PB2000-105035

DOT/FAA/AR-00/21

Office of Aviation Research
Washington, DC 20591

Test and Evaluation Plan for the Rapiscan Dual View X-ray Machine

Michael D. Snyder
J. Michael Barrientos

Office of Aviation Security Research and Development
Federal Aviation Administration
William J. Hughes Technical Center
Atlantic City International Airport, NJ 08405

March 2000

Test Protocol

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 United States Government assumes no liability for the contents or use thereof. The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because the information is essential to the objective of this report. This document does not constitute FAA certification policy.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-00/21		

4. Title and Subtitle	5. Report Date
Test and Evaluation Plan for the Rapiscan Dual View X-Ray Machine	
	6. Performing Organization Code AAR-510
7. Author(s) Michael Snyder and J. Michael Barrientos	8. Performing Organization Report No. DOT/FAA/AR-00/21
9. Performing Organization Name and Address U.S. Department of Transportation, Federal Aviation Administration William J. Hughes Technical Center Atlantic City International Airport, NJ 08405	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation, Federal Aviation Administration ACP-400 800 Independence Ave., S.W. Washington, DC 20590	13 Type of Report and Period Covered 14. Sponsoring Agency Code ACP-400

15. Supplementary Notes

16. 16. Abstract

This Test and Evaluation Plan describes the evaluation process of dual-view X-ray technology. While a conventional Rapiscan X-ray machine presents only a top-down view of passenger baggage, their Dual View system presents both a top-down and a side view (on individual monitors). Screener performance with this additional view will be compared to performance with only the conventional top-down view. Measures of detection performance will be recorded, analyzed, and evaluated, in addition to usability issues. To acquire usability data, human factors engineers will assess the Dual View system from a technical perspective and screeners will answer questionnaires so the system can be assessed from a user's perspective. The results will be published in a test and evaluation report.

17. Key Words	18. Distribution Statement
Dual View X-Ray System Usability Laboratory Test and Evaluation	This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Page	22. Price
Unclassified	Unclassified	20	

ACRONYMS AND ABBREVIATIONS

ASL	Aviation Security Laboratory
FAA	Federal Aviation Administration
HFE	Human Factors Engineer
IED	Improvised Explosive Device
IRB	Institutional Review Board
MOP	Measure of Performance
P_d	Probability of Detection
P_{fa}	Probability of False Alarm
SIP	Strategic Implementation Plan
TEP	Test and Evaluation Plan

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

1. INTRODUCTION.

1.1 BACKGROUND.

Federal Aviation Regulation 108 requires all air carriers in the United States to provide for the safety of their passengers and property. To comply, air carriers procure equipment and train personnel to screen passengers and their carry-on baggage before they board the aircraft. The Federal Aviation Administration (FAA) ensures compliance with these and other regulations through scheduled and random inspections at airports. Maintaining a proficient screening process is critical to the mission of aviation security, both domestically and internationally.

The FAA, working with the aviation industry, encourages the development of new technology and equipment to improve aviation security for the traveling public. X-ray systems currently in use at airports were designed to aid the screener in the detection of weapons such as guns, knives, and explosive devices like grenades. Because of the increased sophistication of terrorists and Improvised Explosive Devices (IEDs), threat detection is difficult with existing X-ray systems.

Previously, if screeners could not identify an object in a bag, they would re-scan the bag in a different orientation. This two-step process is not time efficient. To address this issue, Rapiscan Security Products, Inc. has developed a dual-view X-ray system. This system simultaneously displays multiple views of a piece of luggage to the user. This technology may enable screeners to increase their screening efficiency and threat detection performance without decreasing throughput.

1.2 PURPOSE.

The purpose of this test is to determine if dual-plane X-ray technology enhances screener performance in threat detection.

1.3 SCOPE.

This evaluation will include the collection and analysis of empirical data of screener performance using the Rapiscan Dual View X-ray machine, as well as human factors issues involving usability. Screener performance in detecting threats with the dual-view system will be compared to performance with only the conventional view of the bag.

2. CRITICAL OPERATIONAL ISSUES, CRITERIA, AND EVALUATION STRATEGIES.

The following Critical Operational Issues and Criteria will be used to evaluate screener performance with conventional and dual-view technology based on the Measures of Performance (MOPs) listed below.

