DOT/FAA/CT-94/14

FAA Technical Center
Atlantic City International Airport
New Jersey, 08405

FAA Technical Center Enhanced Airport Security System Project

Image Processing (IP) System Contraband Assessment Effectiveness Test Report

Walter Wall
Edward Ocker

August 1994

Final Report

This document is on file at the Technical Center Library, Atlantic City International Airport, NJ 08405

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.

Technical Report Documentation Page

1. Report No. DOT/FAA/CT-94/14	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle FAA TECHNICAL CENTER ENHANCED AIRPORT SECURITY SYSTEM PROJECT: IMAGE PROCESSING (IP) SYSTEM CONTRABAND ASSESSMENT EFFECTIVENESS TEST REPORT		5. Report Date August 1994 6. Performing Organization Code ACA-400
7. Author(s) Walter Wall and Edward Ocker		8. Performing Organization Report No. A-2001001-94-U-10056
9. Performing Organization Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Aviation Security Research and Development Service Atlantic City International Airport, NJ 08405		10. Work Unit No. 11. Contract or Grant No. DTFA03-93-C-00042
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Assistant Administrator for Civil Aviation Security, ACS-1 Washington D.C. 20591		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code ACS-1

15. Supplementary Notes:
Report Prepared by: DCS, Inc. Robert Felbinger
2511 Fire Road, Suite A-5
Absecon, NJ 08201

16. Abstract

This report summarizes the results of Image Processing (IP) testing conducted at BWI. The purpose of these tests was to evaluate the effectiveness of the IP system in increasing the assessment capabilities of screeners. Testing was conducted in both the Automatic and Normal modes of operation. Data results were collected, compiled, analyzed, and recommendations were made. Testing conclusions are also presented in this report.

17. Key Words Airport Security, Image Processing, Contraband Detection, Linescan System 10, X-ray Image Scan Processing		18. Distribution Statement This document is on file at the Technical Center Library, Atlantic City International Airport, NJ 08405	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

EXECUTIVE SUMMARY vii

1. INTRODUCTION 1

1.1 OBJECTIVES 1
1.2 ORGANIZATION OF TESTS 1

2. TEST DESCRIPTION 2

2.1 METHODOLOGY/APPROACH 2
2.2 TEST CONFIGURATION 2
2.3 DATA COLLECTION/ANALYSIS METHOD 4
2.4 TEST RUNS/ARTICLES 7

3. RESULTS AND DISCUSSION 9

3.1 GENERAL 9
3.2 SECURITY EFFECTIVENESS RESULTS 10

3.2.1 Analysis Results 10
3.2.2 Detailed Test Results (Automatic Mode) 11

3.2.2.1 Detailed Discussion 11

3.2.3 Detailed Test Results (Normal Mode) 11

3.2.3.1 Detailed Discussion 12

3.3 OPERATIONAL TEST RESULTS 12

3.3.1 Equipment Performance/Guns (Automatic Mode) 12
3.3.2 Observations 13
3.3.3 Equipment Performance/Guns (Normal Mode) 13
3.3.4 Observations 13
3.3.5 Equipment Performance/Knife (Automatic Mode) 13
3.3.6 Observations 14
3.3.7 Equipment Performance/Knife (Normal Mode) 14
3.3.8 Observations 14

TABLE OF CONTENTS (Continued)

3.4 DISCUSSION. 14

3.4.1 General 14
3.4.2 Test Series 1 - Automatic Mode 15
3.4.3 Test Series 2 - Normal Mode 16
3.4.4 Screener Observations 16

4. CONCLUSIONS 19

5. RECOMMENDATIONS 20

6. REFERENCES 22

7. TABLES 23

APPENDIX A - TEST ARTICLE ORIENTATIONS A-1

APPENDIX B - TROUBLE REPORTS B-1

LIST OF ILLUSTRATIONS

Figure 1. Basic System Components and Interface 3

Figure 2. IP Data Collection Form 6

Figure 3. Examples of Test Article Positions/Locations 8

LIST OF TABLES

Table 1. Contraband Types/Orientations for Different Test Bags Both With and Without Clutter (Automatic Mode Operation) 24

Table 2. Contraband Types/Orientations for Different Test Bags Both With and Without Clutter (Normal Mode Operation) 26

Table 3. Image Processing Test Articles 34

Table 4. Automatic Mode of Operation, Test Article Assessments 35

Table 5. Normal Mode Operation, Test Article Assessments 36

Table 6. Automatic Mode Operation, Percentage of Successful Gun Assessments 37

Table 7. Normal Mode Operation, Percentage of Successful Gun Assessments 38

Table 8. Automatic Mode Operation, Percentage of Successful Knife-2, Test Article K, Assessments 39

Table 9. Normal Mode Operation Percentage of Successful Screener Knife-2, Test Article K, Assessments 40

LIST OF ACRONYMS AND ABBREVIATIONS

BWI	Baltimore-Washington International Airport
EASSP	Enhanced Airport Security System Project
FAA	Federal Aviation Administration
FAATC	Federal Aviation Administration Technical Center
IP	Image Processing
LTI	Lead Test Inspector
R&D	Research and Development
RF	Response Force
SOP	Standard Operating Procedure
S&W	Smith & Wesson
TM	Test Manager
TR	Trouble Report
XISPS	X-ray Image Scan Processing System

EXECUTIVE SUMMARY.

The Image Processing (IP) System Test Report has been prepared in support of the Federal Aviation Administration Technical Center (FAATC) Enhanced Airport Security System Project (EASSP). IP testing was performed at the Baltimore-Washington International Airport (BWI) to determine system effectiveness in enhancing IP contraband assessment capabilities in passenger carry-on baggage. An evaluation of scanner ability to assess/identify contraband placed in different style bags in various orientations was also made. Test results disclosed that certain test articles and/or orientations were more difficult to discern/identify than others. In both the Automatic and Normal modes of operation the basic IP algorithm performed as designed and expected; the system alarmed when required and conversely, did not alarm when it did not find contraband.

Although the IP system is in a primitive development stage, the test results support the conclusion that this concept is viable and warrants further development and investigation.

Details of two test series are discussed in the report. Automatic Mode operation and open screener evaluations in the Normal Mode were conducted using an x-ray image scan processing system (XISPS) and results tabulated for carry-on baggage of various sizes and shapes with contraband items in different orientations and positions and with and without clutter items enclosed.

Conclusions and recommendations are presented showing a definite trend toward IP as a useful contraband assessment tool and a valuable aid to screening personnel. Improvements in the IP software as well as an expanded database will help maintain IP system capabilities current with state-of-the-art technology.

1. INTRODUCTION. This report presents and discusses the results of the Image Processing (IP) subsystem effectiveness tests conducted at the pier B Enhanced Screening Point, Baltimore-Washington International Airport (BWI) during the period July through November 1993. The testing was accomplished in accordance with Section 4.2 of the Security Effectiveness Test Plan: Enhanced Airport Security System Project at BWI (Reference a.).

1.1 OBJECTIVES. The primary objective of the IP performance effectiveness tests was two-fold:

a. Determine the presence of an area in the passenger carry-on bag which could possibly be concealing contraband; and

b. Evaluate the overall effectiveness of the IP as an aid to screeners in assessing/identifying contraband items.

1.2 ORGANIZATION OF TESTS. The above objectives were addressed during two separate test series. During the first test series, the IP system was placed in the Automatic Mode of operation where the basic IP software algorithm was evaluated with no screener present and no human intervention. In the second test series, the system was operated in the Normal Mode where a trained screener was present and tasked with the responsibility of determining whether or not the contents of the carry-on bag contained possible contraband.

2. TEST DESCRIPTION.

2.1 METHODOLOGY/APPROACH. For the Automatic Mode of operation, (test series one (1)) four (4) different parameters were varied and randomly presented. These included ten (10) passenger carry-on bag types of different sizes and shapes, nine (9) different types of test articles, different test article orientations ranging from three (3) to twenty-four (24) depending upon the specific test article (see appendix A), and nine (9) different test article positions in the bag.

The second test series, open screener (meaning that the screeners were aware beforehand that some of the bags might contain contraband) evaluation in the Normal Mode, included a slightly different testing configuration. These tests utilized the same ten (10) passenger carry-on bags and, the same number of orientations and positions used in the Automatic Mode tests. However, the test article set was expanded from nine (9) to twelve (12).

The primary objective of the Automatic Mode was to determine whether the system alarmed when it was supposed to, and conversely, did not alarm when it was not supposed to (i.e it did or did not find an area in the bag that could possibly be hiding contraband). During all tests, the bags were run both with and without clutter. The test articles used included the six (6) original items comprising the FAA test article set, plus four (4) additional items including a Smith and Wesson (S&W) .38-caliber special revolver and a Glock 9mm automatic pistol.

The test article set did not include any of the explosive materials or test simulants originally listed in figure 4.2.1-3 of the Security Effectiveness Test Plan.

2.2 TEST CONFIGURATION. The overall equipment configuration for the IP system is depicted in figure 1. The current x-ray image scan processing system (XISPS) is a research and development (R&D) prototype installed at BWI. The system consists of the following components:

a. A personal computer with black and white display monitor;

b. An image processor;

c. An i860-based coprocessor;

d. A high resolution video display monitor with touchscreen;

e. An optical disk recorder;

f. A time base corrector;

g. A video distribution amplifier; and

h. An optical scan converter.

The XISPS components (figure 1) are grouped into three separate units for test purposes: 1) the processing unit, 2) the storage unit, and 3) the display unit. The processing unit is responsible for image acquisition, digitization and processing as well as database management functions. It includes a computer with display monitor, an image processor and a coprocessor. The display unit, which is comprised of a high resolution monitor with a touchscreen, a timebase corrector and video distribution amplifier, is used to augment the normal x-ray machine's color display monitor for image display, enhancement and assessment. The storage unit consists of an optical disk recorder normally used to record images for performance evaluation and training. The optical scan converter is used to convert high resolution video from the image processor so that it can be displayed on a regular video display monitor.

