

# Threat Image

# Projection: enhancing performance?

*The importance of aviation security has increased dramatically since the 9/11 terrorist attacks. The recent August 2006 terror threats in the UK have shown that the aviation industry remains a key target of terrorists and that we need effective airport security systems involving well-trained and attentive human operators. Threat image projection (TIP) is a software package available on state-of-the art X-ray machines to project threat images throughout the routine baggage X-ray screening operation. This technology is now being used in several countries with the general expectation that it will increase the performance of screeners. However, evidence from covert tests at different European airports questions the benefits of TIP for training screeners. There have been reports showing that TIP performance increased but that covert test results remained unaffected. **Adrian Schwaninger** explains why TIP alone is not an effective training tool and how screener performance can be increased to achieve good results at covert tests.*

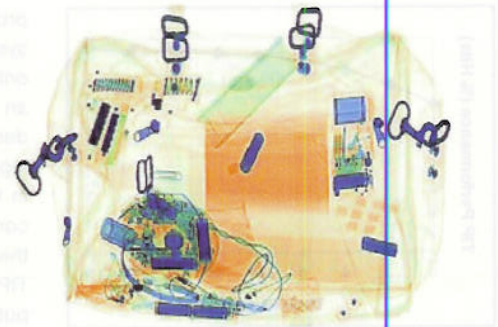




X-ray image of a real passenger bag



Pre-recorded fictional threat item (FTI)



Result on the operator screen: image of the bag with the FTI

Figure 1: Illustration of TIP functionality in cabin baggage screening (CBS).

**T**IP consists of a software package installed on state-of-the art X-ray screening equipment. The functionality in cabin baggage screening (CBS) is illustrated in Figure 1. The TIP software inserts fictional threat images (FTIs) of actual pre-recorded threat items into passenger bags when they are screened using conventional X-ray systems. X-ray operators (screeners) have to press a specific button on the control panel ("threat key") whenever they detect a threat, no matter whether it is a real threat object or a FTI.

There are three types of feedback messages. When a FTI has been projected and the screener pressed the threat key, a "hit" message is presented to inform that a particular category of FTI has been correctly identified (Figure 2).

When a FTI has been projected and screeners do not press the threat key within a specified amount of time, a "miss" message is shown. It informs the screeners that they failed to identify a FTI. For hits and misses, the FTI is highlighted within the bag by a rectangle, which provides immediate visual feedback (see Figure 2). When the threat key has been pressed but no FTI has been projected a "non-TIP alarm" message is shown. This message informs the screener that a FTI was not presented and that appropriate security procedures (usually hand search) should be followed for examining suspicious articles within a

bag. All three types of feedback messages (hit, miss, non-TIP alarm) remain on the screen until a "stop" button is pressed. This removes the feedback message from the screen. For hits and misses, the FTI is removed from the X-ray image of the passenger bag. The X-ray operator is then required to re-examine the original bag image for real threats.

There are two modes in which TIP can be used: FTI and Combined Threat Image (CTI)