2.1 ISSUE 1 – IMPACT OF DUAL-VIEW TECHNOLOGY ON IMPROVISED EXPLOSIVE DEVICE DETECTION.

Does a dual-view X-ray machine enhance screeners' ability to detect IEDs?

Criterion 1-1 Dual-view performance is better than single-view performance.

MOP 1-1-1 Operators' Probability of Detection (P_d) for IEDs in single-view mode.

MOP 1-1-2 Operators' Probability of False Alarm (P_{fa}) in single-view mode.

MOP 1-1-3 Operators' P_d for IEDs in dual-view mode.

MOP 1-1-4 Operators' P_{fa} in dual-view mode.

2.2 ISSUE 2 – IMPACT OF DUAL-VIEW TECHNOLOGY ON WEAPON DETECTION.

Does a dual-view X-ray machine enhance screeners' ability to detect weapons?

Criterion 2-1 Dual-view performance is better than single-view performance.

MOP 2-1-1 Operators' P_d for weapons in single-view mode.

MOP 2-1-2 Operators' P_{fa} in single-view mode.

MOP 2-1-3 Operators' P_d for weapons in dual-view mode.

MOP 2-1-4 Operators' P_{fa} in dual-view mode.

2.3 ISSUE 3 – USABILITY.

Are there any software or hardware factors or procedural aspects that degrade system usability by screeners?

Criterion 3-1 Investigative in nature.

MOP 3-1-1 Human Factors Engineers (HFEs) will evaluate usability issues.

MOP 3-1-2 Deficiencies found through questionnaires, surveys, interviews, and debriefings with screeners.

3. LABORATORY TEST AND EVALUATION.

Prior to the start of the laboratory test, the test directors will obtain approval from the Institutional Review Board (IRB) to conduct the study. The Board ensures that human

participants will be protected according to 45 CFR, Part 46 of 1981; 49 CFR, Part 11 of 1991; and FAA Order 9500.25, Protection of Human Research Subjects.

3.1 TEST SITE.

The Aviation Security Laboratory (ASL) will be the site of the test. Laboratory #1 will be the specific room used.

3.2 PARTICIPANTS.

Eight screeners from a Category X airport and eight screeners from a Category 1 airport will participate in the study. All screeners must be currently employed as an X-ray operator, 18 years of age or older, and not pregnant. Screeners will participate in the study during their regularly scheduled days off and will be monetarily compensated for their participation.

3.3 TEST PERSONNEL.

Because of the inherent dangers of handling explosives, four FAA explosive specialists from the ASL will also participate in the study. They will be responsible for handling all test bags. Neither screeners nor data collectors will be allowed to touch or handle any objects or equipment in the laboratory except for the X-ray machine console and data collection items.

3.4 EQUIPMENT.

The study will incorporate the use of a Rapiscan Dual View X-ray machine, which is a dual-plane, dual-energy system. This system has two monitors, one that displays an X-ray image from a top-down view and one that displays an image from a side view.

3.5 TEST ARTICLES.

3.5.1 Test Bags.

There will be 120 carry-on test bags used in this study. Twelve of the 120 test bags will contain a single threat (i.e., threat bags). Of the 12 threat bags, 8 will contain an IED, 2 will contain a gun, and 2 will contain a knife. The remaining 108 bags (i.e., comparison bags) will contain only innocent items, such as clothing, sundry items, hair dryers, curling irons, and the like. Table 1 shows a breakdown of the threat and comparison bags according to bag type. The bag types, quantities, and ratios are identical to those used by Fobes and Barrientos [1].

TABLE 1. BREAKDOWN OF TEST BAG SET BY BAG TYPE

Bag Type	Comparison Bags	Threat Bags
70% Briefcases Duffle/Gym Bags Garment Bags Rollaboards	 19 Briefcases 19 Duffle/Gym Bags 20 Garment Bags 18 Rollaboards	 2 Briefcases 2 Duffle/Gym Bags 1 Garment Bag 3 Rollaboards
20% Backpacks Overnight Cases Purses Shoulder Bags	 5 Backpacks 6 Overnight Cases 6 Purses 5 Shoulder Bags	 1 Backpack 1 Shoulder Bag
10% Camera Bags Make-up Kits Personal Computer (PC) Carrying Cases Shopping Bags	 3 Camera Bags 2 Make-up Kits 2 PC Carrying Cases 3 Shopping Bags	 1 Make-up Kit 1 PC Carrying Case
Total Number of Bags	**108**	**12**

3.5.2 Improvised Explosive Devices.

Each of the threat bags will contain a single threat article (e.g., an IED, gun, or knife), which HFEs will randomly assign to the bag set. Explosive specialists will assemble eight IEDs, each of which will contain a different type of explosive and will insert them into the appropriate bags. Table 2 shows these explosives and the types of concealment.