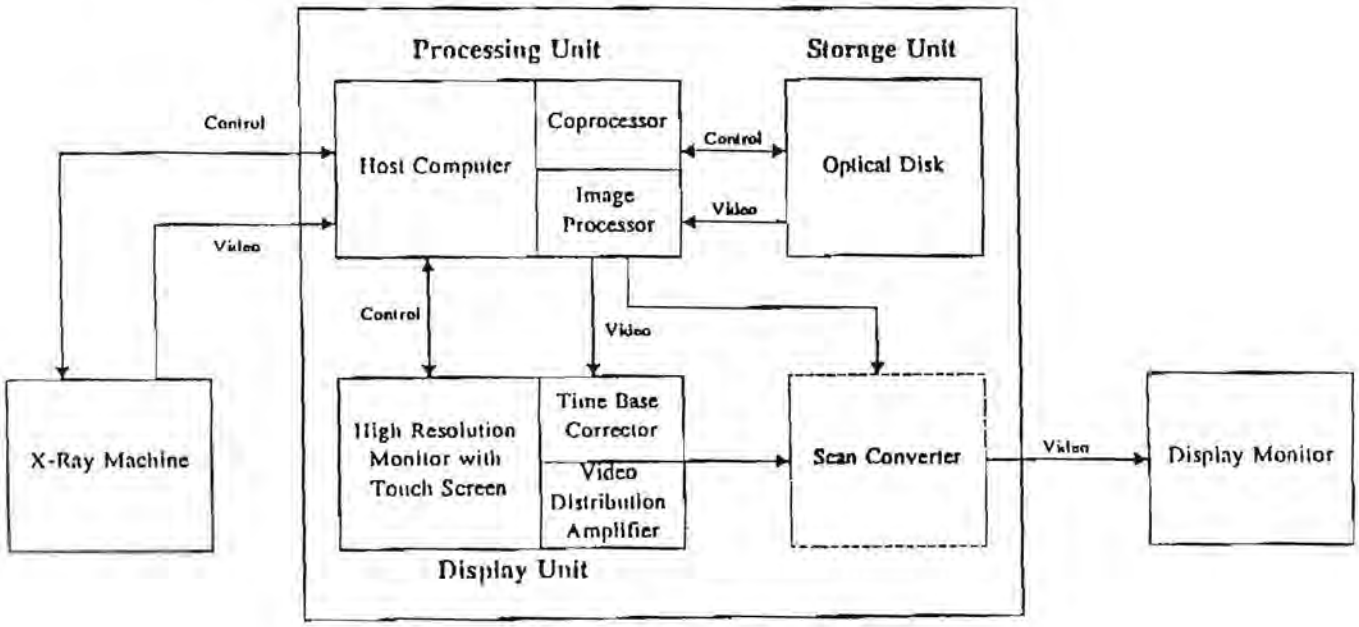


Figure 1. Basic System Components and Interface

The software algorithm includes startup and shutdown, system power off, error recovery and operation, supervisor, and database menus. The database menu is used to access and configure the IP system databases. The database menu requires the supervisor database hardware configuration to add data to the contraband database or view operator records. The contraband database includes contraband ID, file name, and description. Other menus include the Op Mode, Operator program (i.e. OPMENU) and Supr User Menu. A record menu which allows the supervisor to select the constraints for recording x-ray images to the optical disk was not used.

For this testing, the contraband database consisted of twenty-eight (28) files including seven (7) contraband items, each in four (4) different orientations, i.e. 0, 90, 180, and 270 degrees. The contraband items are:

a. A-12 encapsulated gun;
b. Simulated mini-gun;
c. Grenade (pineapple shaped);
d. Opaque circle;
e. Opaque rectangle;
f. Pipe bomb; and
g. Butterfly knife.

2.3 DATA COLLECTION/ANALYSIS METHOD. The basic approach used to prove the concept of the IP system was to place the bags containing the test articles, which were in different positions and orientations, on a conveyor belt feeding an E-scan x-ray machine and pass the bags, one by one, through the x-ray chamber. In the Automatic Mode of operation, each bag would automatically be stopped inside the chamber and be held there until processing had taken place, i.e., until the IP system either detected the presence of metallic material or clutter (found an area in the bag that could possibly be concealing contraband), or the bag was determined to be clean and the bag was allowed to pass through the x-ray chamber. Once processing had taken place, the "ASSESS," "ENHANCE," and "ZOOM" icons appeared on the touchscreen monitor. Touching the "ASSESS" icon started-up the conveyor belt causing the bag to move out of the x-ray chamber. Touching this same icon also acknowledged that the image processing had taken place. Unless the "STOP" icon was touched on the touchscreen monitor, the conveyor belt would start-up automatically after fifteen seconds had elapsed.

In the Normal Mode of operation, the screener indicated to the person doing the data recording, ie. Test Manager, if the bag needed to be analyzed, "handchecked" or that he/she could positively identify the test article. In analyzing the bag contents, the screener had the option of calling for the bag to be rerun in a different orientation. As each bag underwent processing, the screener observed images displayed on both the color monitor and the touchscreen monitor, which showed the results of the x-ray and image processing.

The primary difference between the Automatic Mode and the Normal Mode of operation was that in the latter mode the screener had to physically touch the "ANALYZE" icon on the touchscreen monitor display surface to stop the bag inside the x-ray chamber. In the Normal and Automatic Modes, touching the "START" icon on the touchscreen monitor caused the conveyor belt to start-up and move the bags one at a time into the test chamber. Each bag was required to be placed on the conveyor belt with the flattest, widest surface facing downward.

All IP testing at BWI was conducted at the pier B Enhanced Screening Point, x-ray lane 2. Tests were conducted during daily airport hours of operation (8:00 a.m. to 5:00 p.m.), but did not interfere with normal passenger traffic flow. The IP test team was comprised of two (2) people, with the addition of a screener, during testing in the Normal Mode of operation. One test team member, the Lead Test Inspector (LTI), was assigned to prepare bags for testing, i.e., placing, positioning, and orienting the test articles in the individual bags; loading them on the conveyor belt, one at a time, prior to the start of each run; and retrieving the bag at the completion of the run.

The second test team member, the Test Manager (TM), was responsible for directing each test coordinating overall problems, and recording results and comments on special data collection forms, which were prepared prior to the start of each test. The Data IP Collection Form, figure 2, provides instructions for randomly positioning and orienting test articles in the bags prior to the start of each run.

TEST SERIES: _____ RECORDER NAME: _____ PAGE NUMBER: _____

MODE: _____ SCREENER NAME: _____ DATE/TIME: _____

RUN NO.	BAG NO.	SEQ. NO.	CLUTTER		TEST ARTICLE			IP RESULTS		SCREENER RESULTS						NOTE
			Y	N	NO.	POSIT	ORIENT	MATCH	NO MATCH	ANAL	NO ANAL	INSP. BAG	NO INSP. BAG	RECOG IMAGE	NO IMAGE RECOG	

Figure 2. IP Data Collection Form

2.4 TEST RUNS/ARTICLES. Testing was started after setting-up, powering-up, initializing and checking-out the IP system hardware and software. Test bags were prepared with the particular test article by placing it in the bag in a specific position and orientation. The particular bag, position, and orientation varied with each run. Nine (9) different test article positions with up to twenty-four (24) different orientations were employed (refer to figure 3 and appendix A). It was difficult to test some test articles when placed in specific orientations in some bags due to the sheer size of the test article and the configuration of the test bag. For example, the depth of the leather briefcase did not easily accommodate the gun when placed in an orientation with the barrel/handle grip facing up or down relative to the operator. When using the narrow width briefcase/attache (test bag #1) certain test article orientations using the Glock 9mm automatic pistol were necessarily constrained.

Several different test articles were used in addition to the original FAA set contained in the IP database and listed on page 4. Table 3 lists test articles used in both Automatic and Normal Mode operation testing.

Ten (10) different test bags of varying sizes, types and shapes were used for testing in both the Automatic and Normal Modes of test operation.

Test Bag No.	Description
1	Briefcase/attache - mahogany leather
2	Tote bag - children's multicolored
3	Tote bag - brown
4	Gym bag - black
5	Garment bag - green
6	Garment bag - black
7	Gym bag - large blue
8	Tote bag - black
9	Tote bag - fabric brocade
10	Tote bag - (Samsonite) black canvas

The above ten test bags contained various kinds and amounts of clutter, including clothing and other items normally found in traveler carry-on bags. Additional metallic items including hair dryers, baby food containers, alarm clocks, tools, vases, radios, miniature tape recorders, etc. were added to the bags during the latter phases of the Automatic Mode of operation testing. Each bag was properly identified by tagging it beforehand according to the numbering indicated above.