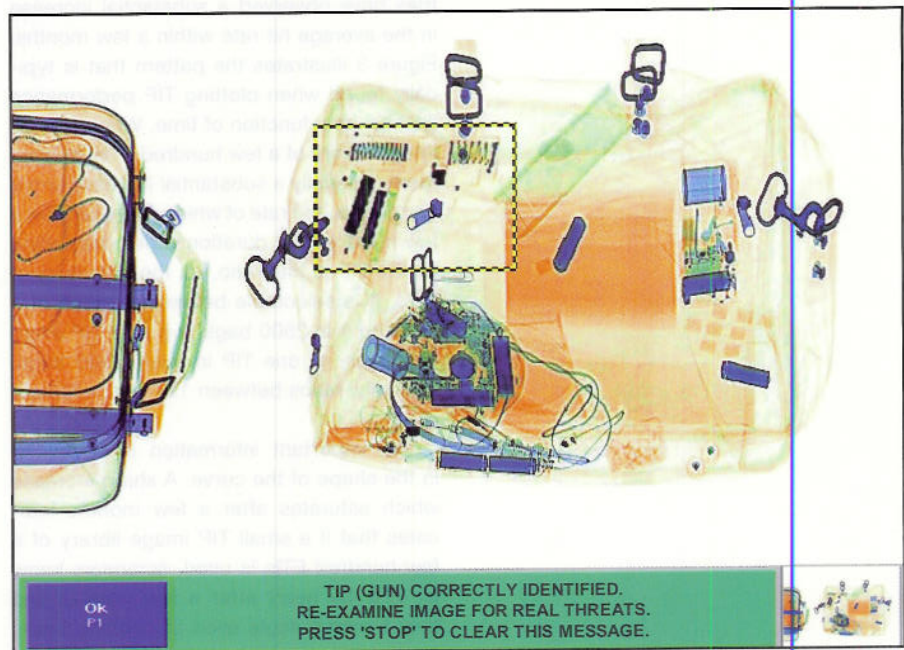


Figure 2: Screen shot showing the real passenger bag with an FTI and a hit message. The FTI is highlighted with a rectangle.



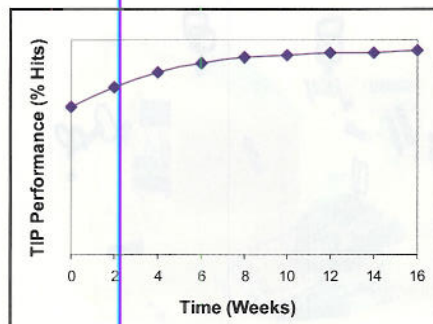


Figure 3 Typical TIP performance data (% hits) as a function of time when using a TIP library of a few hundred images and a TIP to bag ratio of 1:50.

projection. Cabin baggage screening TIP systems are usually operating in FTI mode only, where an FTI is superimposed onto an X-ray image of a real passenger bag as described above. In hold baggage screening TIP is usually operating in CTI mode. In this case an entire X-ray image of a bag containing a threat item is presented during the screening operation. In both modes, the TIP software, which is contained on a computer inside the X-ray machine, controls the projection and placement of the FTIs, and records TIP response data (hits, misses, non-TIP alarms, reaction times, etc.).

#### Why TIP often could not improve performance in covert tests

When I attended an international human factors advisory group meeting in 2001 I explained that I did not believe that TIP could increase detection performance at the checkpoint unless a large threat image library was used in combination with individually adaptive computer based training (CBT). Interestingly, since the early days of TIP several years ago, TIP has often been seen as a training tool for improving screener performance. This view seemed to be confirmed by the following observation: after introducing TIP using a small image library of a few hundred FTIs, several countries have observed a substantial increase in the average hit rate within a few months. Figure 3 illustrates the pattern that is typically found when plotting TIP performance (% hits) as a function of time. When a small image library of a few hundred FTIs is used, there is usually a substantial increase in the first weeks, the rate of which plateaus after a few months. The duration varies depending on the TIP to bag ratio, i.e. the frequency of TIPs. It is selectable between a range of 1 in 2 and 1 in 2500 bags, e.g. one TIP every two bags, or one TIP in every 2500 bags. Typically, ratios between 1:50 and 1:100 are used.

The important information is contained in the shape of the curve. A sharp increase which saturates after a few months indicates that if a small TIP image library of a few hundred FTIs is used, screeners know all FTIs by heart after a few months and they become eagle eyed at spotting them. As a consequence, screeners focus on identifying the FTIs of the TIP library while

their attention and imagination needed for identifying real threats vanishes. This is the first reason why at several airports the results of covert tests did not improve even though TIP has been operational for years. The second reason for failure at covert test is related to the fact that in some cases the threat items used in such tests do not resemble the FTIs used in TIP. As will be shown below, screeners can only recognise a real threat object if it is similar to items that have been learned during computer-based training (CBT) or operational experience. In order to be effective, CBT must include a large image library of thousands of threat item images in which hundreds of different threat types are depicted from many different viewpoints. The third reason is that humans often fail to react appropriately if something happens that they do not expect. When TIP is operational screeners expect FTIs and TIP feedback messages but not real threat objects used in covert tests. If practical tests are not conducted frequently, it is unavoidable that screeners sometimes fail when covert tests are conducted, even if TIP is operational.

#### A large multiple views library is essential

Visual cognition and object recognition studies have shown that you can only recognise an object if it is similar to something you have seen before (Graf, Schwanager, Wallraven, & Bülhoff, 2002; Schwanager, 2004b, 2005a). The consequences for X-ray screening are illustrated in Figure 4.