TABLE 2. THREAT BAG CONCEALMENT AND EXPLOSIVE TYPES

This material is classified confidential and not contained in this report. To obtain access, submit a written request citing this document and including a justification to:

The Assistant Administrator for Civil Aviation Security, ACS-1
U.S. Department of Transportation
Federal Aviation Administration
FAA Headquarters
800 Independence Ave., S.W.
Washington, DC 20591

3.6 DATA COLLECTION FORMS.

Prior to the commencement of the study, HFEs will prepare data collection forms that will include the participant number, date, X-ray machine status (i.e., dual view on or off), a listing of the bag numbers, and the screener's response.

They will also distribute a questionnaire to elicit usability information from screeners (see Appendix A). In addition to acquiring screener comments on dual-view technology in general, the test directors hope to gain insight of any system deficiencies.

3.7 TEST SCHEDULE.

The laboratory test will be conducted over a two-week span. Eight screeners will participate each week. They will be brought to the ASL the day before data collection for an overview of the study, safety training, and X-ray machine training. Table 3 provides a tentative schedule of events.

TABLE 3. SCHEDULE OF EVENTS

Day	Date	Event
1	Monday, April 10, 2000	Test overview and safety training for participants 1 and 2
2	Tuesday, April 11, 2000	Data collection for participants 1 and 2 Test overview and safety training for participants 3 and 4
3	Wednesday, April 12, 2000	Data collection for participants 3 and 4 Test overview and safety training for participants 5 and 6
4	Thursday, April 13, 2000	Data collection for participants 5 and 6 Test overview and safety training for participants 7 and 8
5	Friday, April 14, 2000	Data collection for participants 7 and 8
6	Monday, April 17, 2000	Test overview and safety training for participants 9 and 10
7	Tuesday, April 18, 2000	Data collection for participants 9 and 10 Test overview and safety training for participants 11 and 12
8	Wednesday, April 19, 2000	Data collection for participants 11 and 12 Test overview and safety training for participants 13 and 14
9	Thursday, April 20, 2000	Data collection for participants 13 and 14 Test overview and safety training for participants 15 and 16
10	Friday, April 21, 2000	Data collection for participants 15 and 16

3.7.1 Test Overview and Safety Training.

Prior to the commencement of the study, test directors will brief screeners on specific objectives and experimental procedures. In addition, they will address the risks involved and exact duties required of the screeners. All participants will have plenty of opportunities to ask questions during this time. Screeners who are willing to continue will then be asked to sign a consent form (see Appendix B) stating that they understand the risks involved and that they are willfully volunteering to participate.

Following this, an ASL Safety Officer will offer a safety training class to those individuals willing to continue. The training will include evacuation routes, emergency telephone numbers, and a safety video. The initial briefing and safety training should take approximately 45 minutes.

3.7.2 X-Ray Machine Training.

After the completion of the briefing and safety training, the session will conclude with X-ray machine training. A Rapiscan representative will show screeners how to operate their system, including specific machine functions such as zooming, organic and inorganic stripping, and inverse video. The training will continue until each participant feels comfortable operating, and shows proficiency in using, the X-ray machine's functions. Typical carry-on bags will be available for screeners to scan, thus giving them a hands-on opportunity to use the system.

3.8 TEST PROCEDURES.

The Dual View X-ray machine will be tested in conjunction with another X-ray system that has a 3-dimensional display, however the Test and Evaluation Plan (TEP) and results will be published independently [2]. Therefore, the following test procedures incorporate both of these new systems.

Two screeners will participate in the study each day. Each participant will assess the bag set (120 bags) on both X-ray machines (i.e., Dual View and 3-D) under four treatment conditions (dual view on and off and 3-D on and off). The bag set will be broken into four subsets (A, B, C, and D) to counterbalance bag order.