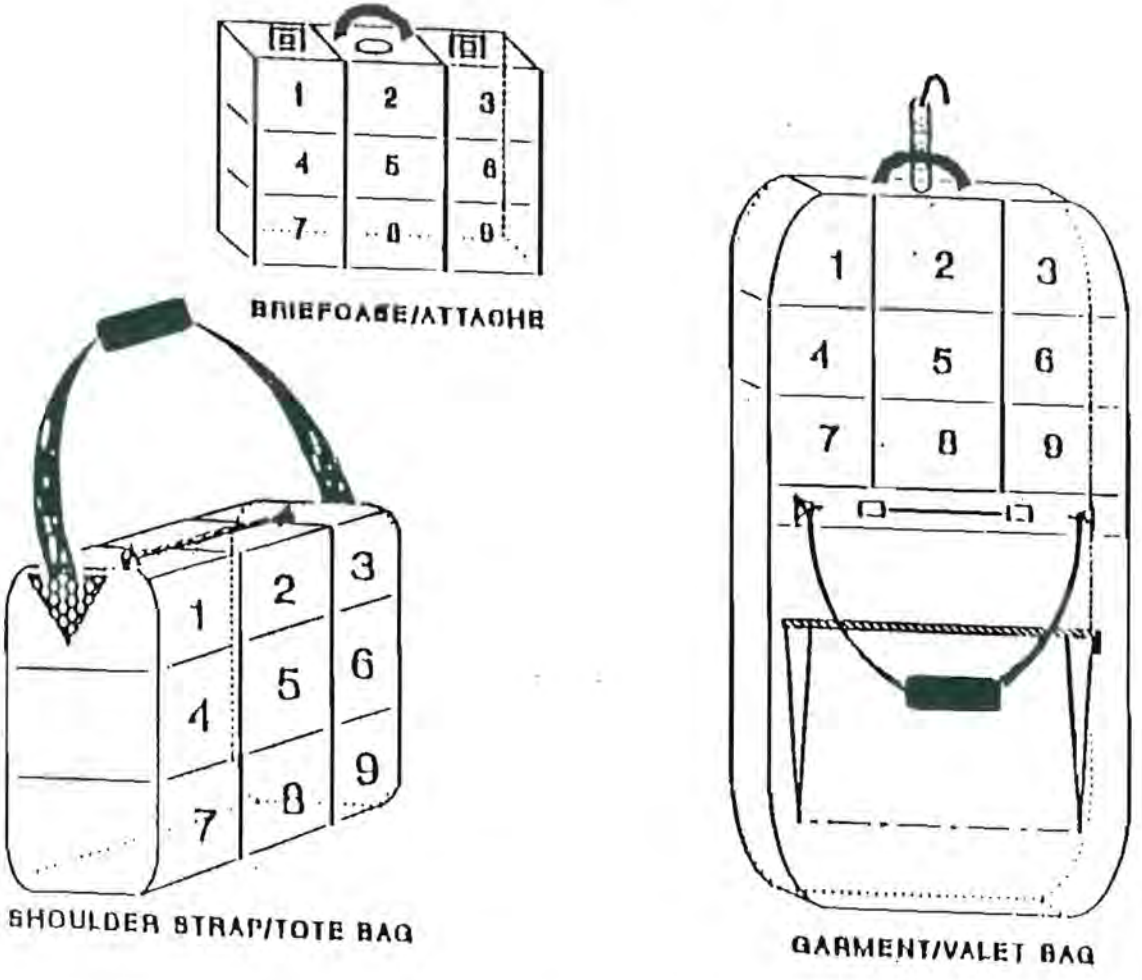


Figure 3. Examples of Test Article Positions/Locations

3. RESULTS AND DISCUSSION.

3.1 GENERAL. During the initial IP test series, with the system in the Automatic Mode of operation, a total of 273 individual runs were completed. Table 1 lists the test runs completed for the various test parameter combinations.

The second test series was performed in the Normal Mode of operation and included the services of four (4) screeners, whose performances were independently evaluated. A total of 374 individual test runs with bags containing test articles were completed, including forty (40) repeats. Additionally, another fifty-five (55) runs were completed, wherein the bags did not contain test articles constituting a grand total of 429 individual runs. Some runs were made more than once since selection of test variable combinations was random. Table 2 indicates the test runs completed for the various test parameter combinations. Similar to the first series of tests, these tests also included running the bags with and without the presence of metallic clutter, and added some new test articles including the two hand grenades, a common steak knife with a four and one-half inch blade, and a Dick Tracy model toy cap pistol of the approximate size and configuration of a 25 caliber automatic pistol as listed in table 3.

The following notes are applicable to Normal Mode Operation Test Results, table 2:

a. Some test bags contained clutter while others did not;

b. Although test article position in the bag was found not to be a significant variable, it was randomized for each test run;

c. Bags containing test articles were presented in random sequence with other test bags on each run;

d. Orientations ranged from three (3) to twenty-four (24) for the knife and gun (see appendix A); and

e. Four screeners were utilized in testing:

1. Screener A = X;
2. Screener B = ●;
3. Screener C = O; and
4. Screener D = +.

3.2 SECURITY EFFECTIVENESS RESULTS.

3.2.1 Analysis Results. The results obtained from the Automatic and Normal Mode operation test series are presented in tables 4 through 9. As indicated in table 4, the system, while operating in the Automatic Mode of operation, alarmed on 197 out of 263 runs where the bag contained test articles, but did not alarm in the ten (10) cases where the bag did not contain test articles. The system also alarmed on all fifty-two (52) runs in which additional metallic clutter items were inserted into the bags. This occurred regardless of whether the bags did or did not contain a test article. The system alarmed on the metallic mass where the clutter completely or partially masked the test article.

In the Normal Mode series of tests using the four screeners independently as test subjects, the results, although still positive, were not as conclusive as in the Automatic Mode test series. The system failed to alarm on forty-two (42) out of 374 runs in which test articles were present in the bags (see table 5). However, at least one screener was curious enough about the bags contents to call for a bag check or to rerun the bag in twenty-eight (28) out of forty-two (42) times that this occurred. Test results were categorized into three sets of responses solicited from the screeners after they had viewed the IP touchscreen monitor and color monitor displays. These were:

a. Deciding whether to further analyze or not analyze the bag contents using IP capabilities of "ZOOM" and "ENHANCE";

b. Deciding whether to call or not call for a bag check; and

c. Positively identifying the image appearing on the screen as a recognized/known contraband item.

In the first response category above, the analysis by the screener could be accomplished in either one of two ways. A bag could be called for to be rerun, in which case, the test bag was again placed on the conveyor belt by the Lead Test Inspector (LTI) and run through the x-ray chamber a second time, but at a different angle. The screener then had the option of using the "ENHANCE" and/or "ZOOM" features on the IP touchscreen monitor to provide greater contrast and/or definition to the displayed image, thus, more often allowing for an assessment to be made. In the second category of response, the screener could, based upon his/her suspicion about the presence of contraband, decide to call for a bag check, in which case the contents of the bag would be hand-searched by the LTI at the screener's request.

In the third and final category or response, the screener always had the option of making a positive identification of the image appearing on the screen as a recognized and known contraband item. In such cases, the standard operating procedure (SOP) would be for the screener to announce a decision to summon their supervisor for confirmation of the finding

and the supervisor, if they concurred, would call for the Response Force (RF) by depressing the "ALERT" button located on the x-ray machine side panel.

The results of the screener analysis responses showed that in ninety (90) out of a total of 374 runs, (or 24 percent of the time) the screeners decided to further analyze the bag contents and in 102 of the total cases the screeners actually called for a "bag check". Screener ability to positively identify the contraband item contained in the bag was successful in 118 of the 374 runs (or 27 percent of the time), although the test article was found on 332, or on 89 percent of the total runs (see table 5). In addition to the information gathered on the data collection forms, post-test interviews were held with each of the screeners to solicit their personal feelings, attitudes, opinions, and recommendations concerning the test conduct, operations, procedures, and conditions. The results of these interviews are discussed in paragraph 3.3 Operational Test Results.

3.2.2 Detailed Test Results (Automatic Mode). The results of test series 1, "Algorithm Assessment, Automatic Mode of Operation" are presented in table 4. The number and percentage of successful alarms are listed for each test article. With the exception of the guns and common steak knife, when presented with clutter the IP system successfully alarmed on all test runs. In the test article runs with the guns (test articles A, B, I, and J), these caused the system to alarm 80 to 88 percent of the time. However, the system failed to alarm when these articles were presented in test bag orientations 17, 18, 19, or 20 (i.e. orientations with gun barrel pointing directly upward toward the screener).

The common steak knife (test article K) resulted in the system alarming approximately 20 percent of the time and these alarms only occurred when the knife was contiguous to a mass of metallic clutter items also contained in the bag.

3.2.2.1 Detailed Discussion. The results presented in table 4 for Automatic Mode operation testing are as one might predict. In the case of the gun (test articles A, B, I, and J), the IP on most runs, was able to fit it within the defined area of the test article contained in the IP database and hence, alarmed. In runs where the IP system failed to alarm, the weapon was placed in such an orientation in the bag (gun barrel facing directly upward) that the image of the test article was so small in that orientation that it could be easily concealed within the total area of the test article stored in the IP system memory.

3.2.3 Detailed Test Results (Normal Mode). The results of the open screener testing in the Normal Mode of operation are presented in table 5. With the exception of the guns and common steak knife, the screeners using the FAA approved test articles were 100 percent successful in finding all test articles contained in the ten (10) different bags regardless of

their orientation. The common steak knife (test article K) again proved to be the most difficult to find by both the IP system and the screeners. Except in the case of one screener, the screeners as a group were unable to discern the presence of the common steak knife in the bags regardless of its orientation. This test article was found only about one-third of the time that it was presented in the test bags.

In the case of the test runs with the guns (test articles I, J, and L) assessment also presented a somewhat difficult task for the screeners. In particular, the Dick Tracy model toy cap pistol, resembling a .25-caliber special automatic pistol in size and shape, because of its low density profile, was found only slightly more than half the time. Conversely, encapsulated test guns A and B were discerned for the most part by all screeners.

3.2.3.1 Detailed Discussion. The results presented in table 5 for the common steak knife (test article K) and further described in paragraph 3.2.1 are explainable on the basis that the knife is easily concealed in the test bags and readily masked by other metallic clutter items contained in the test bags. Additionally, the thin blade and low metallic content of the knife presents a low density image. The one (1) screener who was successful in finding the knife was able to do so by recognizing the pattern of the rivets on the knife handle as learned through prior training. The screener considered this to be a "dead giveaway" to the presence and identity of the object.

