Threat Image Projection – An Overview

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1 Introduction

This report presents an overview of Threat Image Projection (TIP). TIP is a means to randomly insert threat images into passenger bags as they pass through airport checkpoints. It is then the responsibility of the screener to identify the potential threat and take the appropriate actions [Gal03]. When a screener hits the button to stop the suspect bag, TIP flashes a “congratulations” for detecting the threat and records the screener’s performance. It also records missed threat images.

TIP not only will help train screeners and keep them more alert, but also will allow companies to monitor each screener’s performance. Those who need retraining in detecting specific items can be removed and retrained, while those who have general difficulty in detecting threat images could be shifted to other responsibilities, such as operating hand wands or trace detectors. It also will give the FAA objective data for measuring the screening companies’ performance. Under a proposed rule expected to become final next year, companies could lose FAA certification if their screeners don’t meet performance standards [Dot00].

Previous technology only used X-ray systems to scan carry-on baggage and other items as travelers and their companions moved through checkpoints into secure areas. TIP will add a training function that FAA officials hope will increase screeners’ diligence by inserting fictional threats throughout the duty cycle and keeping a record of responses. Travelers won’t notice much difference between the new systems and the X-ray systems they have become accustomed to pushing their bags through. A conveyer belt moves the bags through the same metal scanning device that captures X-ray images and displays them on a monitor just as it always has [Gcn00]. A typical TIP console and resulting image are shown in Figure 1.

The following sections of this report cover many aspects of TIP, such as background, how does it work, how and for what can it be used, testing and evaluation, availability, etc.

![Figure 1. (a) TIP system inserts an image of a gun, (b) superimposed ghost image of an explosive near the suitcase’s top edge [Gcn00].](image)

2 Background

This section will provide a brief background or history of TIP development and evolution.
Originally, during the training of aviation security personnel, the instructors at the training center manually produced X-ray images for interpretation. This required much time and resources and resulted in higher training costs. Classroom-based training and testing is not an optimum or even reliable method of training and/or certifying the operators of X-ray inspection systems. In response to this situation, computer-based training was developed as an alternative. This involved pre-scanning a large number of items and storing the resultant X-ray images in a computer library. However, in recent years, a more sophisticated system (TIP) has been introduced. TIP now allows instructors to construct their own X-ray images from a library of pre-scanned images. Therefore, the trainee operators are exposed to a broader range of X-ray images, which may contain unusual threat items or items which are placed in unusual positions [Yon01].

The history of TIP begins in 1996. The Federal Aviation Reauthorization Act of 1996 directed FAA to certify screening companies and improve screener performance. FAA was prepared to issue its final rule on the Certification of Screening Companies during the week of September 10, 2001. However, following the terrorist attacks of September 11th, publication of the final rule was delayed to allow reevaluation of the certification requirements [Sub03].

In 1997, the White House Commission on Aviation Safety and Security issued 57 recommendations, the majority of which focused on improving aviation security. Most importantly, the Commission acknowledged that aviation security was a national issue that required a national focus and reliable funding. In the area of security technology, it was recommended that FAA deploy existing security technologies, establish standards for developing technologies, and work with other government agencies and industry to develop new technologies [Gar01].

2.1 Early Implementations

Initial TIP technology implementations were limited to simply blending X-ray images of threats into the stream of baggage images. If the operator detected the threat and activated the appropriate control, the threat object was erased and feedback was provided to the operator indicating that he or she had successfully detected the threat. However, such TIP implementations never adequately worked in the field.

For example, TIP technology could not be efficiently used at actual checkpoints because the images generated by the TIP technology for training purposes would generally be indistinguishable from true threats. Where the TIP technology was set up to be automatic, i.e., without input to help distinguish between test and true threats, operators often reacted to test threats as though a true threat actually existed. For example, an operator's detecting a test threat image representing a bomb has resulted in that operator calling a bomb squad. These types of events resulted in large costs, delays and inconvenience. Where human supervisors were used to overcome problems associated with automatic testing, the testing method still proved to be cumbersome and ineffective due to cost, logistical problems and potential coaching of the operator by the supervisor.
More recently (2002), a TIP process was developed that was somewhat more successful to a limited degree. This more recent process: 1) employed automatic testing, 2) avoided the above-mentioned costs and delays by providing sufficient feedback to the operator to avoid the situation where a test threat was treated as a true threat and 3) recorded individual operator performance in detecting threats so as to track performance over extended periods [PatApp03].

