SCIENCE & SECURITY Issue 21

CASRA NEWSLETTER

Spring is in the air and it is time for our first newsletter in 2019!

With this 21st issue, we become more flexible regarding the publication dates of our newsletter. From now on, the CASRA Newsletter issues will not always follow a fixed schedule of three issues per year delivered in March, July and November. More flexibility regarding publication dates will allow us to inform you about results of our research and development in a more timely way when appropriate.

In this issue, the section "Research Put Across" presents our study on 2D vs 3D imaging for detecting bombs in X-ray images of hold baggage. The study was recently published in the high impact journal Human Factors. This study is a nice example for applied research leading to important insights for airports, regulators, manufacturers and security service providers. In the "Security in Practice" section, we explain CASRA's Systematic Threat Assessment by showing you concrete examples of new threats we have found in the last years and immediate countermeasures that we have provided.

We are looking forward to receiving any feedback you might have as well as your input on topics you would like us to address in upcoming newsletters. We hope you continue to enjoy reading our articles and we wish you a beautiful spring and a Happy Easter.

Dr. Diana Hardmeier
Director

A. Schwaninger

Prof. Dr. Adrian Schwaninger
Chairman

TOPICS IN THIS ISSUE:

RESEARCH PUT ACROSS

AIRPORT SECURITY X-RAY SCREENING OF HOLD BAGGAGE: 2D VERSUS 3D IMAGING

At airports worldwide, hold baggage is screened using X-ray machines with automated explosive detection. Older systems are based on 2D multi-view X-ray (2D imaging) whereas newer systems are based on computer tomography (CT) that features 3D rotatable images (3D imaging). We compared the visual inspection performance of screeners using 2D imaging versus 3D imaging. Results showed that despite lower image quality of 3D imaging, screeners achieved a similar detection performance with 3D imaging to that for 2D imaging. Screeners required more time for visual inspection of 3D versus 2D images. However, due to lower false alarm rates of 3D imaging systems compared to 2D imaging systems, baggage throughput is still much higher when using 3D imaging in hold baggage screening.

SECURITY IN PRACTICE

SYSTEMATIC THREAT ASSESSMENT

We live in a fast-moving world in which vast amounts of data are produced at an accelerating pace. A systematic analysis of data from the open and deep web allows identifying new and emerging threats against civil aviation at an early stage. With the Systematic Threat Assessment (STA), we monitor large amounts of data in open source media and the deep web using different methods for search, data ingestion, and analysis by applying machine learning algorithms. This allows early threat identification to define immediate countermeasures such as updates to recurrent training for keeping screeners up to date regarding new and emerging threats. In this article, we explain our STA process and countermeasures using concrete examples.

AIRPORT SECURITY X-RAY SCREENING OF HOLD BAGGAGE: 2D VERSUS 3D IMAGING

Text: Nicole Hättenschwiler

Hold baggage screening targets only fully functioning improvised explosive devices (IEDs). This is why at airports, all hold baggage is screened with X-ray machines that are explosive detection systems (EDS). They indicate areas in X-ray images that might be explosive by colored frames or a specific surface color. X-ray images on which an EDS has raised an alarm are sent to remote screening locations for on-screen alarm resolution (OSAR) by airport security officers (screeners). The task of hold baggage screeners is to visually inspect alarmed areas in X-ray images and decide whether such EDS alarms are harmless (false alarms of the EDS) or whether the hold baggage needs further inspection because it might contain an IED.