Encapsulated guns (test articles A and B), were easily discerned largely because of the screener's previous exposure and familiarity with their appearance. The encapsulated material in which the guns were encased was quite visible to all screeners, both on the color monitor and black and white IP touchscreen monitor.

The apparent difficulty encountered by screeners in finding the Dick Tracy model toy cap pistol, similar in shape and size to the .25 caliber special automatic pistol, may be due to the fact that the article is easy to conceal in the bags and it too can be easily masked by other metallic clutter items. More importantly, test articles I, J, and L in orientations 17, 18, 19, and 20 where the gun barrel is pointing upward, are also very difficult for the IP to fit into a defined area (see table 2). This supports the gun test article findings in table 4 where the results of testing the IP Algorithm in the Automatic Mode of operation are presented.

3.3 OPERATIONAL TEST RESULTS.

3.3.1 Equipment Performance/Guns (Automatic Mode). Table 6 indicates the assessment results achieved using the guns (test articles A, I, and J) in the IP system Automatic Mode of operation. Results are presented only for gun orientations 17, 18, 19, and 20 where the gun barrel is pointing directly upward with respect to the screener. As indicated in table 6, the

guns were only found about 50 percent of the time when presented in these orientations. All other test articles/orientations, with the exception of the common steak knife (test article K, table 4), were 100 percent discernible by the IP system.

3.3.2 Observations. The results presented in table 6 and described in section 3.3.1 are supportive of results presented earlier in which it was found that in certain Automatic Mode orientations (gun barrel pointing directly upward), the image appearing on the color monitor and touchscreen monitor was too small and non-specific to be defined as contraband. In other cases where the contraband item was hidden within the masked area, and therefore non-discernible to the screener, the system nevertheless alarmed on the clutter as it was designed to do. The screener in this case, however, would usually become suspicious of the area and call for a bag rerun or bag check.

3.3.3 Equipment Performance/Guns (Normal Mode). The test results presented in table 7 for Normal Mode operation are similar to the findings of IP algorithm assessment tests conducted in the Automatic Mode of operation. The percentage of gun test articles (A, B, I, J, and L) discerned by screeners in orientations 17 through 20 was small, except for the runs involving test articles A and B. In this case, as discussed earlier, the encapsulated guns were found in five (5) out of the nine (9) screener runs.

3.3.4 Observations. The results of the open screener tests conducted in the Normal Mode of operation depicted in table 7 show that except for test articles A and B in orientations 17 and 18, the gun test articles went largely undetected by the screeners. This supports the previous IP test series Algorithm Assessment Results, which showed that when the gun is placed in an orientation in which the barrel is pointing directly upward, it is extremely difficult, if not almost impossible for the IP to assess.

3.3.5 Equipment Performance/Knife (Automatic Mode). Table 8 shows the results obtained in algorithm assessment testing of the common steak knife, test article K, (Knife-2) in the Automatic Mode of operation. Because the Knife-2 (unlike the gun test articles) went undiscovered on thirty-nine (39) out of the forty-nine (49) runs, this data is presented separately. Results show that the IP system was able to alarm on the common steak knife, Knife-2 in only a few orientations.

3.3.6 Observations. These results support earlier findings that the knife, because of its low image density and ability to be easily masked by other clutter items contained in the bags, is not easily detected by the IP system, regardless of its orientation. The system would nevertheless alarm on the presence of the clutter, although not being able to specifically detect the presence of the test articles.

3.3.7 Equipment Performance/Knife (Normal Mode). The results of the open screener tests conducted in the Normal Mode of operation for test article K (Knife-2) are listed in table 9. These results, for the most part, support findings conducted in the Automatic Mode to the extent that the screeners also failed to discern the presence of this test article in all but a few orientations, and that the successful assessments that did occur were made by only one of the four (4) screeners involved. One of the screeners, because of previous experience and/or training, was able to identify the knife by the rivets holding the handle together as portrayed by the image appearing on the color monitor and IP black and white display monitor.

3.3.8 Observations. These results support earlier findings that the knife, because of the low density image that it provides, is difficult, if not impossible, to detect. However, there is some reason to suggest that prior experience with the test article in question may tend to improve the level of assessment through better pattern recognition by screeners.

3.4 DISCUSSION.

3.4.1 General. Certain problems were encountered during testing which caused the tests to be disrupted or the process to not flow completely problem free. On several occasions the IP system tests had to be suspended or delayed due to hardware and/or software failures, which were unpredictable, but nevertheless anticipated due to the R&D prototype maturity of the IP system. These problems are summarized below and documented in the Trouble Reports (TRs) provided in appendix B. During both test series hardware problems were encountered, especially with the HP keyboard used to "boot-up" the system software. Although disassembled and cleaned during the initial test series, repeated log-ins were necessary to bring the system on-line. The problem, attributed to a dirty keyboard, was not so apparent during the second test series. Cleaning the keyboard seemed to improve hardware performance.

Another problem occurred with bags not stopping within the confines of the x-ray chamber prior to processing. Bags are supposed to be totally contained and remain within the x-ray chamber until processing has taken place and the clutter and/or test article is discovered, thus precluding access by a would-be adversary. In many cases, particularly with the larger,

elongated bags, the bag itself extended out of the x-ray chamber sometimes as much as half-way. This problem was subsequently isolated to a belt position timing problem, and was partially corrected by an adjustment to the software.

A third problem encountered during testing dealt with the touchscreen monitor screen locking-up. Initial diagnosis attributed the problem to the monitor or control box. Subsequent investigation, however, disclosed that the problem resided in the software code. For example, when using the "ZOOM" capability, the screeners would occasionally touch the screen surface outside of the normally functioning area causing the software to lock-up. This problem was not corrected during testing and still remains a major weakness in the IP system software.

A fourth problem uncovered during testing dealt with the bags not clearing the x-ray inspection chamber after the "ASSESS" function was depressed on the touchscreen monitor. While occurring only intermittently, (i.e. mostly when the operator/screener failed to stop the bag in time so that it was totally contained within the chamber), procedural flow was interrupted to the extent that the bag had to be backed out of the chamber by repeatedly depressing the "START" function on the touchscreen monitor. Once the bag was backed out far enough to be accessed, pressing the conveyor belt "ON" button on the x-ray machine operating panel would allow the bag to flow through the chamber without stopping. Once the bag had cleared the chamber, pressing the "ON" button again served to stop the belt and allowed the touchscreen function to return to normal. This problem has been attributed, once again, to a peculiarity of the software and has not yet been corrected.

3.4.2 Test Series 1 - Automatic Mode. The results of this test series clearly indicate that the IP algorithm does perform within design specifications. The system does alarm when it is supposed to and conversely, does not alarm when it is not supposed to (i.e. confirms the effectiveness of the IP algorithm). While these results are based upon a sample size which is obviously too small to be statistically significant, they do tend to at least lend support to the basic test hypothesis. The results are also important in the sense that certain test articles (gun and knife), with or without clutter present, when placed in certain orientations, are not easily discerned. With the barrel or blade pointed in an upward orientation in the bag the IP system seems to encounter considerably more difficulty in assessing these test articles. The test article position or the type of bag used, appeared to have no impact whatsoever on the system's ability to assess/identify the test article. Although it was neither feasible to test all variable combinations possible, nor to do repeated testing on these variable combinations, the results nevertheless point to a definite trend confirming the value of the IP system as an aid to screeners in the assessment of contraband items contained in passenger carry-on bags.

3.4.3 Test Series 2 - Normal Mode. In the second test series the four (4) individual screeners of different ages, sex, and experience levels were used as test subjects. The four screeners had received some amount of training and exposure to the IP system and equipment prior to their participation in testing. The overall results seem to support the notion that the screener's ability to assess contraband items contained in passenger carry-on bags is to some degree enhanced by the IP system. It should be cautioned that because the IP monochrome touchscreen monitor was never tested by itself, but always in conjunction with the color monitor, the results might tend to be skewed. On several occasions it was noted that the screeners tended to focus primarily upon or rely solely upon the color monitor for information. In some cases they even ignored the image appearing on the black and white IP touchscreen monitor. This may be due in part to the fact that the screeners had more prior experience in working with the color monitor independent of the IP system. Hence, they were more adept and had more confidence in this system/equipment versus the other.

Other factors that could have contributed to the skewing of the test results include the following observations:

a. Screeners had substantial prior experience in the limited set of test articles that were used during the tests;

b. The number of carry-on bags used during testing was too limiting, and therefore operationally unrealistic. After several runs with the same bag the screeners became overly familiar with the bags and the clutter items contained within them; and

c. Non-existence of a normal screening point traffic environment allowed the screeners to operate almost completely stress-free. This condition was considered operationally unrealistic.

3.4.4 Screener Observations. Post-test screener interviews provided some additional valuable insights into how well the IP system was received, as well as some comments on the overall screening point equipment configuration, operational performance, and test procedures. All four (4) security screeners felt that the IP, while currently in a primitive stage of development, offered considerable promise as a viable future aid to screeners in assessing contraband items in passenger bags. They generally found it to be helpful in stopping and holding a bag in which contraband was contained and which posed an obvious threat to life and property.

The screeners as a group seemed to like the overall concept of a touchscreen as a means of controlling/accessing information, but they found it difficult to use. Although recognizing the prototype maturity of the IP, all screeners felt that the equipment was not always as sensitive and responsive as it might be. They also thought that the IP took much too long to

process information, which would tend to unnecessarily disrupt passenger traffic flow at the screening point. The screeners also expressed concern about how they should react when confronted with a system failure, such as a software lock-up. They were of the opinion that additional training was needed in this area.

When queried about the effectiveness of the IP equipment and layout, most screeners felt that it could be improved. While they seemed to like the location of the two monitors, side by side, they thought that the operations control panel on the Linescan System 10 x-ray machine was in an awkward position, making its access less than optimal for sit-down operation and even constituting an obstacle to screeners. They expressed concern that the operator panel mounting was not rigid enough, and as a result of the screener's continually bumping into it, that it would eventually break away from the main chassis. The screeners commented that raising the panel for convenient sit-down, as well as stand-up operation, would tend to enhance their overall performance.