Each bag contains a threat object and each of them looks quite different in the X-ray image than in reality. This is one reason why many threat items are difficult to recognise without training. A second reason is that several objects are not known from everyday experience, which accounts at least for the self-defence gas spray depicted in Figure 4c and the improvised explosive device (IED) depicted in Figure 4d. In addition, some threat objects look similar to harmless objects. For example the switchblade knife depicted in Figure 4b resembles a pen or a laser pointer. Another problem is image deciphering resulting from viewpoint changes (see Koller & Schwanager, 2006 for a recent study). If an object is depicted from an unusual viewpoint, it becomes difficult to



Figure 4 Different types of threat items in X-ray images of passenger bags. a) Electric shock device, b) switch blade knife, c) self defence gas spray "Guardian Angel", d) improvised explosive device (IED).

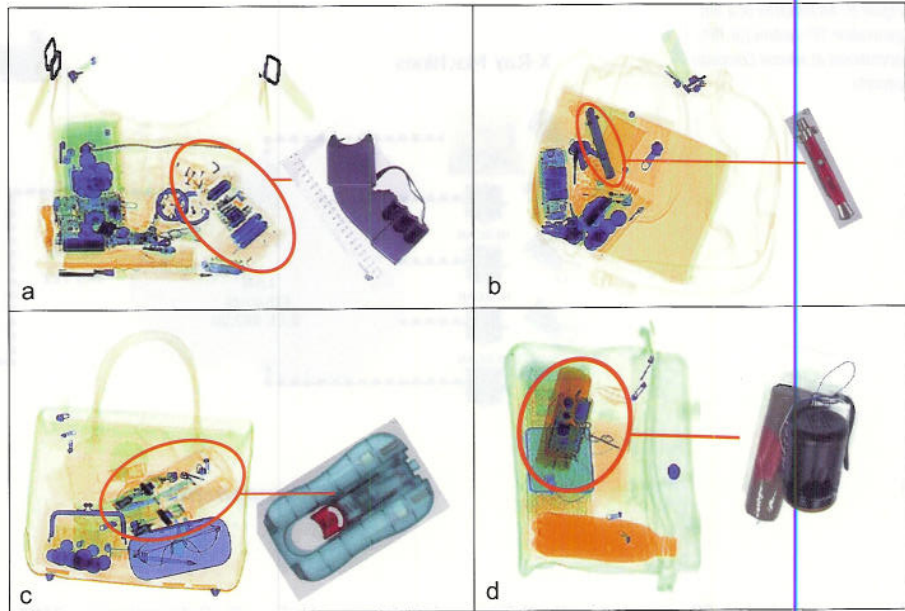


Figure 5 Objects are difficult to recognise when depicted from an unusual viewpoint.



recognise. This is illustrated in Figure 5.

Each of the three objects is well-known from everyday life. However, most people have great difficulty in recognising the images at the top without training because they are depicted from an unusual viewpoint. These examples illustrate how important it is to use a large threat image library in which objects are depicted from many different viewpoints. Based on a close collaboration between vision scientists and aviation security experts we have built a multiple views library that currently contains more than 50,000 threat items based on more than 700 different types of threat objects depicted from many different viewpoints. Based on police and intelligence information, this image library is constantly being updated and loaded into adaptive CBT (X-Ray Tutor) to keep screeners ready and prepared using weekly recurrent training.

#### **Adaptive CBT: an effective tool for increasing performance**

While TIP is a good tool for increasing motivation and alertness of screeners at the checkpoint, it is not a very effective tool to train screeners. When using TIP, screeners see only a few FTIs per day. In contrast, during a 20-minute session of adaptive CBT screeners are exposed to about 200 X-ray images containing FTIs. Since training is conducted off-line, screeners are not stressed and have time to review images in a self-paced manner that is important for visual learning. Figure 6 summarises the results of a study conducted over the last two years with 334 aviation security screeners. Most screeners trained at least

