the competence of testing and calibration laboratories during their life cycle

4.1 Key actors

Explosive Detection equipment is generally approved case by case according to the manufacturer / industry . The two last steps are sometimes classified, depending on the security measures taken by the related body involved (police,security services, civil aviation authorities etc.)

The other key actors are the standards organizations, national, regional and international. The International Organization for Standardization (ISO) is described as follows in [9]:

> "a global network that identifies what International Standards are required by business, government and society, develops them in partnership with the sectors that will put them to use, adopts them by transparent procedures based on national input and delivers them to be implemented worldwide. They make transparent the requirements that products must meet on world markets, as well as the conformity assessment mechanisms for checking that those products measure up to standards. As a result, suppliers from developed and developing countries alike can compete on an equal basis on markets everywhere. Its members are not, as is the case in the United Nations system, delegations of national governments. Nevertheless, ISO occupies a special position between the public and private sectors. This is because, on the one hand, many of its member institutes are part of the governmental structure of their countries, or are mandated by their government. On the other hand, other members have their roots uniquely in the private sector, having been set up by national partnerships of industry associations".

The European related organization is CEN- European Committee for Standardization which contributes to the objectives of the European Union and European Economic Area with voluntary technical standards which promote free trade, the safety of workers and consumers, interoperability of networks, environmental protection, exploitation of research and development programmers, and public procurement. CEN works closely with the European Committee for Electrotechnical Standardization (CENELEC), the European Telecommunications Standards Institute (ETSI), and ISO.

4.2 Situation in Europe

The basic regulations established by the EU for aviation security are:

Regulation (EC) No 2320/2002 of the European Parliament and of the Council of 16 December 2002 establishing common rules in the field of civil aviation security, (O.J. L355 of 30.12.2002)

Commission Regulation (EC) No 622/2003 of 4 April 2003 laying down measures for the implementation of the common basic standards on aviation security, (O.J. L89 of 5.4.2003).

Regulations 2320 and 622 contain detailed requirements as regards the performance of the screening equipment to be used and the methodology. In this field, standards and test protocols have been established in close cooperation with the European Civil Aviation Conference, which regroups experts from the appropriate authorities of the Member States and other European States. Furthermore, the Commission is regularly in close contact with the industry and other stake holders concerned (Stakeholders Advisory Group on Aviation Security – SAGAS Group), which is an effort to focus investment on standardization, research, certification and interoperability of detection systems and to transform research results into useful and applicable tools.

In addition to these European laws and to the international standards for the process of R&D and production -the European Commission published a Green Paper on detection technologies in the work of law enforcement, customs and other security authorities detection technologies for law enforcement authorities COM(2006) 474 that aims to find out what role the Union could play in order to foster detection technologies in the service of the security of its citizens. It recognized that more development is needed in quality assurance in Europe and states

"However, very often it is difficult to identify what tools and products are the best or at least meet certain minimum requirements. An EU-wide system of certifying good quality tools and benchmarking them, designed to simplify the process of establishing which of the tools or equipment can meet the particular needs of a particular authority, could address this deficit."

4.3 Situation in US

In the US, the Food and Drugs Administration must approve any instrument that is applied to humans or to food items, including those in luggage. Active EDS is affected by this, so the manufacturer must meet the FDA's requirements. In particular, The FDA generally requires compliance with the US Good Manufacturing Practice (GMP) Regulation, which goes beyond the ISO standard.
Equipment has to meet two major requirements:

(1) Quality assurance during the design and production,
(2) Validation Certification process.

The basic quality requirements for production of equipment involved with food or the human body include the main topics:

(1) Meeting the requirements of the ISO standard,
(2) Identification of device as well as manufacturing process specifications,

(3) Validation of device design and manufacturing processes,
(4) Documented control of device manufacturing processes,
(5) Feedback on the quality management program through in-process and final device inspection and testing, device complaints (e.g., internal, customers, regulatory), and audits (e.g., internal, customer, regulatory).

The attractive feature of applying the GMP regulation to the manufacture of explosives-detection equipment is that it would allow the FAA or other federal agency to monitor progress of the design, development, and manufacture processes. Furthermore, use of the GMP regulation would allow for feedback regarding existing and potential problems early in the development and manufacturing cycle. This would enable corrective action, resulting in higher-quality product and a more-reliable manufacturing processes.

5. Test & Evaluation

Compliance with the specification agreed by the buyer and manufacturer should be proved during the performance test and evaluation process, to measure the effectiveness of the EDS under normal conditions including all the environmental specifications mentioned.