The IP system, for the most part, proved to be "user friendly". The software had a tendency to "hang up" on a frequent basis largely because of the poor user interface. For example, when using the "ZOOM" capability on the IP touchscreen monitor, screeners would often touch the screen outside of the functional area, thus, causing the system to immediately go down. This resulted in loss of valuable test time and resources as the system software had to be "re-booted", a rather involved and lengthy procedure. Whenever the system failed in this manner, it could not help but procedure a detrimental effect on the patience and confidence of screeners who were operating the system.

Only one screener had any familiarity or prior experience with the IP system Automatic Mode of operation. All screeners were in agreement that the IP analysis process was much too slow and actually impeded the normal flow of traffic at the screening point. As indicated earlier, the screeners as a group found the IP touchscreen somewhat difficult to use. The fact that it didn't provide an immediate response or feedback when touched resulted in the tendency on their part to more often ignore the image displayed on the touchscreen monitor and direct their attention instead to the color monitor. Even with the option available to further analyze bag contents using the "ZOOM" and "ENHANCE" features and/or to call for a "bag check", one screener preferred to have a bag suspected of containing contraband re-run through the x-ray machine, but at a different angle. His personal experience was that many passengers were annoyed over having their bags subjected to a physical search and that the "ZOOM" and "ENHANCE" features on the IP offered little, if any, advantage over the color monitor.

All of the screeners seemed to be of the opinion that the standard FAA test article set employed during the tests did not match the present "state-of-the-art technology in weaponry and, therefore, did not sufficiently stress their abilities as a screener. Because they had significant prior exposure to the set being used, they naturally became familiar with it and

knew exactly what to expect in so far as the images being projected on the IP touchscreen monitor display. Particularly, in the case of the opaque lead masking devices, (Circle-1 and Rectangle-1) all screeners were able to recognize these items almost immediately and were always suspicious about what might be hiding behind them. This also turned out to be a similar situation with the encapsulated weapons, gun A12-1 and the simulated test gun, Simgun-1. In the case of at least one screener, even the common steak knife (presently a non-FAA test article and not resident in the IP database), was readily discerned. While this article exhibited a rather low density image profile, the rivets on the handle of the knife proved to be a "dead giveaway" even in the presence of clutter to this particular screener.

Although not part of the IP tests per se, all of the screeners seemed to concur that "good" communications were a vital part of their operations and the addition of headsets would be a significant improvement. They also felt that an intercom system that would allow everyone to converse with each other would enhance overall performance. Furthermore, having enough equipment available so that each screener would have his/her own headset which he/she could leave at the end of the shift, but pick-up again at the beginning of the next shift, would alleviate any cleaning-related problems associated with maintaining good health practices.

4. CONCLUSIONS. Evaluation of the IP test results show a definite trend toward image processing becoming a useful contraband assessment tool and a valuable aid to screeners. While certain test articles placed in specific orientations with and without clutter present were determined to be difficult and sometimes impossible for the system and screeners alike to discern, improvements to the IP software and increased training may tend to overcome these limitations. Although still unsubstantiated, there may be some added value to using the IP touchscreen monitor in combination with the color monitor to enhance the overall capabilities of the screening point and its operators in assessing and discerning contraband contained in passenger bags and other carry-on items.

The image processing seems to be a viable and promising concept for operational deployment in the future, the IP system employed/tested at BWI is still very primitive in design. The user interface needs to be improved to support effective operation and minimize possible passenger tie-ups at the screening point. In this regard, considerable effort should be directed at reducing the IP processing time as well as introducing a data control/access capability which is more "user friendly" in design.

5. RECOMMENDATIONS. Future IP tests should consider testing and evaluating the IP system independent of a color monitor so that the screener would have to rely entirely on the IP monochrome touchscreen monitor and displayed image for assessment of contraband items in passenger carry-on bags.

The planned tests did not allow for testing the IP system in the Automatic Mode of operation with screeners present. No conclusions can therefore be drawn relative to the advantages/ disadvantages that the Normal versus the Automatic Mode may have over one another as a contraband assessment aid to screeners. The IP system operating in the Automatic Mode, as previously discussed, tends to slow down passenger movement through the screening point. By capturing the bag and holding it within the x-ray chamber, the screener is forced to take a closer look at those bags containing highly suspicious objects. In contrast, in the Normal Mode of operation, the bags containing contraband would be allowed to pass through sometimes undiscovered by the system unless the screener decided to check the bag's contents. The screener would then take the necessary actions to stop the bag within the x-ray chamber and analyze it.

New "state-of-the-art" weapons need to be added to the standard FAA test article set and incorporated into the existing IP test article database. These items would make test conditions more realistic, as the items constitute a real and current threat. The screeners have had only minimal prior exposure to these conditions. Additional metallic clutter items placed in the bags, as well as an increase in the number/type of test bags used, would also tend to make the human screener assessment process more challenging and perhaps enhance the overall fidelity of the IP test environment.

Periodic refresher training and frequent screener proficiency testing, as well as modifications to the IP software and database, will also help to maintain the IP system capabilities current with the state-of-the-art technology. This program would utilize more realistic "state-of-the-art" test articles and focus on human cognitive processing, vigilance, and fatigue factors as well as x-ray image pattern recognition. Finally, minor human engineering improvements to the equipment design and layout should provide for a more effective man-machine interface. A detailed human factors analysis study needs to be conducted at BWI's pier B Enhanced Screening Point to identify human/equipment functions and tasks and relationships. This analysis would focus on identifying key x-ray image identification characteristics used by screeners to recognize both weapons and explosive devices. Once these tasks/behavioral factors have been identified and defined, selection criteria and training programs can be effectively developed for screeners.

Future R&D test efforts at BWI and/or other airport testbeds should include the installation/testing of new and improved hardware systems as well as the generation of new and better computer programs, which are less cumbersome to use, are more reliable and optimize human-computer interface compatibility. It should also be noted that there may be other candidate IP systems available in the marketplace which meet the basic requirements and can readily be tailored to this specific application. These should be fully investigated.

6. REFERENCES.

a. Security Effectiveness Test Plan: Enhanced Airport Security System Project at BWI Airport (Draft), July 14, 1993.

b. A Technology Assessment of the Enhanced Airport Security Demonstration Project at Baltimore-Washington International Airport (BWI), Prepared by A. A. Lupinetti, Chief Scientist, FAA Technical Center, November 19, 1992.

c. Master Test Plan: Enhanced Airport Security System Project at Baltimore-Washington International Airport (BWI) (Final Plan), February 1, 1993.

d. Interim Test Status Summary Report, Report Number 1, Test Series 4.2 Image Processing (IP) Subsystem Effectiveness Testing, November 3, 1993.

e. FAA Technical Center Enhanced Security at BWI Image Processing System Procedure (Draft), November 17, 1992.

7. TABLES. The nine (9) tables referenced in the "Image Processing (IP) System Contraband Assessment Effectiveness Test Report" are grouped together and provided in this section.

Table 1. Contraband Types/Orientations for Different Test Bags
Both With and Without Clutter (Automatic Mode Operation)

ORIENTATION	POSITION									
Position/Bag	1	2	3	4	5	6	7	8	9	0/0
1	1-G, 1-H, 1-A, 1-C, 6-D	1-H, 4-G, 1-A	3-D, 9-F, 1-F, 1-A, 1-C	6-B, 4-G, 1-C, 2-K	10-A, 1-F, 1-A	1-D, 4-A, 1-A, 1-C	1-C, 5-B, 1-B	6-B, 4-F, 1-A, 1-B, 4-K	1-G, 1-F, 4-H, 1-A, 1-C	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
2	5-G, 7-G, 1-A	5-A, 1-A, 1-K	10-F, 1-C	7-G, 1-A, 1-C	10-F, 4-F, 1-A	1-A, 1-C, 7-K	7-G, 1-A, 8-C	5-G, 1-A, 1-C	10-A, 9-A	
3	1-A, 1-G	1-C, 5-K	1-C		1-A	1-A, 4-K	1-A, 1-C	1-C	1-C, 9-K	
4	1-A, 1-F	9-E	5-G	9-G, 6-K	1-I		7-A, 1-K	10-F	10-K	
5	1-A	4-I	4-F	9-F	1-A	4-A		4-I	7-G, 1-G	
6	1-A, 9-F, 3-K	6-B		5-H	10-G, 2-K	9-H	1-A, 5-K	4-A	6-K	
7	1-A	9-H, 1-K		4-F	1-A	7-G	7-A		9-H	
8	1-A, 1-A	4-G	1-I, 1-K	5-A	7-A	9-G	3-K	10-A	4-G	
9	1-A, 8-K		3-D	4-G	1-A	1-F	6-A	5-G		
10	10-A, 1-4		4-H	9-F	10-G		1-A, 2-K			
11	1-A	7-A, 4-K		4-H	9-A	4-I, 10-K		4-I, 4-K	7-G	

Table 1. Contraband Types/Orientations for Different Test Bags
Both With and Without Clutter (Automatic Mode Operation) (Continued)

ORIENTATION	POSITION									
Position/Bag	1	2	3	4	5	6	7	8	9	0/0
12	1-A, 7-K	10-A		1-K	9-F	4-F	8-A	4-K	1-A	
13		9-F	1-C, 2-K	5-G	10-A		1-A, 4-G, 4-K	5-F	3-A	
14	1-A		6-F	5-K	10-F	7-A	1-A		1-I	
15	3-D, 1-K	5-H	4-I		1-A, 3-K	1-A	1-A	6-A	6-G	
16	1-A	1-A	4-A	7-G	1-A	5-G, 7-K	1-A	4-F	1-F	
17	2-A, 4-I	6-A	3-F, 5-K	3-A		4-G	3-F	2-A	7-A, 10-K	
18	6-F	2-A, 4-K	8-K	10-J	10-A	7-A	4-I		6-G, 1-K	
19	5-G	3-K	8-J	7-F	9-A	6-F	5-G, 2-K	10-G	6-F	
20	7-A	10-G	5-F, 7-A	10-A		6-K	6-J		8-F	
21	3-G	8-A			4-F, 7-G	2-A, 4-K	1-K	3-G		
22	10-F		4-F	9-A		6-K	9-A		6-F	
23	4-K	2-A	10-F	6-G	4-G	4-A		7-F		
24	3-G	6-F	7-G	5-F	3-F	8-G, 6-K	5-J	5-G, 9-K	6-G	

NOTE: First number indicates bag, second number indicates test article indicated by alpha.