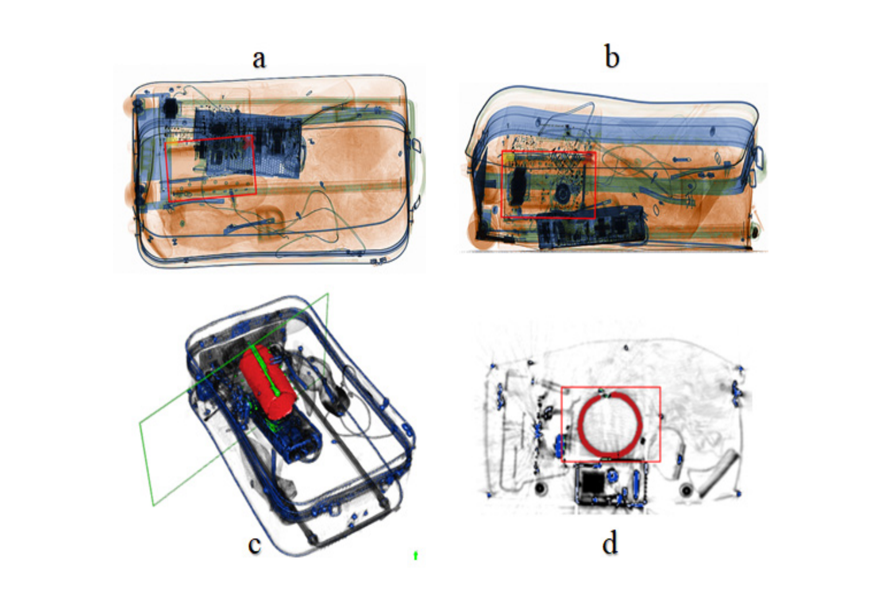

Figure 2: Bag with an IED recorded with 2D and 3D imaging: (a) 2D default image, (b) 2D image with 90 degrees difference in perspective, (c) 3D-rotatable CT image, and (d) CT slice image

In order to decide whether a bag contains a fully functioning IED or not, screeners need to identify the following components of an IED (see Figure 1): a triggering device, a power source, explosive charge, and a detonator that need to be connected to each other by, for example, wires [1, 2]. Through computer-based training, screeners can learn to recognize these components, and they can achieve and maintain a high detection performance for IEDs [3, 4].

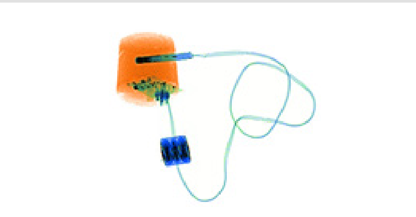

Figure 1: Example of a fully functioning IED (triggering device, power source, explosive charge, and a detonator connected by wires)

At airports, 2D multi-view X-ray imaging systems are currently the most widely used technology to screen hold baggage. However, 2D multi-view systems are not able to unambiguously reveal the exact bag content for complex packed and cluttered bags (Figure 2 a, b). Newer technology is based on computer tomography (CT). Such systems generate a stack of contiguous slice images that are used to calculate and visualize a volumetric view of the bag [3]. Screeners have then the possibility to inspect bags as 3D-rotatable images that are enhanced by using depth cues with the additional option to slice through them [1, 5, 6] (Figure 2 c, d).

Due to these imaging features, 3D-rotatable images should facilitate the recognition of threats when they appear from an unusual viewpoint or when they are superimposed by other objects [5]. Further, continuous exposure to 3D objects could result in richer visual object representations that could improve screeners' visual inspection performance in general. However, CT systems have lower image quality compared to 2D imaging [6, 8], which could impair detection performance with 3D imaging.

WHAT IS BETTER, 2D OR 3D IMAGING?

3D imaging based on computer tomography features better automated detection of explosives and higher baggage throughput than older 2D X-ray imaging technology [6]. Nonetheless, some countries and airports hesitate to implement 3D systems due to their lower image quality and the concern that screeners will need extensive and specific training before they can be allowed to work with 3D imaging. It is interesting to compare 2D and 3D imaging because it is unclear whether the benefits of 3D imaging outweigh the potential negative effects of lower image quality. Comparing 2D and 3D imaging is also of high practical relevance: Regulators, airport operators and security service providers currently discuss whether extensive and specific training is necessary for screeners who are used to 2D multi-view imaging before they can be allowed to work with 3D imaging. At CASRA, we conducted a study to compare the visual inspection performance of screeners using 2D versus 3D imaging. To address these issues, screeners working with 2D imaging (2D screeners) and screeners working with 3D imaging (3D screeners) conducted a simulated hold baggage screening task with both types of imaging.