2.2 Initial Tip Deployment

In 1999, the FAA purchased 30 TIP Ready X-Ray (TRX) systems for evaluation in the field. The FAA began to purchase TRX systems in large numbers for deployment at Category X and Category 1 airports (i.e., the airports with the highest security risk) in the summer of 2000.

In July of 2000, the FAA announced three contracts worth a total of up to $120 million to Rapiscan, PerkinElmer, and Heimann Systems of Pine Brook, N.J., that would allow the agency to purchase up to 800 TIP-installed X-ray machines (at a price of $40,000 to $50,000 per unit, the cost for upgrading all airport security scanning systems could run as high as $80 million) from each vendor. While a small airport might need only one unit; a large airport such as JFK International in New York might install as many as 40. The agency had already purchased and begun installing 476 TIP-installed X-rays at airport security checkpoints. Over the next three years, the FAA expected to replace every X-ray machine at every airport in the country with new TIP-installed X-ray machines, for a total of more than 1,200 units at 454 airports [Ihs00]. By October of 2001, 691 of these units had been deployed to 71 U.S. airports for checkpoint usage [Gar01].

Currently, there are 703 TRX systems installed at U.S. airports. More than half of these 703 units, including those at 15 of the 20 Category X airports, have the TIP feature activated. Within the next month or so, the FAA expects to finish activating the TIP feature on all units at Category X airports, which will bring the number of TIP-activated units to 475. According to the FAA, the time lag between purchase of the TRX systems and activation of the TIP feature was caused by the time FAA took to develop standardized TIP training. The FAA began providing standardized training at Category X airports in April 2001. Prior to development of the standardized training course, each vendor supplied its own training course, which resulted in non-uniform training of uneven quality [Sub03].

2.3 Initial Tip Manufacturers and Requirements

The FAA initially approved PerkinElmer of Boston, Rapiscan Computer Products Inc. of Hawthorne, Calif., and Heimann Systems Corp., a German company with American offices in Pine Brook, N.J., to provide TIP systems. For the initial test of TIP, FAA in the summer of 1999, signed agreements to lease 10 units from each vendor and bought those systems. The Heimann contract was for $76,550, PerkinElmer’s $47,750 and Rapiscan’s $98,330.

PerkinElmer and Rapiscan began developing the TIP library of images under a cooperative R&D agreement with FAA’s Human Factors Research Lab in Atlantic City, N.J. The agency
issued a list of specifications for the proposed system. Heimann joined the effort later. Other
companies could qualify to supply TIP systems with FAA’s approval.

Much of TIP’s design was left to the companies. But to be included on the TIP qualified-
vendor list, vendors had to meet a set of minimum requirements:

- The custom TIP software must contain at least 350 X-ray images in specified categories of
  threats defined by the FAA.

- To host the TIP library of images, each system must have at least a 2.1GB hard drive that
  can be expanded.

- The system must allow the addition of new images via scanning, through electronic upload
  from a zip drive or via a network link.

- The system must support report generation in a Microsoft Excel or Excel-compatible format.

- Files must be downloadable to floppy disks or zip cartridges with the capacity to store a
  month’s worth of data.

- Airport users must have read-only access privileges to data, and the units must be
  password-protected.

All three vendors supplied systems that used Pentium PCs for the screening terminals.
PerkinElmer and Rapiscan planned to use off-the-shelf PCs from a variety of makers.
The PerkinElmer systems ran TIP under Microsoft Windows 95, Rapiscan under Windows
NT. Heimann supplied 600-MHz Pentium III PCs designed in its German laboratory running
Linux to host TIP.

User responses were stored and downloaded every three months to a zip disk. FAA
uploaded the data to a Microsoft Access 97 database. Eventually, FAA wants to create a network link
between the TIP units at the airports and an agency data center to handle the data transfers.
If a screener fails to identify a projected threat image, the program stops the system’s
conveyor belt and sends a message to the user. “You have not identified a fictional threat,”
the program notifies the security worker and then directs the user to search the bag.

The original threat image library contained nearly 2,400 images of items such as guns, knives
and bombs that security teams are trained to watch for. Lyle Malotky, FAA’s chief scientific
and technical adviser for civil aviation security, said that although the concept of threat
imaging was conceived roughly a decade ago, only recently have PCs had the crunching
power to make the system a reality [Gcn00].