5.1 Field-operationa testing description

Performance in some of the extreme conditions may be tested for a short time (max. and min. temp etc.). The working conditions need to be recorded during all the test. The environment that the equipment will work in when it is in service should be the base for the evaluation test.

It is highly recommended that the following characteristics are included in such an evaluation process:

- Throughput rate in a real working demonstration.
- Explosive-type detection tests and sensitivity.
- Reliability, false alarm (false negative and false positive data).

The contamination performance should be demonstrated using a specimen of a real item.

5.2 Results of tests – Example description

An important study of the performance of EDS in realistic scenarios was presented and undertaken by the Transport Research Board of the US National Academies [1]. Real time testing was done, with data collected at a combination trolley, bus, intercity-rail and commuter rail stop; and a combination intercity-rail and bus stop. The data collection period included peak-hour commuting. There needed to be a clear distinction among the baggage categories because of the wide variety of items included in each. Two test objects were used for trace detection instruments:

- Luggage handle
- Luggage zip fastner

Results, shown in Tables 4 and 5 give a good example of a format for summary of data collected during a field trial. In this case, the results indicate that the instrument's performance was poor.

Table 4: Example of trace detection test results [1]

Number of Samples:	350 Handles and 160 Zippers
# of Test Locations:	51 locations
Sample Preparation:	10ng & 50ng of Semtex dry transfer strips, verification standard stick
Alarms:	43 of 51 (84%) — Alarm results: • C4/RDX – 16 alarms • SEMTEX – 12 alarms • PETN – 10 alarms • NG & PETN – 3 alarms • TNT & PETN – 2 alarms
False Negatives:	8 false negatives out of the 51 contaminated samples (16%)
False Positives:	3 false positives out of 510 tests (0.6%)
Time 1 Average:	27 seconds
Time 2 Average:	15 seconds
Total Average Test Time:	44 seconds
Average Test Duration:	14 minutes
Average Temp:	73.4°F
Average Humidity:	49.7

Table 5: False negative test results analysis example

Sample Description	# of Samples Contaminated	# of False Negatives	% False Negatives
10ng Semtex - Handle	3	1	33%
10ng Semtex - Zipper	3	3	100%
TOTAL - 10ng	6	4	67%
50ng Semtex - Handle	17	1	6%
50ng Semtex - Zipper	13	3	23%
TOTAL - 50ng	30	4	13%
Stick - Handle	15	0	0%
Stick - Zipper	0	0	0%
TOTAL - Stick	15	0	0%

5.3 Calibration

Calibration is the comparison of an instrument's performance to a standard of known accuracy. The result of a calibration may be documentation showing the deviation of a measurement from the known standard or it may also include adjusting the instrument's measurement capability to improve measurement accuracy.

Explosive detection equipment is one of the most sensitive and most highly sophisticated detection technologies implemented. Its adjustment may be delicate and it may require frequent re-calibration to ensure reliability of the results.

Calibration is especially important for trace detection equipment where the presence of explosive is indicated by a small change of a signal with respect to a background. Calibration of the detection instrument is made by using an independently calibrated sample of a known explosive and checking that the results returned by the instrument agree with the known concentration or mass of the sample. If there is any deviation, corrective action or maintenance of the equipment must be performed. Repetition of the calibration measurement is used to reduce errors, as a rule, the test should be repeated for every explosive at least twice. For example, in an IMS instrument, calibration allows the instrument to adjust the present values of the mobility (or drift) time to the current conditions. Some IMS explosives detectors have built-in materials and software to automatically perform calibration.

Manufacturers of explosives detectors often provide calibration samples, for example, in the form of sampling pads that have been spiked with known amounts of certain explosives. There must be a sample for every explosive type that the equipment specification indicates. Calibration samples may also be available from industry laboratories such as Advanced Aviation Technology Ltd. Surrey, UK and Sigma –Aldrich Inc. The minimum concentration normally available is 10 nano grams per micro liter (10mg/l), corresponding to 25ml of solution containing 0.25mg of the target substance. Different substances and concentrations are available on request for calibrating chemical-based methods.

For bulk explosive systems like X-ray and nuclear methods, because of the safety problem of using samples of real explosive material in bulk, innocuous "simulant materials" that have similar detection properties to the explosive may be used for calibration. It should be mentioned that, in addition to the machine calibration, there is a human factor that is not perfectly defined because many systems do not alarm automatically and require a person to determine whether a threat item is present on a display screen. Stored images showing bombs or weapons can be shown on the screen at random intervals to ensure that the operator remains alert.