What we found was that despite lower image quality, screeners' detection performance with 3D imaging was similar to that with 2D imaging (see Figure 3). This indicates a very large transfer effect, and has important practical implications in light of the current international discussions on whether specific training should be mandated for 2D screeners before allowing them to work with 3D imaging systems. Interestingly, 3D screeners revealed higher detection performance with both types of imaging than 2D screeners (Figure 3).

The possibility of 360° rotation allowing visual inspection from all angles eliminates, or at least drastically reduces, the challenges resulting from low target visibility due to viewpoint or superposition effects in 2D imaging. This seems to compensate potential negative effects of lower image quality of 3D imaging. Taken together, our results suggest that 2D screeners do not need extensive and specific training to achieve similar detection performance with 3D imaging compared to that attained with 2D imaging.

WHAT IS FASTER, VISUAL INSPECTION OF 2D OR 3D IMAGES?

Screeners needed more time when hold baggage was displayed with 3D imaging compared to 2D imaging (Figure 4). It was anticipated that visual inspection with 3D imaging takes more time, because rotating and slicing 3D images obviously takes longer to process than a visual inspection of static 2D X-ray images. Concretely, both screener groups needed more time (2–4 seconds) when using 3D imaging compared to 2D imaging.

STILL MUCH HIGHER EFFICIENCY WITH 3D SCREENING!

What do our results on screeners' visual inspection performance mean for the efficiency (throughput) of 2D versus 3D hold baggage screening at airports? 2D and 3D imaging systems can process about 1,500 bags per hour, but 2D imaging systems have false alarm rates of about 35% whereas 3D imaging systems achieve much lower false alarm rates (around 15%). The installation of 3D imaging (Level 1 in hold baggage screening) should therefore already result in a 31% increase in efficiency (Table 1). Based on the amount of bags sent to visual inspection and the response times found in our study, an efficiency increase of 36–49% on Level 2 of hold baggage screening (on screen alarm resolution by screeners) can be achieved (see Table 1 for details).

If screeners decide that an X-ray image

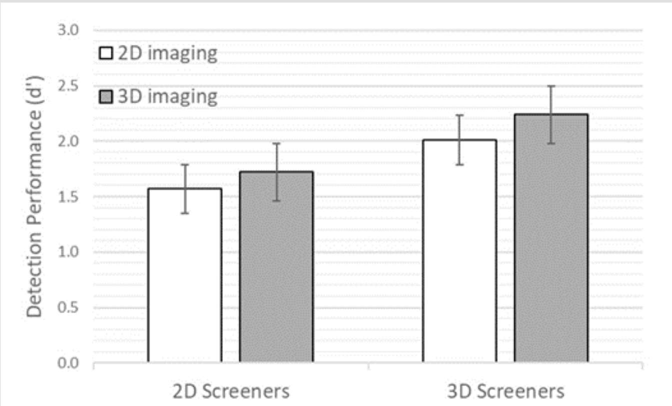

Figure 3: Detection performance (d') by X-ray imaging technology (2D vs 3D imaging) and screener group (2D vs 3D screeners). Error bars are standard errors. Both screener groups show the same performance with both imaging systems while the 3D screeners achieved a higher detection performance.

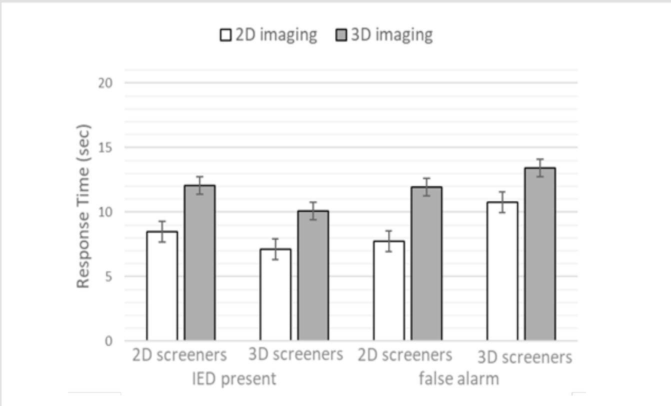

Figure 4: Response time (RT) by X-ray imaging technology (2D vs 3D imaging) and screener group (2D vs 3D screeners) for target present images (with an IED) and target absent images (without an IED). Error bars are standard errors. Screeners need more time (2-4 seconds per image) when using 3D imaging.