Table 2. Contraband Types/Orientations for Different Test Bags
Both With and Without Clutter (Normal Mode Operation)

Test Bag	1										2											3								
Test Article/ Orientation	A	B	D	E	F	G	I	J	K	L	A	B	C	D	F	G	H	I	J	K	L	A	B	E	G	H	I	J	K	L
1	O							O					X		X			+									●		X	
2				●	O										O	X	●					X	X	●			O			
3			O	X	X	●					X		X	X		● O		O					X		X	O				
4	X																								●	●				
5																					●									
6																		O								0				
7																														
8						X			+ +																					
9								●																					+	
10																												+		
11							+ +	+										+	+	●										+
12							+					●						+									● +			
13																														+

Table 2. Contraband Types/Orientations for Different Test Bags
Both With and Without Clutter (Normal Mode Operations) (Continued)

Test Bag	1										2											3								
Test Article/ Orientation	A	B	D	E	F	G	I	J	K	L	A	B	C	D	F	G	H	I	J	K	L	A	B	E	G	H	I	J	K	L
14		O					+ + +					O																●		
15							+			+									+										X	+
16										+								+												
17							+		+											+									+	
18								X		● ● ●										+ +							+		X	
19										●								+												+ +
20										+																				
21																			+											+
22								X			●							+									+			+
23																			+		+						+			
24	O									X																	+			

Table 2. Contraband Types/Orientations for Different Test Bags
Both With and Without Clutter (Normal Mode Operation) (Continued)

Test Bag	4										5									6									
Test Article/ Orientation	A	B	D	E	G	H	I	J	K	L	A	B	D	E	H	I	J	K	L	A	B	C	D	E	G	I	J	K	L
1			+											O O			+					X		●					
2			+	+		X		●			X		X ●	X									X						
3						●	X								X							X		●		●			
4							●	X			●				X						O								
5	●					O		●			X					+				X					X O				
6																●	X												●
7											O O	● O														●			
8					O O												O				X				●				
9	O							O										+	+										
10																	X				O					+			+
11								X											+										+
12																	+	O								O		+	

Table 2. Contraband Types/Orientations for Different Test Bags
Both With and Without Clutter (Normal Mode Operation) (Continued)

Test Bag	4										5									6										
Test Article/ Orientation	A	B	D	E	G	H	I	J	K	L	A	B	D	E	H	I	J	K	L	A	B	C	D	E	G	I	J	K	L
13						+				+																			
14									+								+									O			
15							+		+	+																O +		+ +	
16								+			●					+		+	+									●	+
17	X									+											●					+	X		
18	●									+								O	+									+	
19								+	+							+	+		+										
20		X																●									+		
21							+ +												+										
22									+ +							+													
23								+											+									+	+
24																											+		

Table 2. Contraband Types/Orientations for Different Test Bags
Both With and Without Clutter (Normal Mode Operation) (Continued)

Test Bag	7											8								
Test Article/ Orientation	A	B	C	D	E	F	G	I	J	K	L	A	D	E	G	H	I	J	K	L
1				X								X		X		X ●				
2	●		X										X			X		+		
3			X		X	X				●		● O	X	O	O					
4								+								●				
5																			O	
6												O						+		
7	●						● O	+									O			
8																				
9										O										
10											+				●			●	+	
11								+		O								+		
12								+	+	+ +							+			

Table 2. Contraband Types/Orientations for Different Test Bags
Both With and Without Clutter (Normal Mode Operation) (Continued)

Test Bag	7											8								
Test Article/ Orientation	A	B	C	D	E	F	G	I	J	K	L	A	D	E	G	H	I	J	K	L
13								●									+			
14									+	+ +										+
15								●												
16		O							+ O										+	
17								+		+		O								
18																				
19	X										O	X						+ +		
20		●							●		+						●		+	
21								X	X		+						+	+ O	+	
22										+										
23									+									+		+
24										+										+ +

Table 2. Contraband Types/Orientations for Different Test Bags
Both With and Without Clutter (Normal Mode Operation) (Continued)

Test Bag	9									10								
Test Article/ Orientation	A	B	E	F	H	I	J	K	L	A	B	D	E	H	I	J	K	L
1		X		X								X		X				
2	O		X	X									X ●			X		
3			X ●	O	X			O									X	
4	O										O							
5																O	+	
6					●						O							●
7									+	X							●	
8																		●
9																		
10								●										
11																+		
12																+ O		
13	O						+	X +							X ●	+	+	
14																+	O	

Table 2. Contraband Types/Orientations for Different Test Bags
Both With and Without Clutter (Normal Mode Operation) (Continued)

Test Bag	9									10								
Test Article/ Orientation	A	B	E	F	H	I	J	K	L	A	B	D	E	H	I	J	K	L
15								+ +							O		●	
16							●										+	+
17						+ +										+		
18								●									+	+
19						+	+										●	
20	●								+							+	+	
21															+			
22								+ +	+									
23						O			+						+ ●	+		
24									+						+		+	

Table 3. Image Processing Test Articles

AUTOMATIC MODE		NORMAL MODE	
A	Encapsulated Gun (A12-1)	A	Encapsulated Gun (A12-1)
B	Encapsulated Gun (D-6)	B	Encapsulated Gun (D-6)
C	Circle-1	C	Circle-1
D	Rectangle-1	D	Rectangle-1
E	Pipe-1	E	Pipe-1
F	Butterfly knife	F	Butterfly knife
I	Glock 9mm semi-automatic pistol	G	Grenade-1
J	S&W .38-caliber special revolver	H	Grenade-2
K	Common steak knife	I	Glock 9mm semi-automatic pistol
		J	S&W .38-caliber special revolver
		K	Common steak knife (Knife-2)
		L	Dick Tracy model toy cap pistol (.25-caliber)

Table 4. Automatic Mode of Operation, Test Article Assessments

Test Article		# of Runs	# of Detections	% Successful Detections
A	Encapsulated Gun (A12-1)	83	73	88
B	Encapsulated Gun (D-6)	10	8	80
C	Masking Device (Circle-1)	10	10	100
D	Masking Device (Rectangle-1)	10	10	100
E	Pipe Bomb (Pipe-1)	10	10	100
F	Butterfly Knife (Knife-1)	5	5	100
G	Grenade-1	Not Tested		
H	Grenade-2	Not Tested		
I	Glock 9mm semi-automatic pistol	46	39	84
J	S&W .38 Special Caliber Revolver	40	32	80
K	Common steak knife (Knife-2)	49	10	20
L	.25-Caliber Special Automatic Pistol (Dick Tracy model toy cap pistol)	Not Tested		
	Bags without test articles	10	0	N/A
Total		273	197	75

NOTES: (1) Bags presented both with and without clutter.
(2) Type of bag not found to be a significant variable.

Table 5. Normal Mode Operation, Test Article Assessments

TEST ARTICLE		# OF RUNS	# OF DETECTIONS	% SUCCESSFUL DETECTIONS
A	Encapsulated Gun (A12-1)	36	35	97
B	Encapsulated Gun (D-6)	17	16	94
C	Masking Device (Circle-1)	7	7	100
D	Masking Device (Rectangle-1)	10	10	100
E	Pipe Bomb (Pipe-1)	17	17	100
F	Butterfly Knife (Knife-1)	8	8	100
G	Grenade-1	16	16	100
H	Grenade-2	15	15	100
I	Glock 9mm semi-automatic pistol	67	59	88
J	S&W .38-Special Caliber Revolver	58	47	81
K	Common steak knife (Knife-2)	66	21	32
L	.25-Caliber Special Automatic Pistol (Dick Tracy model toy cap pistol)	57	33	58
Total		374	332	89

NOTES: (1) Bags presented both with and without clutter.
(2) Type of bag not considered a significant variable.

Table 6. Automatic Mode Operation, Percentage of Successful Gun Assessments

ORIENTATION/ ARTICLE	A	I	J
17	(5) 20	(1) 0	(0) 0
18	(3) 33	(1) 0	(1) 0
19	(1) 0	(0) 0	(2) 50
20	(3) 0	(0) 0	(1) 0

NOTES:

(1) All other test articles/orientations (except common steak knife) were discerned on 100% of the runs or not tested in these orientations.

(2) Number in parenthesis is total runs including repetitions, lower number is percentage.

Table 7. Normal Mode Operation, Percentage of Successful Gun Assessments

ORIENTATION/ ARTICLE	A	B	I	J	L
17	(2) 100	(1) 100	(5) 20	(2) 0	(1) 0
18	(1) 100	(0)	(1) 0	(1) 0	(6) 0
19	(2) 0	(0)	(2) 0	(1) 0	(5) 0
20	(1) 0	(2) 50	(3) 0	(5) 20	(3) 33

NOTE: (1) Test articles in orientation with gun barrel facing upward.

(2) Number in parenthesis is total runs including repetitions. Lower number is percentage.

(3) All other test articles/orientations (except common steak knife) were 100% discernible by screener.