The bag screening process should take a maximum of 5 hours. Table 4 shows a Latin square design depicting X-ray machine sequence, treatment conditions, and bag order.

The remaining two hours of the day will be used to train participants scheduled the following day. As mentioned earlier, there will be instruction on how to use the X-ray machines, their functionality, and time to scan practice bags. In addition, this period will allow participants to become accustomed to the dual-view and 3-D technology.

TABLE 4. COUNTERBALANCED DESIGN FOR TREATMENT CONDITIONS

Screener	Dual View On		Dual View Off		3-D On		3-D Off	
	Machine Sequence	Bag Order	Machine Sequence	Bag Order	Machine Sequence	Bag Order	Machine Sequence	Bag Order
1	1	ABCD	2	DABC	3	CBAD	4	CABD
2	3	ADCB	4	BDCA	1	CDAB	2	BCDA
3	1	DBAC	2	CADB	4	ABCD	3	DBCA
4	3	CADB	4	CDAB	2	DBCA	1	ACDB
5	1	ACDB	3	ABCD	2	CDBA	4	BCAD
6	4	ADBC	2	BACD	1	DBAC	3	CDAB
7	3	BADC	1	ACDB	4	BDCA	2	DACB
8	2	CBDA	4	CABD	3	DCBA	1	DBAC
9	1	ACBD	4	BCDA	3	CABD	2	DCAB
10	3	BDCA	2	ABDC	1	BDAC	4	DABC
11	2	ABDC	3	ACBD	4	DABC	1	BACD
12	4	BCDA	1	CDBA	2	DCAB	3	BDAC
13	2	DACB	3	BDAC	1	ADCB	4	BADC
14	4	DCBA	1	CBAD	3	ACBD	2	CBDA
15	2	BCAD	1	DBCA	4	ABDC	3	CBAD
16	4	DCAB	3	ADCB	2	ADBC	1	CADB

3.9 USABILITY ASSESSMENT.

In addition to the laboratory test and evaluation, HFEs will conduct a usability assessment of the Dual View X-ray machine. The assessment will determine whether any part of the software, hardware, or required procedures impede rather than enhance operator performance. HFEs will focus on how the machine displays information, the quality of the images, and the compatibility of the user interface with the tasks of the operator. Data collection forms will be used to assess any deficiencies that result in a decrement in screener performance.

4. DATA ANALYSIS.

HFEs will calculate and report quantitative data analyses on the hit rate (P_d) and false alarm rate (P_{fa}) for explosives and weapons for each treatment condition. They will compare screeners' baseline performance (i.e., dual view and 3-D turned off) to their performance using the new technology (i.e., dual view and 3-D turned on). Separate within-subjects analyses will be conducted on the data for each X-ray machine.

In addition, HFEs will summarize the qualitative data from questionnaires and interview notes. Furthermore, they will summarize the data from the usability evaluation and report any deficiencies found with the system. Finally, HFEs will document the results of the data analysis in a final test and evaluation report.

5. TEST MILESTONES.

Table 5 shows the milestones for planning and reporting of the Operational Test & Evaluation. The SIP dates refer to AAR-500's Strategic Implementation Plan required delivery dates.

TABLE 5. OPERATIONAL TEST AND EVALUATION MILESTONES

MILESTONES	TEST DATE	SIP DATE	RESPONSIBLE PARTY
Apply for IRB approval	February 14, 2000	—	AAR-510
Write Health and Safety Plan	February 28, 2000	—	AAR-510
Approve TEP	March 3, 2000	—	AAR-510
Coordinate Screeners	March 10, 2000	—	Contractor
Coordinate Explosive Handlers	March 17, 2000	—	AAR-510/AAR-520
Coordinate X-ray Machine Training	March 17, 2000	—	AAR-510
Prepare Bag Set	March 24, 2000	—	AAR-510
Assemble IEDs	April 5, 2000	—	AAR-520
Prepare Data Collection Forms	April 8, 2000	—	Contractor
Collect Data	April 10-21, 2000	July 7, 2000	Contractor
Develop and Populate Database	April 26, 2000	—	Contractor
Prepare Draft Report	May 6, 2000	September 29, 2000	AAR-510/Contractor
Deliver Final Report	May 27, 2000	September 29, 2000	AAR-510

6. REFERENCES.

1. Fobes, J. L., & Barrientos, J. M. (1997). *Test and Evaluation Report for Alarm Resolution With X-Ray Screener Assist Technologies* (DOT/FAA/AR-97/59). Atlantic City International Airport, NJ: William J. Hughes Technical Center.