Table 1: Efficiency comparison between 2D and 3D imaging

Scenario	Bags per hour	EDS-HBS FAR	Approval capacity	Efficiency increase Level 1	Bags sent to visual inspection	Target absent RT [sec]	Visual inspection time [hr]	Efficiency increase Level 2
2D screeners / 2D imaging	1,500	35%	975		525	8	1.2	
2D screeners / 3D imaging	1,500	15%	1,275	31%	225	12	0.8	36%
3D screeners / 2D imaging	1,500	35%	975		525	11	1.6	
3D screeners / 3D imaging	1,500	15%	1,275	31%	225	13	0.8	49%

Note. EDS = explosive detection systems; HBS = hold baggage screening; FAR = false alarm rate; RT = response time.

is suspicious, more time-consuming investigations follow including rescreening with other X-ray technology, trace detection, explosive detection, dogs, passenger reconciliation and the opening of bags [5]. Therefore, efficiency increase will be even higher in practice because 3D imaging results in less hold baggage being sent to Level 2.

CONCLUSION

Replacing older 2D with newer 3D imaging systems for hold baggage screening can be recommended to increase the efficiency and effectiveness of hold baggage screening. Despite lower image quality, screeners achieved a similar detection performance with 3D imaging to that for 2D imaging. Features of 3D imaging systems (3D rotation and slicing) seem to compensate for the lower image quality. Further, 2D screeners do not need extensive and specific training to achieve comparable detection performance with 3D imaging. It was shown that visual inspection competency acquired with one type of imaging seems to transfer to the other type of imaging.

Last but not least, 2D and 3D screeners required more time for visual inspection of 3D versus 2D images. However, due to lower false alarm rates of 3D imaging systems compared to 2D imaging systems in operation [1, 6, 8], baggage throughput would still be much higher in hold baggage screening.

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SYSTEMATIC THREAT ASSESSMENT

Text: Curdin Brändli

We live in a fast-moving world in which vast amounts of data are produced at an accelerating pace. A systematic analysis of data from the open and deep web allows identifying new and emerging threats against civil aviation at an early stage. With the Systematic Threat Assessment (STA), we monitor large amounts of data in open source media and the deep web using different methods for search, data ingestion, and analysis by applying machine learning algorithms. This allows early threat identification to define immediate countermeasures such as updates to recurrent training for keeping screeners up to date regarding new and emerging threats. In this article, we explain our STA process and countermeasures using concrete examples.