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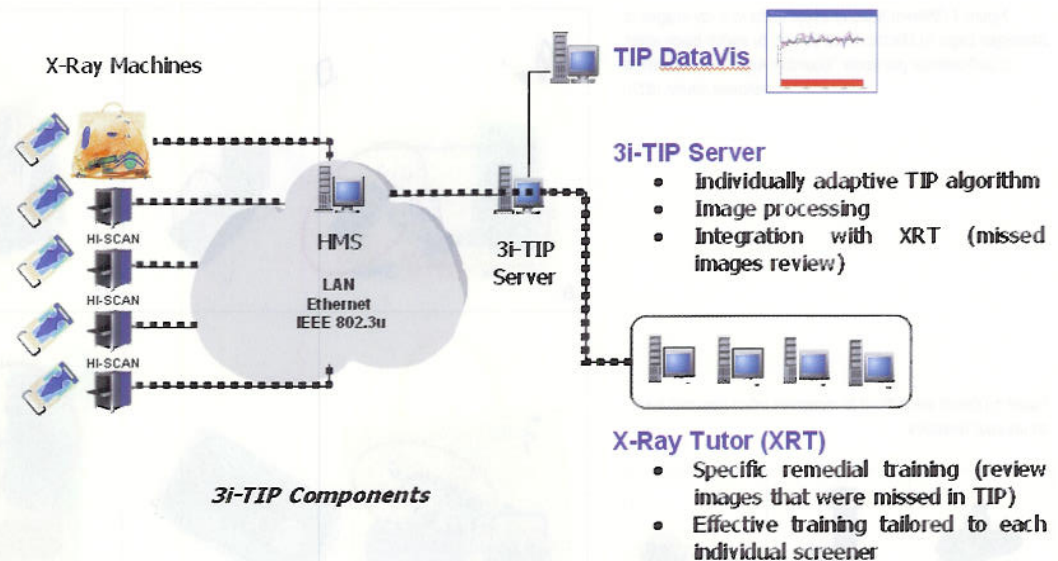
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Figure 8: Architecture of a 3rd generation TIP system (3i-TIP), operational at several European airports.



twice a week for 20 minutes with X-Ray Tutor. Detection performance was measured using the Prohibited Items Test (PIT), being a reliable and valid instrument to measure how well screeners can detect all kinds of threat items in X-ray images. As can be seen in Figure 6 there was a large increase in detection performance before and after two years of recurrent CBT with X-Ray Tutor. Consistent with several earlier studies this result confirms that adaptive CBT can increase the ability to detect threat items in X-ray images substantially.

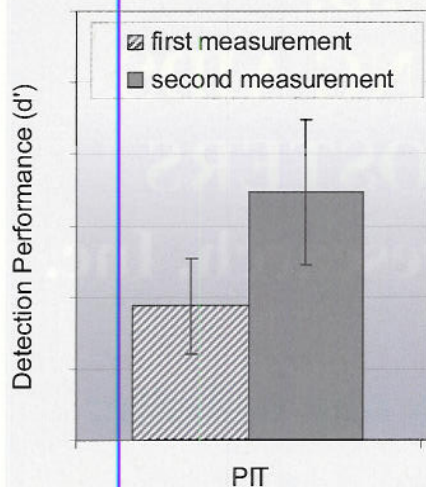


Figure 6: Detection performance before and after two years of weekly CBT with X-Ray Tutor.

### Understanding screener performance

Several factors determine the performance of screeners at the checkpoint (Figure 7). It has become clear in recent years, that there are large differences between people with regard to aptitudes and abilities needed in airport security screening (see for example Schwaninger, Hardmeier, & Hofer, 2005;

Hardmeier, Hofer, & Schwaninger, 2005, 2006a). Performance can be increased substantially if reliable and valid selection tests are used as part of pre-employment assessment. For example Hardmeier et al. (2006a) could show that screeners selected with the X-Ray Object Recognition Test (X-Ray ORT) performed substantially better, after only one year, than other screeners who had been working at the airport but were not selected using this test. Moreover, Hardmeier, Hofer, & Schwaninger (2006b) found that the visual aptitudes and abilities needed for coping with image-based factors such as viewpoint, superposition by other objects and bag complexity did not increase very much as a result of training. This result was predicted and demonstrates the importance of using reliable and valid tests such as the X-Ray ORT as part of a pre-employment assessment system. The previous two sections have shown why recurrent CBT with a large multiple views library is essential in order to increase detection performance of screeners. Although TIP is not a very effective training tool, it is a great instrument to increase and maintain motivation and alertness of screeners. As explained above it is essential to use a large image library with thousands instead of hundreds of FTIs. Otherwise the benefits of TIP are eliminated after several months and screeners lose the attention and imagination needed for detecting real threat objects.