2. Barrientos, J. M., & Snyder, M. D. (in press). *Test and Evaluation Plan for Image Scan Holding's Axis-3D X-Ray Machine* (DOT/FAA/AR-99/XX). Atlantic City International Airport, NJ: William J. Hughes Technical Center.

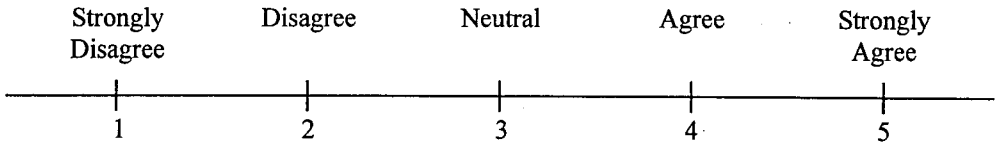
APPENDIX A
USERS' QUESTIONNAIRE FOR THE DUAL VIEW X-RAY SYSTEM

Dual View Study Questionnaire

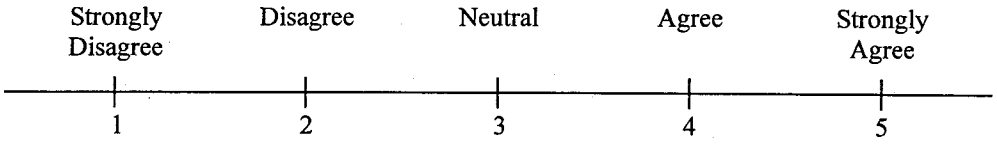
The FAA is interested in your opinion of the study. Your ratings will be an important part of the X-ray machine evaluation. We are not requesting that you provide your name so you can provide your honest opinion. Your help is greatly appreciated.

Please **circle the number** that best describes your opinion.

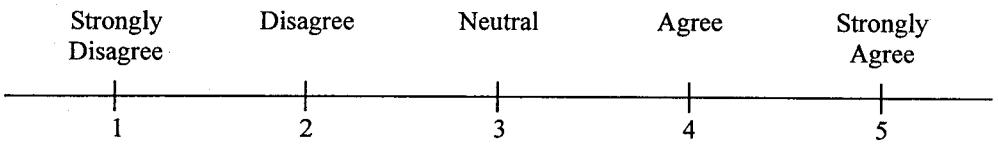
1. The training I received for the Dual View X-ray machine gave me enough knowledge to run the machine adequately.



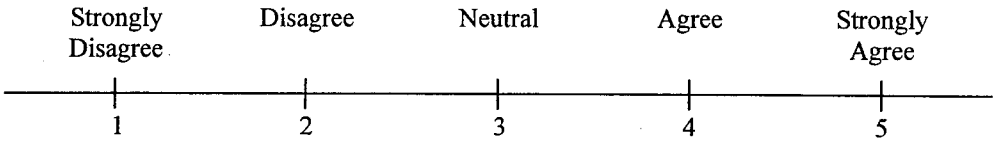
2. The Dual View X-ray machine was easy to use.



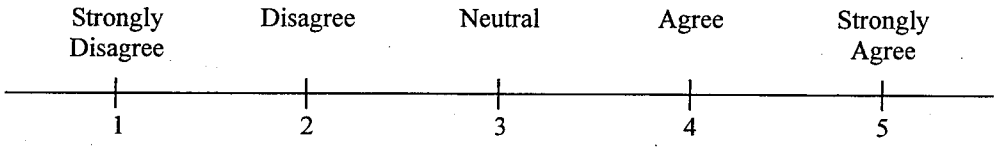
3. The two views on the Dual View X-ray machine were confusing.