Calibration measurements for X-ray systems include those using a step wedge. The step wedge as defined by the American Society of Testing and Materials (ASTM) is a series of steps of aluminum with a series of thin wires of various gauges attached beneath. The purpose of this test device is to determine that the system can produce different distinct image intensity levels for each step while clearly displaying the smallest specified wire beneath each step. Typical X-ray systems can image a minimum of 34AWG solid copper wire through a minimum of 10 steps. Many modern systems can perform at higher levels, tests with 38AWG and 20 steps are common.

6. New threats and EDS improvement need

Recent events have shown that terrorists are using new methods of operation. Terrorists operating today are better organized, more professional and better equipped than their predecessors of the past. A risk assessment process should take into account that there is high probability of further novelties in the future. This presents a big challenge for R&D in detection systems and technology. We list here some of new terrorist threats and suggest possible goals which EDS development programs might seek to reach for.

6.1 New threats

- Development of new explosives- new chemical explosives that do not utilize nitrogen and have very low vapor pressures,
- Operation method - without wiring or electronic devices. (For example, KINEPAK a new high explosive that is created when two non-explosive components are mixed) (Fig. 1)
- Operation methods that do not include any metal parts
- Operation methods that hide all explosives under clothing.(Fig.2)

Weapons of mass destruction. Examples have already been seen of chemical and biological attacks by terrorists.

6.2 Goals for improvement of current EDS: a wish-list

- The method and equipment should be more made effective, in the sense of achieving more true detections for fewer false alarms.
- Dual or multisensor technology should be developed, on the principle of orthogonal detection, (two or more EDS technologies are considered completely orthogonal if the detection methods detect independent characteristics of the explosive device). This will give a higher probability of detecting explosives over a range of potential threats and will give greater effectiveness in detecting explosives than any single technology.
- Systems of real-time integration and decision making are needed. Methods that automate recognition are preferred i.e., the decision to select a suspicious bag for further investigation is performed without human intervention, because inspecting many pieces is a repetitive and boring task of which humans (and even dogs) quickly tire.
- Security should be increased but without increasing the delay or the control time.
- However, threat alarm thresholds should be decreased where appropriate.

- The speed with which the detection is performed is a crucial factor when a potential threat develops rapidly. The control times that will be possible in some scenarios are very limited e.g. suicide bombings. Stand off detection is needed for higher speed.

- In cases where a human is involved (such as a suicide bomber), psychological and physiological methods can be considered for operation together with EDS.

- Automated trace sampling hardware (sampling methods that cover only a small portion of the bag surface for acquisition of adequate residues for analysis), detect only a specific list of explosives and cannot easily be reconfigured to detect an expanded list of explosives.

- New technologies with higher chemical specificity that are capable of detecting a wide range of explosive, chemical, and biological threat materials are needed.

- Low-cost systems are needed using the existing techniques mass-spectrometry or ion mobility spectrometry that can detect a range of threat materials.

- A vapor-based system, which would sample the air surrounding the package without touching it would also be very valuable.

- EDS should be integrated with, or at least operable with, detectors for chemical and biological threats.

Figure 5:
Two components explosive

Figure 6:
Explosives under clothing

Figure 5

Figure 6

7. Summary

In this paper we have surveyed some steps regarding application and fielding of explosive detection systems. We discussed the characteristics of the system which must be considered when procuring it, in order to be sure that the system will fit our requirements and can be smoothly fielded.

We reviewed some basic methods of risk assessment that can be used for any security field and, in particular, are applicable to the process of fielding an EDS. The risk assessment process must consider the scenario, the known existing threats and any new threats that have arisen or which could occur in the future, such as new explosive targets and new methods of delivery and use.

The new threats, and the weaknesses of current systems and methods, need to be reviewed during the process of risk assessment and decision making for future R&D and purchase. In some cases, new threats need to be taken into account in the development process. An astute decision at this stage can provide very important benefits for a small investment.

Quality assurance at the production company is based on the specification of the system that defines all the technical parameters. These should be recognized and agreed with the buyer because they are an important part of the implementation of the security system. The end-product quality is measured against them. The key technical characteristics have to be carefully determined and the technical specification very precise defined to allow it to be a basic document for the purchase and fielding of the system.

We mention the main parameters that should be defined by the customer during the process: the explosives that need to detected by the system, the required sensitivity, maximum tolerable false alarm rate, throughput rate and cost. Privacy and health and safety issues may also need to be considered.

During the purchase process, demonstration and field test and evaluation are conducted to ensure that development and production has met the requirements. At this stage too, the specification document is the key point of reference, defining the parameters and values that are to be checked.

Finally, we describe some of the new threats that are emerging and how EDS might be developed to meet them.

