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TP13148E

Upgrade to the Computer-Assisted X-ray Screening System (X-Array)

Prepared for

Transportation Development Centre
Safety and SecurityTransport Canada

November 1997

Prepared by
Array Systems Computing Inc.
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Upgrade to the Computer-Assisted X-ray Screening System (X-Array)

by

Jane Cunningham

November 1997

Notices

This report reflects the views of the authors, and not necessarily those of the Transportation Development Centre.

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Un sommaire français se trouve avant la table des matières.

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16. Abstract

Over the past six years, Array Systems Computing Inc. (Array) has worked on various phases of a research and development contract to develop a Computer Assisted X-ray Screening System (CAXSS), called X-Array. The last phase of the project was completed in 1996 and made the X-Array operate in real time, while improving its detection rate and system reliability.

The project examined ways to improve the reliability of the X-Array by:

- Developing a new interface between the X-Array and the EG&G Linescan 110 screening machine.
- Identifying and correcting sources of X-Array malfunction.

Array did not develop a new interface between the X-Array and the EG&G machine. We investigated several options, but found them unsuitable for the application. Array does not recommend further development of the interface at this time.

We identified and corrected a number of sources of X-Array malfunctions. These corrections improved the X-Array reliability and Array recommends that the field trials proceed.

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16. Résumé

Au cours des six dernières années, Array Systems Computing Inc. (Array) a réalisé les différentes étapes d'un projet de recherche et de développement visant à mettre au point un système de détection par rayons X assisté par ordinateur, appelé X-Array. Une fois la dernière étape du projet franchie en 1996, le système X-Array a pu être testé en temps réel, son taux de détection et sa fiabilité étant améliorés au fur et à mesure.

Le projet de mise à niveau en question visait à améliorer la fiabilité du système X-Array grâce aux mesures suivantes :

- Élaborer une nouvelle interface entre le X-Array et l'appareil de détection EG&G Linescan 110.
- Identifier et corriger les causes du mauvais fonctionnement du X-Array.

Array n'a pas élaboré de nouvelle interface entre le X-Array et l'appareil EG&G. Nous avons analysé différentes options, mais aucune ne convenait à l'application. Array recommande de ne pas travailler au développement de l'interface pour l'instant.

Nous avons identifié et corrigé un certain nombre de causes du mauvais fonctionnement du X-Array. Ces correctifs ont amélioré la fiabilité du système et Array recommande de commencer les essais pratiques.

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Executive Summary

Array started work on the X-Array Upgrade Project on March 10, 1997. The project examined ways to improve the reliability of the X-Array by:

- Developing a new interface between the X-Array and the EG&G Linescan 110 screening machine.
- Identifying and correcting sources of X-Array malfunction.

Array divided the project into four stages:

- Requirements Analysis
- Design
- Implementation
- Test

The Requirements Analysis phase started on March 10, 1997 and finished on May 9, 1997. The result of this phase was a document entitled, "X-Array Upgrade Requirements Specification".

The Design phase started on May 1, 1997. The Design phase had three objectives:

- To design the image transfer interface.
- To design the command and control interface (completed).
- To design software and hardware changes required to improve X-Array reliability (identified problems were corrected).

The Implementation phase started on July 2, 1997. The Implementation phase had three objectives:

- Implementation of the image transfer interface (not done).
- Implementation of the command and control interface (not done).
- Implementation of X-Array software and hardware changes required to improve reliability (identified problems have been corrected).

The Test phase started on September 29, 1997 and the test results appear in this report.

In parallel with the X-Array Upgrade Project work, Array invested labour in the X-Array system. This investment demonstrated the feasibility of porting the X-Array system software from its expensive hardware platform to a low cost, single board computer platform.

Sommaire

Array a amorcé le projet de mise à niveau du système X-Array le 10 mars 1997. Ce projet visait à étudier différentes façons d'améliorer l'efficacité du système X-Array grâce aux mesures suivantes:

- Élaborer une nouvelle interface entre le X-Array et l'appareil de détection EG&G Linescan 110.
- Identifier et corriger les causes du mauvais fonctionnement du X-Array.

Array a subdivisé le projet en quatre étapes:

- Analyse des besoins
- Conception
- Mise en oeuvre
- Essais

L'analyse des besoins a commencé le 10 mars 1997 pour se terminer le 9 mai de la même année. Il en est résulté un document intitulé "X-Array Upgrade Requirements Specification".

La conception a commencé le 1er mai 1997; elle visait trois objectifs:

- Concevoir l'interface de transfert des images.
- Concevoir l'interface de commande et de contrôle (terminé).
- Établir les modifications logicielles et matérielles requises pour améliorer la fiabilité du système X-Array (les problèmes cernés ont été corrigés).