2.4 Summary of Tip Status to Date

This subsection provides a tabular summary of the TIP development path to date:
• Funded development project by the FAA as part of the original SPEARS initiative.
• The overall scope was to establish a method to measure screener performance and efficiency as a component of an overall process to establish a screener certification program.
• The development was over two years.
• FAA paid for a survey of the existing installed base to assist in the development of a baseline for funding. Due to the various generations of electronic platforms the funding varied dependent on the age of the system.
• TIP was Alpha tested at the FAA Technical Center - passed.
• TIP was Beta tested at Atlantic City International Airport, Atlantic City - passed.
• TIP is in the initial deployment phase at major airports throughout the USA [Ame03].

3 Tip Technology – How Does It Work

While TIP operation is fairly simple the technology employed to gain this operation is not. This section provides an expanded view of the technology involved.

3.1 Binocular Stereoscopic X-Ray Systems

Since the power of the TIP techniques relies upon the seamless integration of the ‘live’ host image and the fictional threat image some background information on the automatic extraction of 3D information from binocular stereoscopic X-ray images is appropriate before proceeding. In order to position the threat image correctly with respect to the host image in 3D image space requires that the position of the salient object structure in the host image be determined.

The layout of a typical dual-energy stereoscopic line-scan imaging system is shown in Figure 2. This system utilizes a single X-ray source and a pair of dual-energy folded array X-ray detectors to produce a binocular stereoscopic X-ray image pair. The dual energy approach is being utilized to provide materials discrimination. The “high” and “low” energy signals obtained from the X-ray sensors are then employed to determine the basic organic, inorganic or metal discrimination. The resultant material discrimination information is provided to the screener by color encoding the resultant images.

In order to extract positional information from the stereoscopic pair images requires an automatic matching algorithm which is used to compute 3D spatial information. The matching algorithm flowchart is shown in Figure 3. The removal of noise is applied to ease progress of matching conjugate image features and is accomplished be implementing a 3x3 median filter template. Edge detection is applied to each of the resultant perspective images. The detected edge points are linked such that each object can be represented by a ‘corresponding link’ during matching. The details of this procedure are indicated in Figure 4.
3.2 Description of Basic Tip System Elements

Figure 5 shows a perspective view of a typical X-ray scanning system (10) that includes a housing (12) containing a screening section (14) through which objects to be screened are passed. Screening section (14) may generally comprise a tunnel through which objects pass, and may include an active area where objects are X-rayed and tunnel-like extensions on either side of the active area. The tunnel may reflect different cross-sectional shapes.

The housing (12) preferably includes a flat base section (16) so that the system may readily rest on a flat surface. A video monitor (18) for displaying X-ray images of objects located inside the screening section, and for displaying electronically inserted threat item images (TIP), may be attached to a top section (20) of the housing. The system preferably includes a conveyor (22) for transporting objects through the screening section. An information input
device or means, shown in this embodiment as a keyboard (24), is attached to a front section (26) of the housing. The input means (24) allows an operator to log onto and off of the system, to control the conveyor, to indicate when the operator believes that a threat item image appears on the monitor and/or to perform various other functions.

![Flowchart](image)

**Figure 4.** Flowchart for matching and extraction of 3D information [Yon01].

![Perspective View](image)

**Figure 5.** Perspective view of a typical X-ray scanning system [Pat03].

## 3.3 Tip Technology

Figure 6 provides a generalized view of the components of an airport screening system utilizing TIP. The screening system (102) is equipped with TIP technology (112) so that
images of various prohibited items may be electronically inserted into the normal ongoing stream of non-threat images, e.g., passenger baggage, of objects viewed on monitor (104). The non-threat images may be images of actual objects, or alternatively, may be electronically generated images. Thus, an operator may be trained on the screening system without having to use any real objects. In this figure, TIP technology is simply shown as a box within the screening system, but one should be aware that suitable software and electronics are also associated with TIP technology.

