Safety Engineering Series DOI 10.1515/tvsbses-2015-0005

POSSIBLE IED THREAT TO AIRPORT PREMISES DURING SECURITY X-RAY INSPECTION

Stanislav LICHOROBIEC[1], Karla BARČOVÁ[2]

Review article

Abstract: The premises of international airports in CR are major air transport hubs as well as key elements of critical infrastructure, belonging to the very high risk category. Any infringement leading to limitation or complete shutdown would cause considerable economic and psychological damage. The most important task is to ensure high quality and reliable physical and technical protection of the airport, because especially in the summer months these areas collect large numbers of people and a possible terrorist attack could be fatal. This paper focuses on assessing the possibilities of solving the problem of IEDs hidden in travel luggage, and their initiation by X-rays during security checks.

Keywords: Explosives, IEDs, security X-ray, airport departure hall, security check.

Introduction

The use of improvised explosive devices - hereinafter IEDs, the beginnings of which can be traced back to the emergence of resistance fighters in various wars, is an effective method still often used today to intimidate, blackmail and avenge. A very wide range of different types of explosives, whether military, industrial or home-made, as well as aids to their initiation - igniters, blasting caps and detonators, and various sensors and booby trap resources all allow for a broad range of improvised, semi-industrial, but also industrial production of various improvised explosive devices.

IEDs have become a favorite weapon of terrorists, because they can be produced very cheaply and relatively simply from readily available materials and components that are not recorded and are used for other purposes. This eliminates the risk of finding the designer, producer, or IED user. For the perpetrators of these crimes a deciding factor is the fact that after the explosion it is very difficult to identify the entire assembly of the IED and thus trace its designer. The insidious use of IEDs is often accompanied by the presumption that one has a sufficiently valid motive to achieve a certain goal, whether it be military, political or economic influence, or personal, relational and religious motives, or a maximum threat to an individual or group of people to enforce the requirements laid down in this major threat. The explosion of the explosive or subsequent fire destroys all traces left on it by its manufacturer. This assumption feeds the offender's conviction that he/she will never be tracked down and convicted. In order to eliminate this topic it is necessary to detect the IED in time, prevent its explosion and possibly utilize available technical means to minimize potential damage.

One of the possibilities of where to initiate an IED and cause loss of life and damage to human health and property of an essential element of critical infrastructure, which every international airport undoubtedly is, is directly while checking baggage at the security X-ray.

A security X-ray is an apparatus which utilizes the possibility of X-ray penetration through opaque materials, so these devices are used to check the baggage of passengers without opening them. It was therefore essential to determine whether the offender and designer of the IED can directly use the fundamental functions of this X-ray for initiation. The risk of explosion in the security X-ray must not be underestimated, as it is located directly in the departure hall, where a large number of people are periodically concentrated and from the structural design of this device it is evident that in the case of an explosion inside the scan area, where baggage passes freely through the inlet and outlet, a so-called

[1] VŠB - Technical University of Ostrava, Ostrava, Faculty of Safety Engineering, Ostrava, Czech Republic, stanislav.lichorobiec@vsb.cz

[2] VŠB - Technical University of Ostrava, Ostrava, Faculty of Safety Engineering, Ostrava, Czech Republic, karla.barcova@vsb.cz

Safety Engineering Series DOI 10.1515/tvsbses-2015-0005

directional effect of explosion would occur. If we were to consider the possibility of an explosion inside the security X-ray at any time during security checks, then the measures would be technically and economically, particularly with regard to extending the time period of checks, inappropriate and sometimes even impossible.

The aim is therefore to assess the possible misuse of the security X-ray when placing an IED into the diagnostic space and determine under what conditions is it possible to detonate due to the effect of X-ray beams.

Materials and methods

Characteristics of IEDs

An IED is a system consisting of an explosive, an explosive or pyrotechnic object, an incendiary substance, and functional elements of initiation, all combined with insidious planting. Under certain conditions pre-set by the manufacturer, this system is able to set off an explosive effect or cause a fire. The improvised explosive device is usually hidden in a packaging, or has such an external form, that intentionally conceals it, camouflaging the true purpose of its contents - to kill, injure, or cause material damage. A dummy is also regarded as an explosive device. Here one or more objects are structured in such a way to give the impression of an explosive device, although they do not contain explosive substances and therefore cannot have an explosive effect.