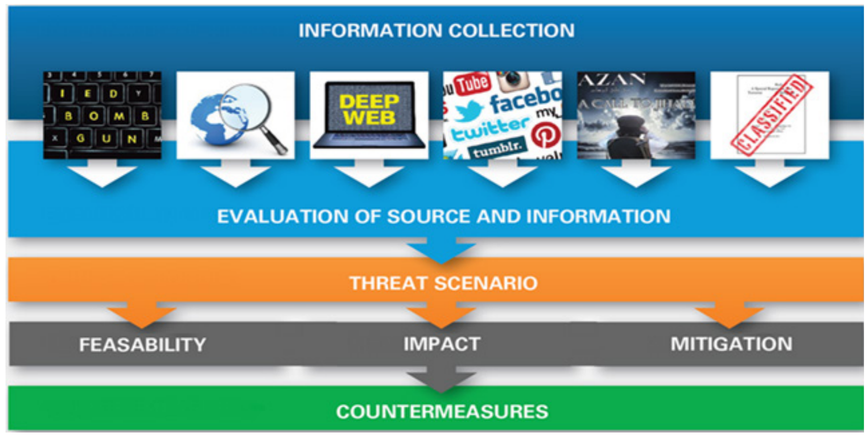

Figure 1: Systematic Threat Assessment process overview

SYSTEMATIC THREAT ASSESSMENT

A secure air transportation system is very important, both for economy and society [1]. In order to prevent terrorist attacks and other acts of unlawful interference against civil aviation, security screening of passengers and their belongings is conducted at airports. Potential threats change over time due to technological developments (e.g. 3D printing) and terrorists continuously seek new ways to carry out attacks. Therefore, a continuous and systematic threat assessment is very important to identify new and emerging threats and develop countermeasures. The Systematic Threat Assessment (STA) of the Center for Adaptive Security Research and Applications (CASRA) is an essential part of research projects that are co-funded by the Swiss Federal Office of Civil Aviation (FOCA). The main goal is to strengthen security performance at airports by using intelligence analysis for regular updates of screeners' training and other countermeasures aimed at keeping up with new and emerging threats. CASRA's interdisciplinary STA team consists of eight analysts with different professional backgrounds, including data science, IT, psychology, political science, sociology, biology, mechanical engineering, as well as law enforcement. This interdisciplinary cooperation is used to achieve the best possible output in a five-step process from information collection through evaluation of source and information, threat scenario identification, threat scenario assessment, and immediate countermeasure development and implementation (Figure 1).

The threat scenario assessment consists of the assessment of the feasibility (i.e. how easily can the necessary expertise and required materials be acquired), the impact (i.e. how high is the damage potential in terms of human, psychological, and economic aspects), and the mitigation (i.e. to what extent are damage minimizing measures already implemented and what still needs to be done).

In recent years, progress has gradually been made on developing algorithms using machine learning techniques to optimize the data collection process and facilitate the classification into relevant and irrelevant data. Furthermore, the data collection was considerably optimized through the development of own application components. With this approach, the amount of processed data has continuously been increased in the last years. In the following sections, we illustrate the five-step process of CASRA's STA for each information source (web alert, surface web, deep web, social media, radical propaganda and confidential reports) with new and emerging threats that we have identified in the last years.

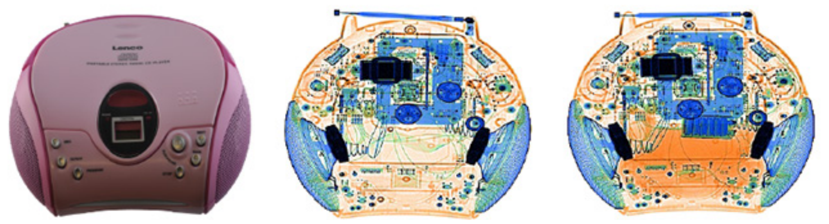

Figure 2: Analysis on how easy an IED can be detected in a radio using visual inspection of X-ray images. Left: photograph of a radio, middle: X-ray image of the same radio, right; X-ray image of the same radio with an IED using explosive simulant (orange color in the X-ray image)

Web alert - IED hidden in audio devices

In January 2018, a web alert appeared on the STA platform with the information on an IED hidden in a radio that exploded in the Indian city of Sagar [2]. One person was killed and two others were injured. The report was subsequently cross-validated by STA analysts using other sources. In addition, another alert appeared on the STA platform about an IED in a microphone, which was used in February 2018 in an attempted attack in Afghanistan [3]. In the STA team, the threat scenario was specified as IEDs in audio devices. Subsequently, STA analysts assessed the feasibility, impact and mitigation possibilities of this threat scenario. As a result of the evaluation, several inert IEDs in audio devices were (re)created and scanned using a state-of-the art X-ray machine (Figure 2 shows example images). The STA team developed several variations of this threat type using different electronic devices with IEDs made with different explosive simulants and triggering mechanisms. The detectability using visual inspection and other technological means for explosives detection was investigated.

Based on a comprehensive analysis, the STA team built several inert IEDs in audio devices as Fictional Threat Items (FTIs). An FTI is a high-quality X-ray image of a prohibited article from various angles or in full 3D that could be used for computer-based training (CBT) or threat image projection (TIP). The FTIs of inert IEDs in audio devices were included in the CBT for initial and recurrent training of screeners. As additional countermeasure, we recommended using unpredictability measures including explosive trace detection (ETD) at security checkpoints.