**Figure 6.** Schematic view of X-ray scanning system [Pat03].

The screening system preferably also includes a database (114) to store general information associated with TIP technology. The screening system also preferably includes a data transmission means (116) to transmit operator performance data (and other data) for data collection and reporting purposes. Also included is a TIP library (118) that may contain images of various prohibited items such as guns, bombs, knives, etc. The TIP library contains a database defining the threat types (i.e., defined as a gun, bomb, etc.) and the difficulty associated with detecting each type of threat or each image orientation. For example, certain types of weapons such as Improvised Explosive Devices (IDEs) are generally considered more difficult to detect than weapons such as handguns and will thus have a higher difficulty rating. The TIP library may also contain images of what may be thought of as ordinary items, but in reality may be used as weapons, e.g., box cutters, personal knives, blades for shaving, etc.

The difficulty associated with detecting a given threat may also depend on is its orientation or angle of view as projected on the monitor. For example, a handgun is generally considered more difficult to detect when viewed from behind, wherein it may appear to be a simple rectangular piece of metal, as opposed to when viewed from the side, wherein the well known shape of a handgun is more readily apparent. The TIP library should also contain a sufficient number of different certification images to prevent memorization by the operator, which would skew any testing or certification effort. It is also suggested that the certification
images contained in the TIP library be kept secret or otherwise confidential in order to prevent operator cheating. To this end, the certification images stored in the TIP library may be changed from time to time to maintain the integrity of the certification process.

The images contained in the TIP library for certification purposes should preferably be approved and regulated by the appropriate certifying body such as the FAA/TSA. In this manner, the system may provide a uniform certification process for system operators. The images are also preferably graded according to difficulty of detection. For example, the FAA/TSA currently recognizes various threat classes and each class is generally associated with a certain difficulty level. It is contemplated that an operator would need to be able to sufficiently detect images from each level of difficulty in order to become certified.

The database in the TIP library should also define the type of images that the TIP capability will provide for viewing by the operator. To this end, images may generally be classified as certification images or training images. Certification images are generally those images used during a certification testing procedure, a given percentage of which an operator must detect to become certified or retain certification. Training images may be similar to certification images in appearance, and are generally used to train operators to detect various threats. However, training images may differ from certification images in that they portray images of different threat objects or images of the same threat object but viewed at a different angle or orientation. Certification images and training images may be kept separately in different libraries. To this end, the TIP library may contain multiple sub-libraries in which the respective types of images are separately contained. Alternatively, two separate TIP libraries may be maintained for this purpose. Maintaining the training and certification images separately allows a training period or certification period to be more readily set up [Pat03].

The actual hardware involved in a TIP upgrade to an X-ray scanner typically incorporates a state of the art Pentium PC that is embedded inside of the machine as shown schematically in Figure 7. The scanner and the Pentium PC communicate via the SCSI and CAN buses. Other functionalities:

- PC contains the threat image library.
- The PC also projects the threats.
- The PC also contains the screener performance databases.
- The projected threat is combined with the actual image information from the DTP board by the TIP program running on the Pentium PC.
- The image information with the projected threat is transmitted to the scanner system via the SCSI data bus.
- The image, with the projected threat, is then displayed by the HIP board.
- Synchronization of the projected threat and the bag image information is accomplished by the CAN bus interface.

### 3.4 Tip Operation

A flow diagram of basic TIP operation (including the certification process) is shown in Figure 8. The operator of the X-ray system does not notice the projection process. During
this procedure the full range of image enhancement functions to support the evaluation process is still available. Even automated operator support functions can be used in combination with TIP. The task of the operator is to detect and mark dangerous or suspect objects.

![TIP upgrade diagram](image)

**Figure 7.** TIP upgrade diagram [Ame03].

![TIP operational flow diagram](image)

**Figure 8.** TIP operational flow diagram [Pat03].

If a suspect object has been detected and marked by the operator, the conveyor is stopped automatically. The fictional threat object is now displayed with a black/yellow frame and a message “You have correctly identified a fictional BOMB threat! Check the bag to make sure
there are no real threats!” displayed as shown in Figure 9. The fictional object then disappears from the screen before further evaluation of the real baggage.

Figure 9. Typical TIP display on monitor [Smi03].

If the operator has missed an object projected on the image, the conveyor will be stopped and a message will be displayed on the screen. The real X-ray images together with the missed threat objects are automatically stored and can be recalled.

Tip interfaces with the user at four different levels as summarized in Table 1. The TIP system provides a library divided into categories and subcategories containing combined, complete threat images and images of individual threat objects. The supervisor can add, edit and delete categories.

Table 1. Summary of TIP access levels [Ame03].