The purpose of IEDs is to cause the effects for which it was constructed. In practice this may be:

- only a threat without causing much damage and a presentation of the fact that I am able to make the IED, plant it anywhere at any time and set it off,
- cause only material damage of varying scope,
- injure or kill a specific person,
- kill a person who has usually been warned several times that this can happen,
- kill as many people as possible via a suicide bomber attack,
- potentiate a terrorist attack for the fulfillment of specified conditions.

The purposes of IED use are approximately sorted by increasing danger. This division also indirectly implies danger to persons intervening as part of the IRS to remove it. If the attacker wants to kill someone, he/she will pay no mind to the interference of a pyrotechnic, especially when from his/her point of view there is a danger that the explosive device will be re-secured, defused or otherwise disposed of, and subjected to forensic and technical expertise aimed at revealing its creator (Janíček, 2002).

Airport departure halls

All international airports are important elements of the critical infrastructure of each country. It is a building designed for take-off, landing and ground movement of aircraft that can both carry passengers (passenger flights) and transport tangible assets (cargo flights).

Places the general travelling public can access are mostly the departure and arrival areas - hall. The departure hall is thus a link between the take-off and landing runway (RWY) that faces public space. The main task is to ensure aviation functions with regards to the check-in process of passengers. (Letiště Ostrava, a.s.)

Departure halls mostly house security X-rays type HI-SCAN 6040i, which use X-radiation, hereinafter referred to as X-rays, to diagnose baggage. It is an ionizing electromagnetic radiation, a stream of photons with an energy of approx. 150 kV. The typical wavelength range for this type of radiation is 10^{-12} - 10^{-8} m. A single line semiconducting detector is used for detection. Since the examined object is moving at a constant speed, the computer can subsequently reconstruct the entire image from the single line detector. X-rays are absorbed by the object diagnosed depending on the nature of the substance from which it is made, or the size of its material density. They are therefore more absorbed by substances with a higher number of protons, which include organic materials and metals. On digitally created images these objects appear darker, as shown in Fig. 1.

An important part is the digitalization of images and real-time processing, including automatic archiving. When checking cabin baggage all technical possibilities of the X-ray can be used, such as the differentiation of organic and inorganic materials by so-called quasi-colors, magnification of the image or highlighting via relief. There is a considerable number of types of industrial and military explosives that are logically different in density and proton number. But there are plenty of substances, mainly of organic origin, whose density and average proton number will match some kind of explosive. In addition, the X-ray must be set to automatically detect the density of a given type of plastic explosive with a certain tolerance, because the molding of plastic explosives into misleading shapes also partially changes its density.

Safety Engineering Series DOI 10.1515/tvsbses-2015-0005

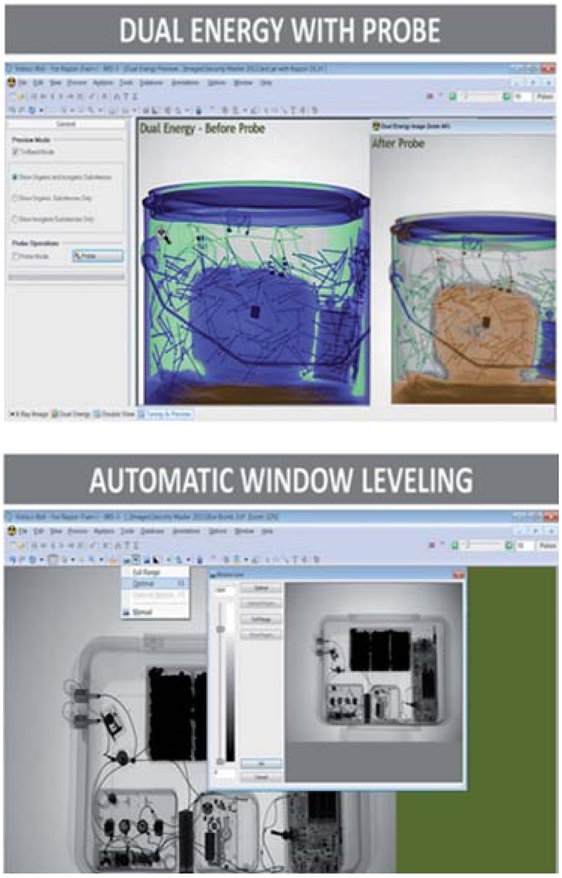

Fig. 1 Digital display of screened bag
(Smiths detections, online)

Technical description of the HI-SCAN 6040i security X-ray

HI-SCAN 6040i is a newly designed, compact X-ray inspection system with a tunnel opening that is 620 mm wide and 418 mm high. The size of this tunnel is perfectly suited for all hand baggage and other small items. This device offers operating personnel optimum support when deciding about the security of luggage content and significantly reduces inspection time. (Smiths detections, online)

Technical parameters: (X-ray Inspection Units, online)

- high-speed digital transmission with high resolution ability,
- 24-bit image processing in real time,
- maximum object size 615 (width) x 410 (height) [mm],
- dimensions 2004 (length) x 850 (width) x 1284 (height) [mm],
- weight 400 kg.