8. Glossary

Bulk explosives detection system
An EDS which detects a solid mass of explosive material, including indirectly by means of the presence or ratio of one or more chemical elements. A bulk detection system will not usually detect explosives if only a residue is present.

CBRN
Chemical, biological, radiological or nuclear, used to describe a weapon or threat.

Comité Européen de Normalisation (CEN)
The European Committee for Standardization, was founded in 1961 by the national standards bodies in the European Economic Community and EFTA countries.

Certification
A process through which an EDS is tested and, if it performs successfully, will be approved for a certain application.

ECAC
European Civil Aviation Conference, or Conférence Européenne de l'Aviation Civile (CEAC) is an international organization with close ties to the United Nations, the International Civil Aviation Organization, Council of Europe and the institutions of the European Union.

EDS
Explosive detection system is a means of detecting the presence of explosives, in either trace or bulk quantities, typically employing some combination of electronic sensors, software and/or chemical reagents. Sniffer dogs or other animals may also be considered part of an EDS.

FAA
Federal Aviation Administration, an agency of the United States Department of Transportation with authority to regulate and oversee all aspects of civil aviation in the U.S.

False alarm
Any alarm of an EDS which occurs when no explosive material or explosive residue is really present. It can be caused by chemically similar compounds, or by a deficiency of the system.

False negative
An indication from an EDS that there is no explosive material in an item, when in fact some is present.

False positive
An indication from an EDS that there is explosive material in an item, when in fact none is present.

ISO
A network of the national standards institutes of 157 countries, on the basis of one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system.

Probability of detection
Te probability that a certain explosives detection system (EDS) can detect a certain amount of a given type of explosive under a particular set of conditions. of course that the probability need to determined based on number of test during the development stage and the evaluation process.
Threat
Event or occurrence that can potentially cause harm to an individual (person), systems or assets. (The threat itself is not harmful).

Threat probability
The likelihood of a particular threat event actually occurring, on a scale of 0 percent (no probability of occurring) to 100 percent (certainty that the event will occur).

Throughput rate
The rate at which an EDS can process the objects being screened. It is generally expressed in units such as objects per hour.

Trace detection
EDS in which the explosive material is detected from vapor or from particulate residue.

Two-part explosives
Explosives that consist of two separate components, which are sold as a unit in separate containers and need to be mixed together prior to detonation.

8. References

[1] Steven G. Haupt, Shahed Rowshan, William C. Sauntry, science applications international Corporation Vienna, VA. TCRP report 86, Volume 6, Applicability of Portable Explosive Detection Devices in Transit Environments.

[2] Dana A. Shea & Daniel Morgan, Detection of Explosive on Airline Passengers: Recommendation of the 9/11 Commission and Related issues, 2006 (CRS report for Congress).

[3] Hannum, D.W., Performance Evaluations of Commercial Explosives Vapor/ Particulate. Detectors, Sandia National Laboratories, 1996.

[4] Ben Hayes, The EU's Security Research Programme Transnational Institute, 2006.

[5] Peter Munday, Michael Pakenham, Alexander Nicoll, Jean-Yves Haine, Kristiina Rinkineva, Meeri-Maria Jaarva,Judith Johnson and Adrian Waller,New European Approaches to Counter Terrorism. ESSTRT Consortium, 2006.

[6] Raymond J. Decker, Homeland security key elements of a risk management approach, GAO[General Accounting Office), US.

[7] Guide for the Selection of Commercial Explosives Detection Systems for Law Enforcement Applications, NIJ Guide 100-99, http://www.ojp.usdoj.gov/nij.

[8] D. M. Sheen, D. L. McMakin, H. D. Collins, T. E. Hall, and R. H. Severtsen Concealed explosive detection on personnel using a wideband holographic millimeter-wave imaging system, Pacific Northwest National Laboratory.

[9] ISO in Brief International Standards for a sustainable world;
http://www.iso.org/iso/en/aboutiso/isoinbrief/isoinbrief.html.

[10] Final report of ISO Advisory Group on Security ISO/TMB AGS N 46 2005/01/06.

[11] Counter Terrorism: the UK Approach Speech by Dr Kim Howells, Minister of State, Kuala Lumpur, 22/07/05 UK Foreign and Commonwealth Office.

[12] Council Of The European Union,The European Union Counter-Terrorism Strategy Justice and Home Affairs Council meeting, Brussels 1 December 2005.

[13] The Convention on the Marking of Plastic Explosives for the Purpose of Detection, signed in Montreal in 1991, available from the International Civil Aviation Organization, Committee on Marking, Rendering Inert, and Licensing of Explosives et al., 1998.

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