<table>
<thead>
<tr>
<th>Group Level 1</th>
<th>Group Level 2</th>
<th>Group Level 3</th>
<th>Group Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator</td>
<td>Group Level 2</td>
<td>Group Level 3</td>
<td>Group Level 4</td>
</tr>
<tr>
<td>(screener)</td>
<td>Checkpoint supervisor (CSS)</td>
<td>Site manager (airline/guard firm)</td>
<td>FAA representative</td>
</tr>
<tr>
<td>• Allows x-ray mode operation</td>
<td>• Allows viewing of reports</td>
<td>• Allows viewing and downloading of reports, User administration for groups 1,2, and 3</td>
<td>• Scheduling threats for operator training</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Moreover, users with supervisor access level can specify:
  • from which categories and at which percentage in proportion to the other categories combined threat images and single threat objects are projected during the normal operational flow
• which images from a category are to be projected
• which decision times are provided for the operator to detect a threat image
• how many projections are made randomly rather than within the diversification range
• in what time the operator should detect a threat image
• the number of projections compared with the number of real bags
• the ratio between fictional projection and number of real bags.

A configuration menu similar to that shown in Figure 10 is used for setting these parameters as well as others of pertinence. From reports assigned to individual users, higher level users can read how many times projected objects and images have been detected and how many of them have been missed. Conclusions on the efficiency of the security checks of the different operators/user and the different workload can be drawn. Figure 11 displays a typical TIP report screen as used by Heimann Systems [Smi03].

Figure 10. Configuration main menu [Smi03].

Figure 11. Example TIP report [Smi03].

4 Operator Certification and Training

In response to a mandate in the Federal Aviation Reauthorization Act of 1996 and a recommendation from the 1997 White House Commission on Aviation Safety and Security,
FAA is creating a program to certify the security companies that staff the screening checkpoints. The agency plans to establish performance standards that the screening companies will have to meet in order to earn and retain certification. It will also require that all screeners pass automated readiness tests after training and that all air carriers have TIP units on the X-ray machines at their checkpoints so that screeners' performance can be measured to ensure FAA's standards are met. The FAA believes that the need to meet certification standards will give the security companies a greater incentive to retain their best screeners longer and so will indirectly reduce turnover by raising the screeners' wages and improving training.

The agency plans to use data from the TIP system to guide it in setting its performance standards, but because the system will not be at all airports before the end of fiscal year 2003, the agency is having to explore additional ways to set standards. FAA planned to issue the regulation establishing the certification program by May 2001, over 2 years later than its original deadline. According to the FAA, it has needed more time to develop performance standards and to develop and process a very complex regulation. The first certification of screening companies was expected to take place in 2002 [Dil00].

Specifics of actual screener training and certification using TIP are detailed in the following paragraphs. The parameters of a given training or certification period (referred to generally as a testing period) are preferably set by an authorized user, such as a manager of a scanning company or an appropriate certification authority. These parameters are generally referred to as test scripts, because they "script" a test that will be administered to one or more scanner operators. In a preferred scenario, standardized test scripts may be used across the security industry, or segments thereof.

In order to set the test scripts for a given testing period, an authorized user logs onto the system and enters an ID and password provided by the appropriate authorities. After the authorized user logs on, a menu appears, such as the on-screen menu shown in Figure 12, from which the user may select a desired operation, which, in the case of setting test scripts, may be a “TIP Configuration” operation (190). Other operations may include system maintenance (191), importing/exporting databases (192), uploading new TIP images (193), downloading TIP reports (194), viewing TIP reports (195), viewing access reports (196), and any other suitable operations. A “log out” option (197) is also included on the menu. Once the “TIP Configuration” operation is chosen, the authorized user can take the following steps to set the test scripts for a given testing period.

First, a period unit of “DAY” or “MONTH” may be chosen, from a drop-down list appearing on the video monitor. Next, a period length may be chosen, preferably from a drop-down list, or by entering a number corresponding to the desired period length via the keyboard. The period length is generally the length of time that the testing period will run. In a preferred embodiment, an option to repeat the test may be given. A pass percentage, which indicates the test score that an operator must achieve to obtain certification as a scanner operator is also set. Additionally, a description including any information relevant to a particular test may optionally be entered.
The library containing certification images may also contain information pertaining to the detail of, or difficulty level in identifying, each certification image. The library containing training images may generally contain more images to allow operator training with a variety of images on which to gain experience. A certification image list for a given test, or set of tests, may be created or "scripted" by selecting threat item images from a general source threat list and moving or dragging the selected items to the certification image list. In a similar manner, threat items may be removed from the certification image list and placed back into the general source threat list. Once the test scripts for a given test, or set of tests, are established, the user may save the test scripts in the system memory by clicking on a "Save Test" icon displayed on the video monitor. Training images may be used during a certification test, i.e., they may be randomly merged into the stream of baggage images, to keep operators alert and prevent them from memorizing which images are certification images.