Security X-ray HI-SCAN 6040i is visible in Fig. 2. (Letiště Ostrava, a.s.)

Fig. 2 Inlet and outlet of the security X-ray

Results

The possibility of initiating the IED using X-rays

Sensors responsive to X-rays are usually devices of a more complex character. Generally, they respond to the presence of radiation of a certain type and intensity, and in most cases they create a custom electronic signal that can be measured. Devices sensitive to X-rays are therefore relatively wide-spread as measuring devices - so-called dosimeters. They are devices that are able to provide information not only about the presence but also the intensity of X-rays at the site. Dosimeters can therefore be used as X-ray detectors with instantaneous signalization after irradiation. They are:

- **Ionization chambers** - consisting of two electrically charged electrodes, between which there is an air gap. After X-rays pass through the space between the electrodes a weak electric current is created, which is taken to the indicator

 DOI 10.1515/tvsbses-2015-0005

and evaluated, and its size can determine the amount of transmitted radiation. This electrical current could therefore be the initiating current to activate the detonator of a similarly structured IED. Ionization chambers are produced in many size variations. The entire device can be designed so that it, for example, fits into a normal briefcase, including explosives. Ionization chambers of this type, however, are usually very sensitive to relatively small percussions. These can cause an electrical signal (sometimes very large) even without the presence of X-rays, which is why they are inappropriate for IEDs, as an explosion could occur during transport of the IED to its destination, or during handling.

- **Semiconducting detectors** - designed as a semiconducting diode in the reverse direction. When it passes through the X-rays, it will cause a very weak instantaneous electric current, much weaker than the ionization chamber. It must then be multiplied, followed by an evaluation. A semiconducting detector is very small, e.g. on an area of one millimeter cubed, so it is usually covered to prevent damage, or it is part of a larger whole. The important thing is that the semiconducting detector is not sensitive to vibrations and a potential IED designer could use it as a sensor reacting to X-rays. Such a device can be manufactured from commonly available components and could take the form of a small mobile phone.

The above-mentioned semiconducting detector could be used for the production of an IED sensitive to X-rays also because of its availability in various industries.

One of the smallest semiconducting detectors, the device type Unfors XI, the next generation device in a line of other successful products by the Swedish company Unfors Instruments. It is very small (the base unit is only 28 × 74 × 142 mm, weight 250 g) and easy to use. The detector device is equipped with a larger number of sensors that automatically determine the quality of the X-ray beam and correct the voltage readings and doses. It is this change in voltage that can switch the relay and close an electrical circuit with the detonator, which subsequently initiates the explosive. The semiconducting detector depicted in Fig. 3 could be adapted for this method of detection and initiation of an IED. (RADCAL, UNFORS, online).

Another type of semiconducting X-ray detector device is Diados. For the construction of an IED sensitive to this type of radiation, only the sensor (indicated by a red arrow) may be used, without the measuring unit shown in Fig. 4 (DIADOS, online).

Fig. 3 Semiconducting Detector Unfors XI

Fig. 4 Semiconducting detector together with the measuring unit Diados

Here again an electric signal can be used, which develops after the X-rays reach the detector itself. It sends an electric signal that, using a simple switch, may close another electrical circuit with the aforementioned detonator and initiate the explosive used in the IED.

Analysis of the Misuse of a Security X-ray during a Reported Threat of IED Explosion

By law, the airport operator is obliged to carry out an analysis and risk assessment for the purpose of processing a safety program or safety report, identifying sources of risk identification, determining possible scenarios of extraordinary events, estimating the probability of occurrences of major incidents and evaluating the acceptability of the risk of these incidents. This comprehensive airport security risk analysis must contain (Ščurek, 2014):

- Hazard identification - sources of risk, uncovering places, events, and conditions which are likely to cause potential losses,
- Risk Assessment - sizing and estimation of probable losses.