Table 8. Automatic Mode Operation,
Percentage of Successful Knife-2, Test Article K, Assessments

ORIENTATION	NUMBER OF RUNS	NUMBER OF ASSESSMENTS	PERCENTAGE OF SUCCESSFUL ASSESSMENTS
1	2	1	50
2	2	0	0
3	3	1	33
4	3	1	33
5	3	1	33
6	2	0	0
7	1	1	100
8	2	0	0
9	1	0	0
10	2	1	50
11	3	0	0
12	3	0	0
13	2	1	50
14	1	0	0
15	2	1	50
16	2	0	0
17	2	0	0
18	3	0	0
19	2	0	0
20	1	0	0
21	2	0	0
22	1	0	0
23	2	1	50
24	2	1	50
Total	49	10	20

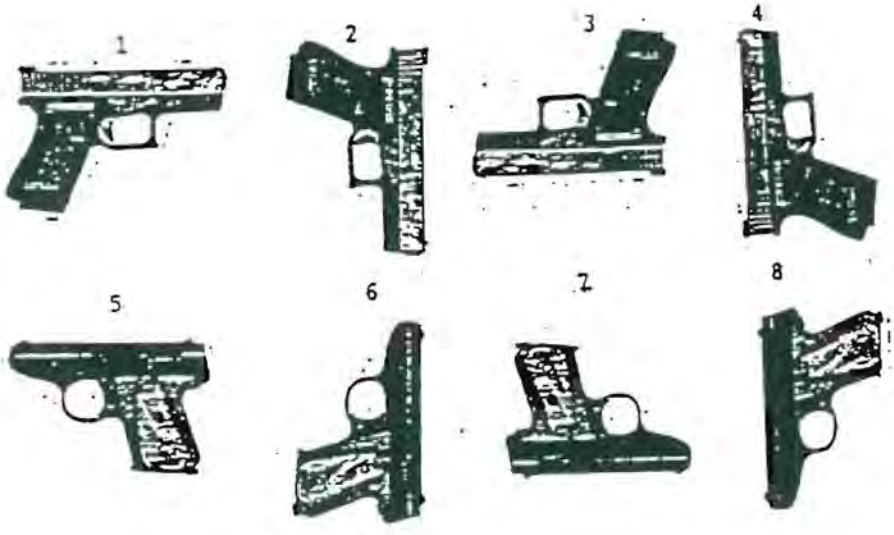
NOTES: Assessments are for Knife-2 in all twenty-four (24) orientations.

Table 9. Normal Mode Operation
Percentage of Successful Screener Knife-2, Test Article K, Assessments

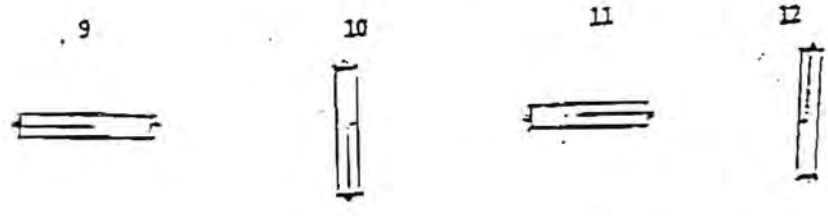
ORIENTATION	NUMBER OF RUNS	NUMBER OF ASSESSMENTS	PERCENTAGE OF SUCCESSFUL ASSESSMENTS
1	1	0	0
2	0	0	0
3	3	1	33
4	0	0	0
5	2	0	0
6	0	0	0
7	1	0	0
8	2	0	0
9	3	0	0
10	2	1	50
11	2	0	0
12	4	1	25
13	3	0	0
14	4	1	25
15	7	1	14
16	4	0	0
17	4	0	0
18	7	1	14
19	2	0	0
20	4	0	0
21	1	1	100
22	5	1	20
23	1	0	0
24	2	0	0
TOTAL	63	8	13

NOTES: (1) Knife-2, test article K, run in all twenty-four orientations

APPENDIX A
TEST ARTICLE ORIENTATIONS

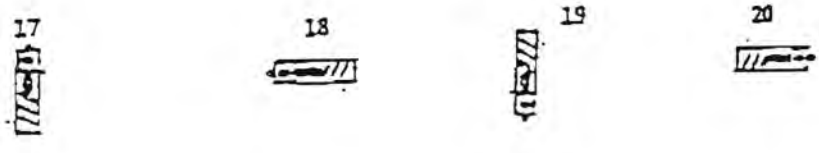


Glock 9mm Automatic and 38 S&W Special Revolver.

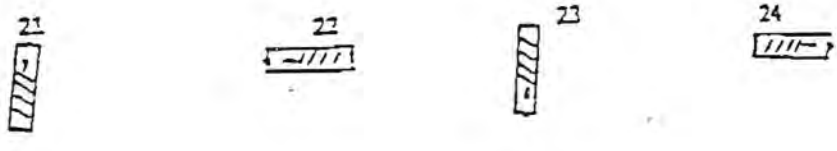


Top side of barrel facing up.

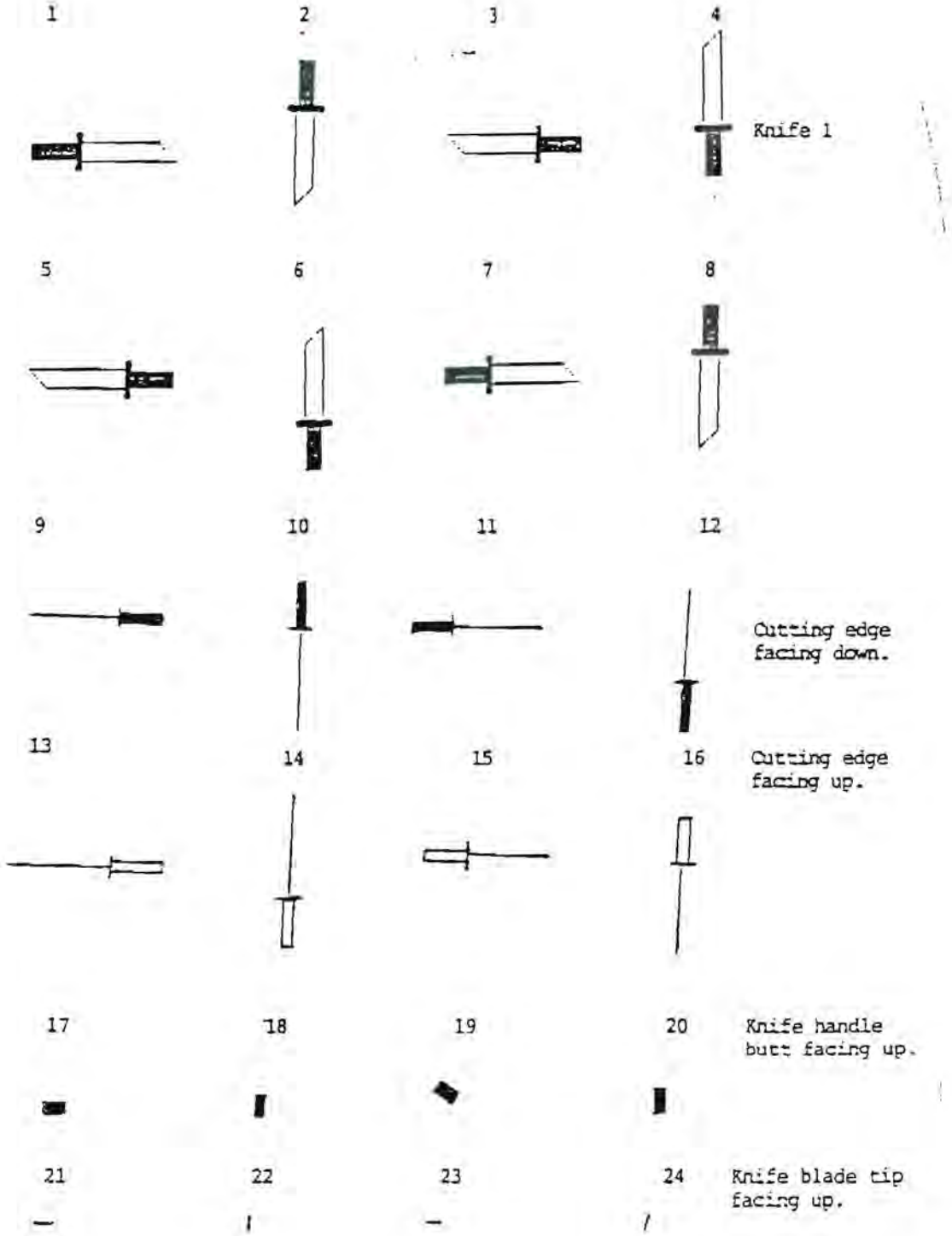
Bottom side of pistol grip facing up.



Gun barrel facing up.