The screening system also includes an operator performance database (OPD) (120 of Figure 6). The OPD contains comprehensive records of test results and performance data for each individual operator. Information that may be stored includes the date and time of each test, the type of image (along with its difficulty) presented to the operator, and the operator's test results, including whether the operator achieved a score at or above the specified pass percentage. To this end, information regarding the operator's detections, non-detections, and false alarms, as well as the amount of time an operator spent evaluating a particular image(s), may also be stored in the OPD. Where applicable, the system may also serve to promote an operator to a higher level of certification by virtue of the information in the OPD.

The screening system also includes a certification criteria database (CCD) (122 of Figure 6) which may generally contain and set forth requirements for operator certification. To this end, the CCD may set forth different sets of requirements that are required to obtain different types of certification. As such, the CCD may specify the number of images, types of images
and levels of difficulty of images that must be successfully detected by an operator during a certification test. This database may specify the length of time over which a certification test is to be conducted or the maximum time allowed for an operator to complete a certification test and may set forth the frequency of testing necessary to maintain certification. The CCD may also specify the criteria for determining whether an operator's performance constitutes an acceptable/certifiable performance (success criteria). The criteria contained in the CCD may also be changed over time to reflect changes in desired certification requirements. For example, should a new type of weapon come into being, the certification criteria stored in the CCD may be revised to include that image as part of the images to be seen by operators during the certification process. In this situation, the TIP library (118) may also be updated to include this new type of image as a training and/or certification image.

The screening system also includes software (130) that accesses information contained in the various databases described above and that analyzes operator performance during testing and certification. More particularly, the certification software may access information in the various databases, receive and record information about operator performance, analyze operator performance and provide reports thereon. To accomplish these objectives, the certification software may perform various functions. For example, the software may control which images are presented to the operator from the TIP library. This may be accomplished via the test scripts input by a user or through a random selection of images. Other functions controlled by this software package may include: control of timing of images presented to the operator, ensuring an appropriate number of certification images are shown to the operator, recording correct/incorrect detection of images, and providing a reporting function on operator performance [Pat03]. Figure 13 provides a detailed flow diagram of the TIP screener certification process.

5  Field Testing of TIP-related Technology

The section summarizes two field tests associated with TIP technology which were planned.

5.1 Threat Detection of Explosives at Different Subcertification Weights

This project involved the field evaluation for threat detection in X-ray images of bags containing explosives at full and subcertification weights. Human Factors Engineers (HFEs) were to administer a test containing a government-supplied set of X-ray images of bags on emulators provided by Rapiscan Security Products. A total of 140 screeners from five airports participated in this evaluation. Analyses focused on screener detection of explosives below full certification weight.

The FAA has established standardized weights for different explosive materials. These weights are used for certification of explosive detection systems. Currently, TIP contains only full certification weight explosives. A previous evaluation of screener performance in detecting explosives at full and subcertification weights was inconclusive. This project was a
re-evaluation of explosive detection for X-ray images containing full and subcertification weights.

**Figure 13.** TIP certification process [Pat03].

The specific purpose of this project was to perform a field evaluation to test the hypothesis that screeners will adequately detect explosives below full certification weight. This evaluation involved comparing threat detection performance with X-ray images of explosives below certification weight and those at full certification weight. The evaluation was accomplished using a government-supplied set of X-ray images of bags that run on emulators. The images included .25, .50, .75, and 1.0 of full weight explosives.

Five groups of 28 screeners, each group at five different airport sites, Atlanta Hartsfield, Detroit Metropolitan Wayne County, Newark, Reno-Tahoe, and Seattle-Tacoma International Airports were utilized for data collection. Each screener judged a set of X-ray images of innocent bags and bag threats (IEDs). The Rapiscan emulators recorded the bag
number of every bag and screeners’ responses. HFEs supervised test administration and downloaded data collected. Following data collection, the data from this study was incorporated into a database developed in Microsoft Access.