Precautions designed to increase airport security are suggested on the basis of the analyses. Based on submitted variants airport management will usually decide which of the measures will be realized and in what order. (Ščurek, 2009)

The criterion for the selection of appropriate methods of risk modeling is its clarity and the opportunity to best determine the most likely causes of the safety risks of security X-ray misuse from a structural and procedural point of view, expressed by a quantitative solution. The "Failure Mode and Effects" (FMEA) method was used to calculate the risk. The results of this analysis are evaluated using "Pareto's principle 80/20" and graphically displayed by the "Lorenz curve".

The Failure Mode and Effect Analysis - FMEA, is used to control elements of the system and identify simple failures. It is based on the calculation of the following formula (Brzybohatý, 2007):

$$R = P \cdot N \cdot H$$

Where in:

R risk rate (in literature also known as MPR),

N severity of consequences,

P probability of the existence of a risk,

H detectability of risk.

The parameters of a common departure hall as a single subsystem were used for the calculation. To analyze the misuse of the security X-ray during the reported threat of an IED explosion, five evaluation parameters were utilized. These parameters are listed in Tab. 1.

Tab. 1 Parameters of the FMEA method

R (MPR)	Risk rate	N	Severity of consequences
0 - 3	insignificant risk	1	IED imitations, false alarms
4 - 10	acceptable risk	2	small explosion, attracting attention
11 - 50	moderate risk	3	medium-sized explosions, injury to personnel with transportation to a hospital, bigger damage
51 - 100	adverse risk	4	big explosion, severe injuries with permanent consequences, severe damage
101 - 125	unacceptable risk	5	very big explosion, death of persons, very severe damage
P	**Probability of the existence of risk**	**H**	**Detectability of risk**
1	incidental, very unlikely	1	risk detectable at the time of its commission
2	somewhat unlikely	2	easily detectable risk in a few minutes
3	likely, realistic threat	3	detectable risk within a few hours
4	high probability of arising	4	not readily detectable risk (a day and longer)
5	permanent threat	5	undetectable risk

Tab. 2 Structural view

Order no.	Event	P	N	H	R	Pareto's principle 80/20
1	The possibility of initiating IED via X-ray beam	5	5	4	100	18,7
2	Blast and fragmentation effect	3	5	5	75	14
3	Fragmentation of glass panes	3	5	5	75	14
4	Combustion of lightly flammable substances	3	3	5	45	8,4
5	A suspicious person at entrance	4	5	2	40	7,5
6	Release and falling of object in lobby	2	4	5	40	7,5
7	Suspicious object in lobby	4	5	2	40	7,5
8	Announcing a threat of IED explosion in X-ray	3	5	2	30	5,6
9	Damage to the departure hall statics	1	5	5	25	4,6
10	The deliberate under-estimation of X-ray staff	2	4	3	24	5,5
11	IED planted by X-ray operators	2	5	2	20	3,7
12	Discovering IED imitation in X-ray or in the airport departure hall	3	1	2	6	1,1
13	Discovering IED in baggage during X-ray check	3	1	2	6	1,1
14	Attack on X-ray operators	2	2	1	5	0,9
15	Breaching of airport security	2	2	1	4	0,7
Σ					**535**	

The degree of risk (R) is determined using the parameters above. Tab. 2 then provides an enumeration and calculation of structural risks.

The degree of risk tolerance is determined by Pareto's 80/20 principle. Upon calculation of the result the risk value was assessed to equal 30. Risks with this value or higher were marked as unacceptable with a necessity for resolution. A graphical representation of structural risks is shown in Fig. 5.

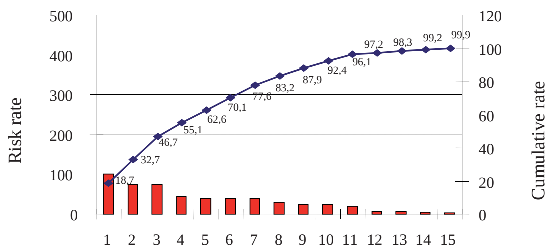

Fig. 5 Graphical output of structural risks

Tab. 3 shows the enumeration and calculation of procedural risks.