As mentioned earlier, another factor, which is still often neglected, is the fact that humans often fail to react appropriately if something happens that they do not expect. It is very important to conduct frequent practical tests so that screeners become used to reacting appropriately if they encounter real threat items during the screening operation. In order to achieve

good results in covert tests these different factors need to be taken into account. Last but not least, a properly developed and maintained system of supervision and quality control is necessary to coordinate all performance improvement efforts.

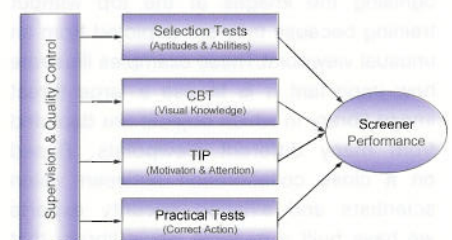


Figure 7: Determinants of screener performance.

### 3rd Generation TIP: Combining the benefits of TIP with effective CBT

Figure 8 shows the architecture of a 3rd generation TIP system (3i-TIP) which combines the benefits of TIP and CBT for increasing screener performance (Schwaninger, 2004a). A large image library of 20,000 images is used in which hundreds of different types of threat objects are depicted from many different viewpoints (the library can currently be upgraded to 50,000 FTIs). The 3i-TIP system uses a dual-mode. In the adaptive mode, each screener starts with FTIs shown in easy viewpoints. View difficulty is then increased based on individual TIP performance. The goal of the adaptive mode is to keep TIP challenging every day in order to increase and maintain screener motivation and alertness. In testing mode every screener sees the same FTIs in a different order, which provides the basis for reliable individual competency assessment if data is aggregated over several months (Hofer & Schwaninger, 2005). TIP data can be analysed off-line with TIP DataVis. With this user-friendly software, reports and



graphics can be created to analyse detection performance for risk assessment, quality control and individual screener competency assessment purposes. Missed FTIs are sent via the network to the 3i-TIP server which uses image processing to analyse image difficulty resulting from viewpoint difficulty, superimposition and bag complexity. The images are then sent to the CBT system for missed images review.

This means that at the beginning of a CBT training session a screener is first exposed to the TIP images that were missed while working at the checkpoint. This provides specific remedial training based on individual TIP data. In addition, the individually adaptive algorithms of X-Ray Tutor provide efficient training tailored to each individual screener. During a training session a screener is exposed to about 400 X-ray images where


about half of them contain threat items. This results in very efficient and effective CBT. Thus, 3rd generation TIP technology combines the benefits of TIP (motivation and alertness) and adaptive CBT (effective and efficient training). It thereby provides a solid basis for increasing performance of screeners. However, as mentioned above, it is also essential to conduct practical tests frequently so that screeners learn to react appropriately when they are exposed to real threats at the checkpoint.

In summary, several factors need to be considered in combination in order to achieve good results at covert tests: reliable and valid selection tests as part of the pre-employment assessment, 3rd generation TIP in combination with adaptive CBT using a large multiple views library, and frequent practical tests.

The author has been lecturing at the University of Zurich and at the Federal Institute of Technology (ETH) in Zurich since 1999. He is a member of the ECAC Training Task Force, the moderator of the ECAC TIP Study Group, and the Chairman of the InterTAG ad hoc Working Group on Competency Assessment (InterTAG CAWG).

### References

All cited publications can be downloaded at [www.psychologie.unizh.ch/vicoreg](http://www.psychologie.unizh.ch/vicoreg)

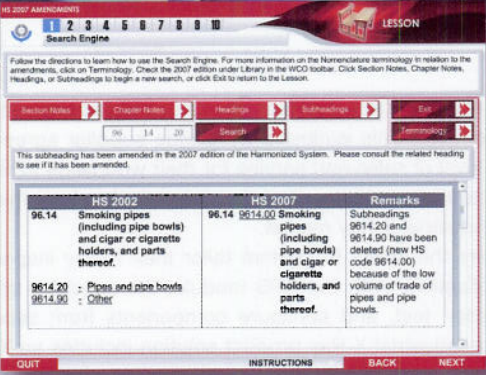


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