The data was then imported into SPSS to complete relevant statistical tests. The analysis allowed the HFEs to produce tables of Probability of Detection, Probability of False Alarm, Sensitivity, and Bias for the each explosive types and each IED configuration presented at each full and subcertification weight. The analysis determine whether any of the measures are significantly affected by certification weight or explosive type. The data reports consisted of these tables and supplementary statistical tables derived from SPSS output [Klo01]. This report was to be “delivered” on 10/16/01 but its present status is unknown.

### 5.2 X-ray Image Screener Selection Test

In this field test the plan was to develop and evaluate an X-ray Image Screener Selection Test (XISST). The XISST was a computer-based job sample selection test, which predicted the effectiveness of X-ray screeners. The selection test, which involved searching for common objects in X-ray images, was tested for usability before being fielded. The field test took place at two airports. HFEs administered the XISST to at least 50 security screeners from these airports who had at least 2 months of TIP experience. The goal of this evaluation was to determine the reliability of the XISST and its validity as a predictor of screener TIP performance.

One specific stated purpose of the XISST was to predict the future threat-detection performance of newly hired X-ray operators. The XISST consisted of multiple test items. The test items were X-ray images of common objects stored in baggage with other non-target articles. The task was to determine if target objects (e.g., tools, guns, or flashlights) were present in each bag. The test measured both speed and accuracy of search performance. A field test of the XISST was conducted using 50 screeners at Seattle-Tacoma International Airport and Reno/Tahoe International Airport. The XISST data was be compared to TIP data to determine the validity of the test as a predictor of X-ray screening performance. The psychometric properties of the test, including reliability, were also determined from the field data.

The XISST is a computer-based test with on-screen instructions, sample items, and keyboard responses for all items. It automatically records accuracy and speed of responses. The creation of the XISST required developing 180 images from 10 basic level categories. A total of 18 Combined Threat Images (CTIs) per search category were created: 6 containing a search target (e.g., gun) and 12 containing no targets. Half of all CTIs contain high clutter and half contain moderate clutter. Table 2 outlines this design. None of the 10 categories should appear as clutter in any of the CTIs.

The X-ray image sets were created at the FAA Aviation Security Laboratory with Rapiscan X-ray machines installed with the TIP system. The FAA provided the test bags to be used. Screener Readiness Test software was adapted so that it could be used for the XISST image
sets. HFEs created instruction pages and a set of data collection requirements that the software engineers integrated into the product.

**Table 2. XISST design [Rub01].**

<table>
<thead>
<tr>
<th>Category</th>
<th>Target CTIs</th>
<th>Non-Target CTIs</th>
<th>Total Per Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moderate Ch</td>
<td>High Clutter</td>
<td>Moderate Ch</td>
</tr>
<tr>
<td>Guns</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Pens</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Shoes</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Key Chains</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Tools</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Cell Phones</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Flashlights</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Watches</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Kitchen Utensils</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Knives</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>30</td>
<td>60</td>
</tr>
</tbody>
</table>

Each screener completed the XISST, which consisted of 10 basic level search categories (TIP X-ray images) containing target images for which the screener was asked to respond with a “Yes” (they see the target) or a “No” (they do not see the target). All answers were entered via the keyboard and each screener had 15 seconds per image to respond. A PC recorded the screeners’ answers, as well as their response latencies. Arrangements were made to download TIP data from both sites. These data were used to analyze test validity.

Data elicited from the XISST were incorporated into an annotated Access database for analyzing, archiving, and reporting. The goal of the data analyses was to determine the validity of the XISST by comparing screeners’ XISST scores to TIP performance. Validity was examined by looking at correlations of XISST scores (e.g., speed or accuracy) with TIP performance measures. An important question was whether speed, accuracy, or some derivation of both is the best predictor of performance. The predictive validity of different search categories was independently evaluated.