Tab. 3 Procedural view

Order no.	Event	P	N	H	R	Pareto's principle 80/20
1	Panic upon IED discovery	4	5	5	100	17,9
2	Death or injury of persons by shrapnel, fragments	3	5	5	75	13,4
3	IED detonation remotely or otherwise	3	5	5	75	13,4
4	Time stress of operators at peak times	4	5	3	60	10,8
5	Loss of airport credibility	2	5	5	50	9
6	Death or injury of X-ray operators by shrapnel, fragments	3	3	5	45	8
7	Suspicious person with baggage	3	5	2	30	5,4
8	Monotony of baggage checks	2	5	3	30	5,4
9	IED planted by X-ray operators	1	5	5	25	4,5
10	Human error	3	5	1	15	2,7
11	Prohibited object in cabin baggage	3	5	1	15	2,7
12	Threat of an attack using explosives, without revealing IED	3	1	4	12	2,2
13	Intentional damage of X-ray by operators	1	5	2	10	1,8
14	The deliberate underestimation of X-ray operators	2	5	1	10	1,8
15	The threat of an attack using explosives and the subsequent discovery of IED imitation	3	1	2	6	1
Σ					**558**	

The degree of risk tolerance is again determined by Pareto's 80/20 principle. Upon calculation of the result the risk value was assessed to equal 30. Risks with this value and higher will again be determined as unacceptable with the necessity of subsequent resolution. A graphical representation of the risk from a procedural view is shown in Fig. 6.

After performing the FMEA analysis methods using Pareto's principle and the Lorenz curve it was concluded that there a number of risks appeared that fall in the unacceptable area and are located in the red, with a value of R ≥ 30 in both tables. These structural and procedural risks would subsequently require adequate measures to be taken in order to mitigate or eliminate them.

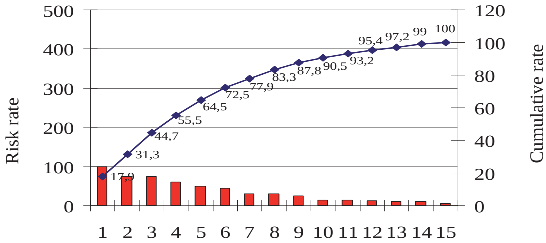

Fig. 6 Graphical output of procedural risks

Conclusion

The answer to the question that was raised in the introduction as to whether it is even possible to build an IED which is sensitive to X-rays is that such a possibility does exist. The design could be used for the fabrication of the initiating system e.g. the semiconducting detector Unfors XI or the measuring sensor of the Diados device. These detectors automatically determine the quality of the X-ray beam and correct the voltage readings and doses. It is this change in voltage that can switch the relay and close the electrical circuit with the detonator, which subsequently initiates the explosive in the IED.

The explosion of an IED in the security X-ray would thus endanger the passengers and staff present in the departure hall. At the same time, physical damage to the airport, airport property, the departure hall and technology would also occur. Depending on the quantity of explosives, the blast could damage airport facilities with a necessary shutdown of air traffic for at least a few days, not to mention the cost of necessary repairs. Nor is it possible to ignore the psychological aspect, such as a loss of credibility for the airport, which could in some cases even have existential consequences.

Acknowledgements

This paper was developed as part of the security research project of the Czech Republic - II BV/2-VS, entitled “Water charges”, recorded under number VG20122014082, focused on special shaped charges for disposal of IED and for opening of closed spaces.

References

BRZYBOHATÝ, M., MIKA, O. J. (2007). *Ochrana před chemickým a biologickým terorismem*. Policejní akademie České republiky v Praze, Praha 2007. ISBN 978-80-7251-271-3.

DIADOS - Ionizing Radiation Products and Solutions, Diagnostic Dosemeter [online]. Available at: http://www.ptw.de/diados_diagnostic_dosemeter.html.

JANÍČEK, M. (2002). *Pyrotechnická ochrana před terorismem*. Educa s.r.o., Vyškov 2002, ISBN 80-902089-6-7.

Letiště Ostrava, a.s. [online]. Available at: http://www.airport-ostrava.cz/cz/page-ke-stazeni/.

RADCAL, UNFORS [online]. Available at: http://www.vmk-rtg.cz/f_kval.htm.

Smiths detection HI-SCAN 6040i [online]. Available at: https://www.smithsdetection.com/index.php/x-ray-inspection/170-parcels-baggage/hi-scan-6040i.html?lang=en#.VT9r7bccSJA.

ŠČUREK, R., ŠVEC, P. (2009). *Ochrana letiště před protiprávními činy*. SPBI, Ostrava VŠB-TUO, 2009, ISBN 978-80-7385-071-5.

ŠČUREK, R., MARŠÁLEK, D. (2014). *Technologie fyzické ochrany civilního letiště*. Cerm s.r.o., Brno 2014, ISBN 978-80-7204-862-5.

X-ray Inspection Units, [online]. HI-SCAN 6040i, 95589062 0/01/12 Smiths Heimann. Available at: http://www.directindustry.com/prod/smiths-detection/x-ray-inspection-machine-35168-1607683.html.