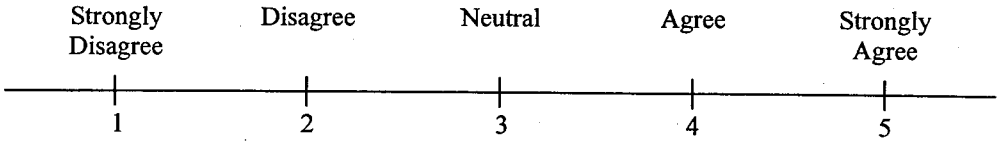
4. The Dual View X-ray machine increased my ability to find bombs.



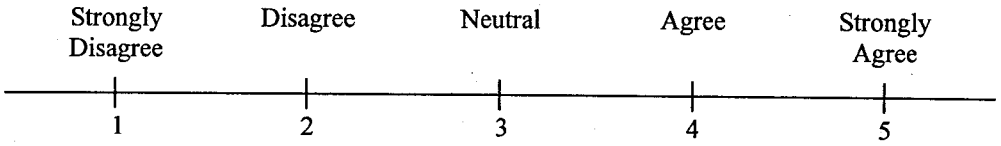
5. The Dual View X-ray machine increased my ability to find guns.



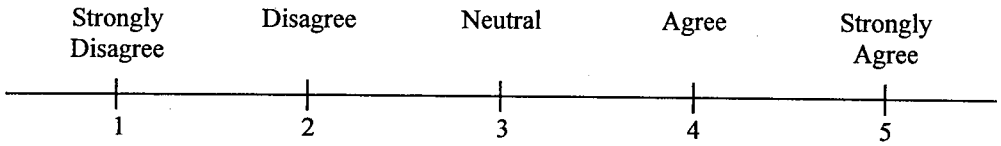
6. The Dual View X-ray machine increased my ability to find knives.



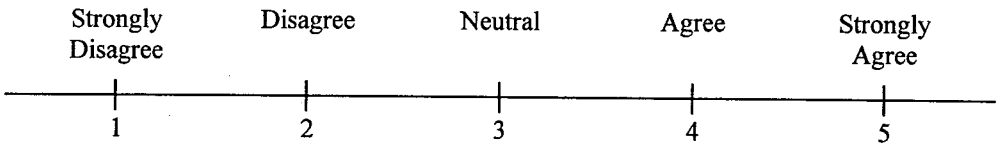
7. Most of the time I watched one display (either the top-view or side-view of the X-ray image) and ignored the other.



8. Operators who use the Dual View X-ray machine should make better screeners.



9. I would recommend the Dual View X-ray machine to other screeners.



Comments: _____

_____

_____

_____

_____

_____

_____

_____

_____

APPENDIX B
CONSENT FORM

INFORMED CONSENT FORM FOR THE
TEST AND EVALUATION OF THE RAPISCAN DUAL VIEW X-RAY MACHINE

I, _____, have received a briefing by the Test Director about the purpose and procedures of the test and have been provided ample opportunity to ask questions. I understand that my participation is voluntary and that I have not given up any of my legal rights or released any individual or institution from liability for negligence.

I know that the test will require training on a dual-view X-ray system and that it involves the screening of carry-on passenger baggage, some of which will contain actual explosives and therefore, involves some risks. However, neither a live detonator nor any other explosive initiator will be present in the bags. To minimize the risk involved, I have been informed of all of the safety precautions that will be taken to ensure that testing is carried out in a safe and secure manner. Training and testing will require approximately one day each.

I also understand that my exposure to X-ray radiation will not exceed that in which I am normally exposed. In addition, I realize that I am required to wear a dosimeter that will be analyzed at the end of each month. I will be informed of any abnormally high radiation exposure amounts. I also understand that I will not be exposed to any toxic materials or devices.
As part of the data analysis, my data will be combined with that of other individuals and I will no longer be identifiable as a participant. I have been informed that my name will remain CONFIDENTIAL.

I have also been informed that I have the right to withdraw from the test without penalty or loss of benefits to which I am otherwise entitled. In addition, I understand that the Test Director may terminate my participation in the interest of safety and the test. I also certify that I am currently a pre-board screener, at least 18 years of age, and am NOT pregnant.

I have been informed that if I have any further concerns or questions, I may contact either of the Test Directors, Michael Snyder at (609) 485-5388 or Michael Barrientos at (609) 485-6825.

I have read this consent form and understand its contents. I freely consent to participate in this study under the conditions described and have received a copy of this form.

Signed: _____
Date: ___/___/2000
Witness: _____
Date: ___/___/2000