Reliability was examined by using standard measures of inter-item consistency. Item analyses looked at item difficulty, item-test correlations, and scoring distributions. Items that had deficient psychometric properties may be candidates for elimination in a revised test. If the demographic distributions of screeners permitted such, HFEs also intended to look for adverse impact of the test and test items on any demographic group. This is the first step in any study of item bias. Based upon these analyses, the quality of the current XISST as a selection instrument can be determined, and any deficiencies in the test can be identified and corrected in a revised test, if necessary [Rub01]. At the present time, it is unknown if this planned study was conducted and, if so, what results were obtained.
6  TIP Manufactures and Distribution

Over the past several years a number of news releases have been made concerning purchase and placement of TIP-enabled scanners at various locations. On July 19, 2000, the FAA announced “three contracts worth a total of up to $120 million to Rapiscan Security Products of Hawthorne, Calif.; PerkinElmer Instruments of Long Beach, Calif.; and Heimann Systems of Pine Brook, N.J., that would allow the agency to purchase up to 800 TIP-installed X-rays machines from each vendor. The agency initially is purchasing 11 units from each vendor for testing and to refine data collection methods. Over the next three years, the FAA expected to replace X-ray machines at every airport security checkpoint in the country with new TIP-installed X-rays, for a total of more than 1,200 units” [Dot00].

On September 12, 2002, Rapiscan Security Products, Inc., announced that “the Department of Transportation has purchased additional Tip Ready X-ray (TRX) Systems from Rapiscan in a contract valued at approximately $1.2 million. The purchase is part of a program funded by the U.S. Department of State to enhance aviation security worldwide”. This order followed a recently announced order of $2.7 million to the same customer, bringing the total procurement to approximately $4 million. Rapiscan expected to deliver the systems by the end of the second fiscal quarter ending December 31, 2002. The units purchased were 500 Series Advanced Imaging Systems. This follow-on procurement included scanners for carry-on baggage, checked baggage, and small cargo [Lex02].

On April 23, 2003, the Transportation Security Administration (TSA) ordered $ 7.3 million worth of certified carry-on baggage X-ray screening systems from Rapiscan Security Products of Hawthorne, Calif., the company said April 15th. Shipment of the systems, outfitted with TIP technology, designed to aid screeners in finding weapons or contraband, was expected to be completed by Sept. 30th [Lex03].

On April 29, 2003, Smiths Heimann (formerly Heimann Systems) was awarded a delivery order for the sale of more than 150 TRX systems equipped with TIP for checkpoint carry-on baggage. The delivery order, valued at approximately $7.5 million, was commissioned by the TSA [Lex03-2].

On August 6, 2003, Rapiscan Security Products, Inc. received a follow-on order for certified carry-on baggage X-ray screening systems outfitted with TIP valued at approximately $2 million from the TSA. This was in addition to the previous order for $7.3 million announced on April 23, 2003, as part of an ongoing TSA initiative to enhance checkpoint security at U.S. airports. Shipment of these systems began immediately and is scheduled to be completed by the end of fiscal second quarter ending December 31, 2003 [Lex03-3].

7  Future Direction and Conclusion

The latest software version of TIP was completed by the British firm, Image Scan Holding, plc (ISH) and delivered to TSA in March of 2003. Following the conclusion in June of the funded development program for the US market, their efforts concentrated on the
introduction of a UK certified system for use in Europe [Ish03]. They most recently reported that development of the EU version of 3D threat image projection ("3DTIP") was being developed with a view for introduction in Europe. This project is continuing and expected to be ready for EU type approval by the end of this calendar year. ISH expects a successful outcome which will ensure that the AXIS-3D® product will be TIP compliant in advance of anticipated EU and USA mandatory compliance [Ish03-2].

It is important to note that TIP was neither intended to be, nor is, a substitute for covert testing with realistic physical threat objects -- using innovative testing techniques. Although TIP is undergoing continued modification, including expansion of the threat image library, development of more sophisticated TIP images is needed. For example, images projected by TIP need to more closely depict what screeners may actually face (e.g., objects partially obscured by clutter in bags) [Dot02].

In conclusion, the major advantages of utilizing TIP technology in screener performance evaluation can be summarized as follows:

- Information in the database may be accessed by the airline and guard firm security managers for collection and generation of reports.
- Information in the database will also be accessed by FAA representatives who will generate and collect reports from each in the field throughout the USA.
- Those reports will be collected and analyzed at the FAA to assess the operators' individual and overall performance.
- TIP keeps the operators of scan machines alert in anticipation of detecting both real and projected threats.
- TIP exposes the screeners to threats that they would not normally see.
- TIP also maintains an image archive of missed projected threats for the screener to review [Ame03].

8 References