Surface web - improvised incendiary device (IID) based on thermite

In February 2015, our STA analysts recorded information from surface web searches about the threat of thermite. The United States Transportation Security Administration (TSA) issued a warning regarding the potentially catastrophic threat of thermite to civil aviation [4]. In order to assess the impact, our STA team carried out experiments with external experts (Figure 3).

Those experiments involved an airplane passenger seat row as well as a piece of aircraft floor (composite floor panel). For the experiment with the seat row, three standardized bags were used, each with a thermite-based incendiary device. All experiments showed a remarkable intensity of a thermite combustion. According to CASRA's assessment, there exists a risk that transported thermite will be detected as metal powder, but then considered hazard-free by security personnel when controlled manually in a follow-up inspection. In order to prevent this, security personnel should be trained specifically for the identification of thermite and thermite-based incendiary devices. To that end, STA analysts prepared thermite-based IIDs for integration as FTIs in the CBT and furthermore created an e-learning module to raise screener awareness for thermite-based IIDs.

Figure 3: Experiment with a thermite-based incendiary device in a piece of luggage on aircraft seats

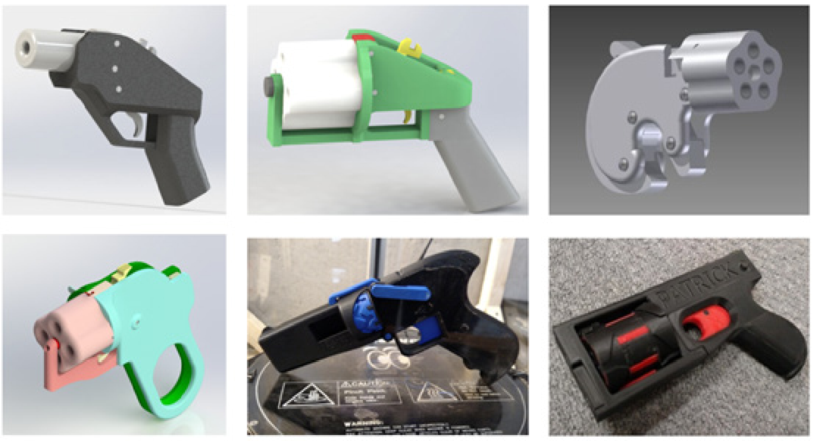

Figure 4: Different types of 3D printed guns found in the deep web: Liberator (top left), Liberator Pepperbox (top middle), Pepperbox Reprringer (top right), Pepperbox Card Counter (below left), Imura Pistol V2.0 (below middle), Washbear (below right)

Deep web - 3D printed guns and their development over the years

As mentioned in an article by Florian Schmid [5], in May 2013, various media reported the fabrication of the first working 3D printed gun called the Liberator. STA analysts were able to access hidden platforms in the deep web that offered such 3D weapons and their blueprints. In cooperation with police and military authorities, as well as other experts, the STA team produced several models of 3D printable weapons and conducted experiments. As a countermeasure, all models were implemented as FTIs in the image recognition training system for security personnel. During the following years, 3D printing was further developed and new models of 3D printed guns evolved (Figure 4). Among these new models, there were also semi-automatic weapons. Thanks to the systematic monitoring of deep web content, STA analysts have continuously been gathering intelligence about the developments in the field of 3D printable weapons and have repeatedly undertaken new experiments and implemented new models as FTIs in the CBT and as an e-learning module to increase screener awareness and X-ray image interpretation competency.

Social media - IED with fragmentation effect

In November 2016, the self-proclaimed Islamic State of Iraq and Syria (ISIS) published a propaganda video on hidden channels in the Telegram messenger. The video contained detailed instructions on how to build a fragmentation IED and even had English subtitles. The demonstrated IED was made from homemade explosive, filled into an aluminum can together with a detonator and then put into a container with metal ball bearings to make an IED with fragmentation effect (Figure 5).