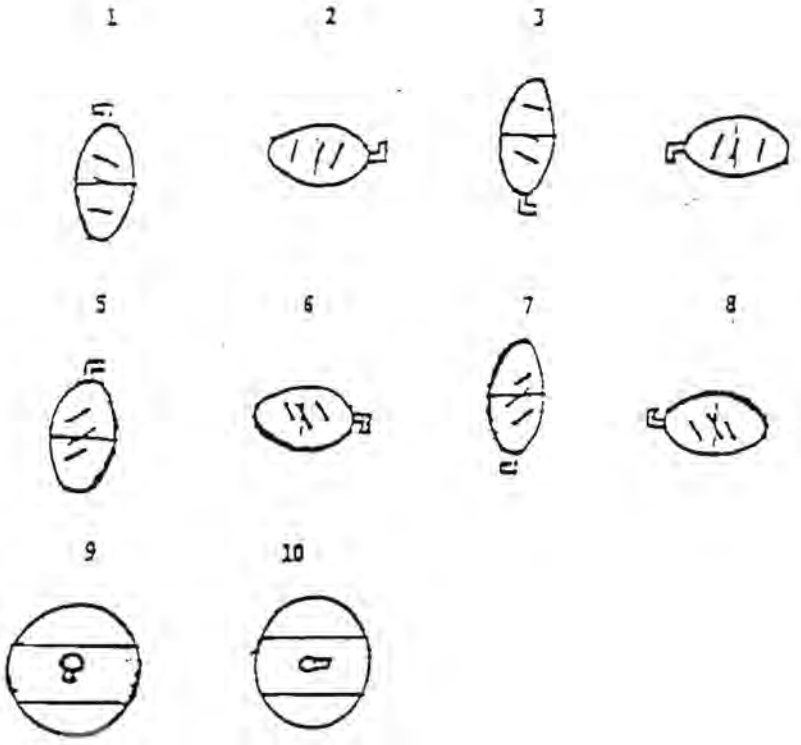
Gun barrel facing down.


1
2
3
4
Knife 1
5
6
7
8
9
10
11
12
Cutting edge facing down.
13
14
15
16
Cutting edge facing up.
17
18
19
20
Knife handle butt facing up.
21
22
23
24
Knife blade tip facing up.

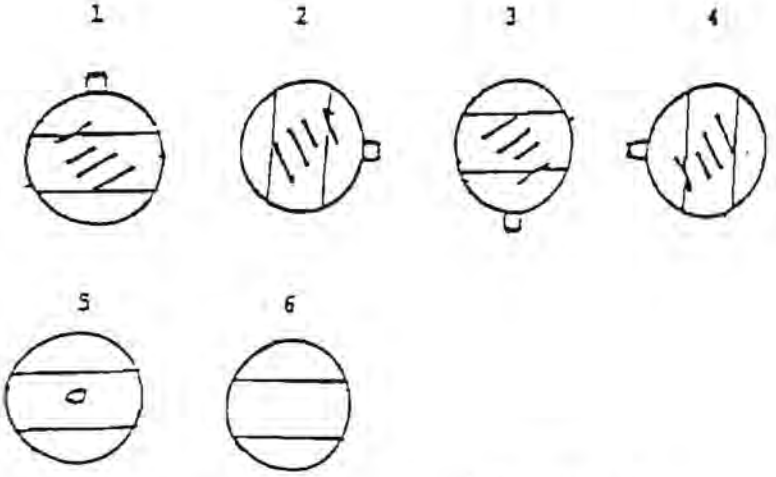
Circle - 1

Rectangle - 1

Pipe - 1



Grenade - 1



Grenade - 2

Test Article Orientation - Grenades

APPENDIX B
TROUBLE REPORTS

TROUBLE REPORT (TR)

PROJECT: ENHANCED AIRPORT SECURITY SYSTEM	TR#:01
TR TITLE: BAG/TEST ARTICLE ACCESSIBILITY DURING IMAGE PROCESSING	TR PRIORITY: Minor _____ Major _____ Critical __X__
ORIGINATOR: R.J.FELBINGER C.BOLLING	DATE/TIME OCCURRED: 8/17/93 - 8/18/93 (10AM-12PM) (1PM-3PM)
SUPPLEMENTAL TROUBLE DATA: NONE	TEST TOOLS: SELF DIAGNOSTICS
SUB-SYSTEM FAILURE: BELT POSITION/TIMING	SOFTWARE/VERSION: XISPS

REFERENCE DOCUMENT:

REV/VOL IMAGE PROCESSOR(IP) TEST PROCEDURE/AUTOMATIC MODE PAGE ____ PARA _____

TEST SEQUENCE:

ID 4.2 STEP 5 THRU 9 PAGE 1&2

TR ORIGIN: BWI AIRPORT, PIER B, LANE 2, X-RAY	PROBLEM REPRODUCED ? Yes/No YES

PROBLEM DESCRIPTION & DUPLICATION PROCEDURE:

During the automatic mode of operation when a bag containing a contraband item is detected, the x-ray chamber will perform processing and the bag is supposed to be totally contained within the chamber for processing. The purpose is to prevent an adversary from grabbing the bag and having access to the contraband. Tests have been conducted, and the bags were found to extend outside of the x-ray chamber.

FOLLOW-UP STATUS: Sandia National Laboratories will contact J.Clement to discuss the problem and possible solution which could involve adjusting the belt positioning/timing.	DATE: 8/20/93
APPROVED: TEST DIRECTOR	DATE:
ACTION ITEM STATUS: OPEN __X__ CLOSED _____	DATE: 8/19/93

TROUBLE REPORT (TR)	
PROJECT: ENHANCED AIRPORT SECURITY SYSTEM	TR#:02
TR TITLE: IMAGE PROCESSING TOUCH SCREEN FAILURE	TR PRIORITY: Minor _____ Major _____ Critical __X__
ORIGINATOR: R.J.FELBINGER C.BOLLING	DATE/TIME OCCURRED: 8/25/93 / 10:00AM
SUPPLEMENTAL TROUBLE DATA: NONE	TEST TOOLS: SELF DIAGNOSTICS
SUB-SYSTEM FAILURE: TOUCH SCREEN FUNCTION FAILURE	SOFTWARE/VERSION: XISPS

REFERENCE DOCUMENT:

REV/VOL IMAGE PROCESSOR(IP) TEST PROCEDURE/AUTOMATIC MODE PAGE ____ PARA _____

TEST SEQUENCE:

ID 4.2-4 STEP 1 PAGE 1

TR ORIGIN: BWI AIRPORT, PIER B, LANE 2, X-RAY	PROBLEM REPRODUCED ? Yes/No YES

PROBLEM DESCRIPTION & DUPLICATION PROCEDURE:

Several attempts were made to re-boot the system in order to get the Touch Screen monitor to operate properly on 8/25/93. The Touch Screen was touched in several places and failed to produce any reaction. Preliminary diagnosis is that it was a hardware failure.

FOLLOW-UP STATUS:	DATE: 8/26/93
Monitor substitution was unsuccessful due to high resolution requirements. Further investigation suggest software problem, possibly corrupted file 8/26/93. Problems in loading backup tapes and counters. Awaiting assistance from Sandia (TAN THAI) 8/31/93.	
APPROVED: TEST DIRECTOR	DATE:
ACTION ITEM STATUS: OPEN __X__ CLOSED _____	DATE: 8/26/93

TROUBLE REPORT (TR)

PROJECT: ENHANCED AIRPORT SECURITY SYSTEM	TR#:03
TR TITLE: KEYBOARD ENTRY PROBLEM	TR PRIORITY: Minor X Major _____ Critical _____
ORIGINATOR: R.J.FELBINGER C.BOLLING	DATE/TIME OCCURRED: 8/25/93 / 10:00AM
SUPPLEMENTAL TROUBLE DATA: NONE	TEST TOOLS: SELF DIAGNOSTICS
SUB-SYSTEM FAILURE: HARDWARE FAILURE(KEYBOARD) FAILED TO ACCEPT THE CHARACTERS TYPED ON THE KEYBOARD	SOFTWARE/VERSION: XISPS

REFERENCE DOCUMENT:

REV/VOL IMAGE PROCESSOR(IP) TEST PROCEDURE/AUTOMATIC MODE PAGE ____ PARA _____

TEST SEQUENCE:

ID 4.2 STEP 1 PAGE _____

TR ORIGIN: BWI AIRPORT, PIER B, LANE 2, X-Ray	PROBLEM REPRODUCED ? Yes/No YES

PROBLEM DESCRIPTION & DUPLICATION PROCEDURE:

Failure of the keyboard to accept user login/re-boot has resulted in delays in testing. Attempts have been made to clean the keyboard and the keyboard function did improve, however the problem still persists.

FOLLOW-UP STATUS: No specific action has been taken at this time although keyboard replacement has been recommended.	DATE: 8/30/93
APPROVED: TEST DIRECTOR	DATE:
ACTION ITEM STATUS: OPEN X CLOSED _____	DATE: 8/30/93

TROUBLE REPORT (TR)

PROJECT: ENHANCED AIRPORT SECURITY SYSTEM	TR#:04
TR TITLE: BAG SEPARATION/PASSAGE THROUGH THE TEST CHAMBER	TR PRIORITY: Minor ____ Major ___X___ Critical ____
ORIGINATOR: R.J.FELBINGER C.BOLLING	DATE/TIME OCCURRED: 8/25/93 / 10:00AM
SUPPLEMENTAL TROUBLE DATA: NONE	TEST TOOLS: SELF DIAGNOSTICS
SUB-SYSTEM FAILURE: FAILURE OF BAGS TO PASS THROUGH TEST CHAMBER	SOFTWARE/VERSION: XISPS

REFERENCE DOCUMENT:

REV/VOL IMAGE PROCESSOR(IP) TEST PROCEDURE/AUTOMATIC MODE PAGE ____ PARA ____

TEST SEQUENCE:

ID 4.2 STEP 4 thru 9 PAGE 1&2

TR ORIGIN: BWI AIRPORT, PIER B, LANE 2, X-Ray	PROBLEM REPRODUCED ? Yes/No YES

PROBLEM DESCRIPTION & DUPLICATION PROCEDURE:

When bags are placed on the conveyor belt in too close succession, they will, on occasion, fail to pass through the x-ray chamber. The operator must then press the "START" key on the monitor touchscreen to back the bags out of the chamber.

May be a procedure and/or timing problem. The software never took account of the mass number of bags passing through test chamber together.

FOLLOW-UP STATUS: No specific action has been taken at this time. We believe this may possibly be a software problem.	DATE: 8/30/93
APPROVED: TEST DIRECTOR	DATE:
ACTION ITEM STATUS: OPEN ___X___ CLOSED ____	DATE: 8/30/93