Due to the potential threat to civil aviation, STA analysts immediately carried out a thorough assessment of the threat scenario. Within a very short time, inert IEDs were recreated and recorded with an X-ray machine (Figure 6 shows one example). The images were forthwith integrated into the CBT. Furthermore, our STA team created an e-learning module to raise awareness of security control personnel as quickly as possible. With this kind of IED [6], a terrorist attack was carried out in a metro station in Russia on 3 April 2017, which illustrates the relevance of this type of threat.

Figure 5: Screenshot from the propaganda video shared on hidden channels in the Telegram messenger

Figure 6: Shows the production of the inert IED (left), the inert IED with ball bearings to increase the damage potential (middle) and the X-ray image of the inert IED (right)

Figure 7: Cover picture and page 73 of the 14th Inspire edition

Radical propaganda - timed hand grenade

On 9 September 2015, Al-Qaida in the Arabian Peninsula (AQAP) published the 14th edition of the radical propaganda magazine Inspire (Figure 7). Our STA analysts constantly monitor radical propaganda magazines that are distributed by terrorist groups, even if they are shared on hidden and hard to access platforms. In the Inspire magazine No. 14, we found detailed instructions for a timed hand grenade with a call to use it to carry out attacks. As a result, our STA team built an inert IED according to the instructions to then produce X-ray images. Since the recognition of the IED in an X-ray image can be learned by screeners (Figure 8), the IED was integrated into the CBT as an FTI in order to enhance the detection possibilities.

Reports from other intelligence organizations - IED hidden in a tennis ball

Another source, from which the STA team receives information about new and emerging threats, are reports provided by other intelligence organizations. Some time ago, our STA team received the information that IEDs camouflaged as tennis balls had seen use by terrorist groups. Based on this information, the threat scenario was assessed by STA experts. Reports did not provide enough detail or visual information to draw conclusions, but at least one image revealed what could be a delay fuse. In such a case, after lighting the fuse, the ball could be thrown at the desired target and would detonate within seconds. In the course of the investigation, our STA analysts decided to rebuild inert tennis ball IEDs to investigate how well they can be detected in X-ray images. Due to the fact that such a type of IED can be detected by trained screeners, if they know the appearance on an X-ray image, the images were integrated as FTIs into the CBT (Figure 9).

SUMMARY AND CONCLUSION

These are just some examples among

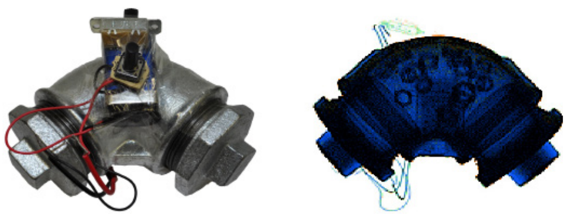

Figure 8: Replica of the Inspire grenade (left) and X-ray image (right)

Figure 9: Illustration of the IED threat using manipulated tennis balls. Left: photograph of a manipulated tennis ball, middle: the same tennis ball with explosive and metal parts, right: normal tennis ball without explosive

Figure 10: Overview of FTIs recorded by the STA team

many. Thanks to the STA, a large number of new and emerging threats have been recorded as FTIs and integrated into our computer-based training (CBT) program X-Ray Tutor and into our TIP libraries (Figure 10).

This article showed how our STA team works and which systematic processes are used. Several examples from different sources demonstrated that it is important to constantly monitor and analyze various media in order to detect new and emerging threats at an early stage. In addition to early detection, it is crucial to conduct a systematic threat assessment and implement countermeasures quickly. Regular updating of training and TIP libraries keeps screeners up to date regarding new and emerging threats. This is very valuable for strengthening security screening processes. Last but not least, it also ensures that CBT and TIP remains interesting and motivating for screeners.

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Contact for authorities

This article contains selected excerpts from the detailed CASRA Threat Reports created regularly in a project that is co-funded by the Federal Office of Civil Aviation of Switzerland (FOCA). If you would like to be added to the recipient list (subject to approval by the FOCA), please contact us at:

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