La mise en oeuvre a commencé le 2 juillet 1997: elle visait trois objectifs:

- La mise en oeuvre de l'interface de transfert des images (non effectuée).
- La mise en oeuvre de l'interface de commande et de contrôle (non effectuée).
- La mise en oeuvre des modifications logicielles et matérielles requises pour améliorer la fiabilité du système X-Array (les problèmes cernés ont été corrigés).

Les essais ont commencé le 29 septembre 1997; les résultats sont présentés dans ce rapport.

Parallèlement aux travaux de mise à niveau, Array a investi des ressources humaines dans le système X-Array. Cet investissement a permis de démontrer qu'il était possible de porter le logiciel du système X-Array de la plate-form matérielle coûteuse actuelle à une plate-form monocarte moins coûteuse.

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1.0 INTRODUCTION

The purpose of the X-Array Upgrade Project was to improve the reliability of the X-Array, a Computer Assisted X-Ray Screening System (CAXSS), in preparation for field trials.

Over the past six years, Array has worked on various phases of a research and development contract to develop the X-Array. This project was a joint venture between the Transportation Development Centre and the Federal Aviation Authority. The last phase of the project, which was completed in 1996, made the X-Array operate in real time and improved its detection rate and the system reliability.

This report describes the progress of the X-Array Upgrade Project from September 19, 1997 to November 25, 1997. Progress Report Number 1 (PR1) described progress made between contract award and July 20, 1997. Progress Report Number 2 (PR2) described progress from July 20, 1997 to September 16, 1997. The project's main objectives were to further improve the reliability of the X-Array by:

- Developing a new interface between the X-Array and the EG&G Linescan 110 screening machine.
- Identifying and correcting other sources of X-Array malfunction.

In parallel with this project, Array invested approximately $18 000 in labour costs developing the X-Array system:

- Array completed a proof-of-concept 'port' of the X-Array software to a single board Pentium computer and, at the same time, discovered and corrected software bugs, at a cost of $10 000.
- Array investigated the development of an interface to the Hiemann X-ray scanner at a cost of $4 000.
- Array initiated the 'port' of the X-Array software to a Windows NT, Pentium platform, at a cost to date of $4 000.

1.1 Background

This section provides additional details on the X-Array system as it existed at the start of the project. The system and its components as they existed then are referred to as the 'original' system or 'original' components.

1.1.1 Malfunctions Due to the Original Interface

The original interface requires the use of a non-standard EG&G Display Processing Unit (DPU). The non-standard DPU provides a low-cost interface that is suitable for the proof-of-concept phase of the X-Array. Array believed that the use of the non-standard DPU during airport trials was not possible for two reasons:

- It interferes with the self-diagnostic capability of the EG&G machine.
- It is unreliable, causing the X-Array system to crash and hang-up.

1.1.2 Other Sources of Malfunctions

During in-house tests of the original X-Array we discovered that the majority of malfunctions were not attributable to the interface. Array began investigating other sources of failure:

- X-Array software errors.
- Interaction between X-Array software and the Windows 3.1 operating system.
- Parallel Processing Unit (PPU) hardware failures, possibly related to the age of the unit.

In parallel with this project, Array also investigated the 'porting' of the original X-Array software to a Pentium platform running Windows NT. The new platform does not require the PPU hardware. The preliminary investigations in this area were undertaken at Array's expense. The results are a slower-than-real-time, single board computer implementation of the X-Array that runs under Windows 3.1.

Since the completion of the single board computer implementation, Array designed and documented the 'port' of the X-Array software to a single board implementation running under Windows NT. The documentation of the design was delivered with PR2. Since then Array has completed (at its own cost) approximately 75 percent of the 'port'. This design has several advantages over the current implementation:

- The cost of hardware is significantly lower.
- Reliability is significantly improved.
- Software will be scalable to a degree not currently possible, e.g., the addition of more detection streams and enhancements to existing detection streams will be possible.

1.2 Document Overview

This report contains the following sections:

- Approach and Procedures
- Apparatus
- Tests

- Results
- Analysis of Results
- Conclusions
- Recommendations

The report contains two appendices:

- Appendix A: X-Array Test Report. This document reports on the results of X-Array reliability and performance testing.
- Appendix B: List of software and hardware procured for the X-Array Upgrade Project.

2.0 APPROACH AND PROCEDURES

The project was divided into four stages:

- Requirements Analysis
- Design
- Implementation
- Test

The objectives and current status of each phase are described in the following subsections.

2.1 Requirements Analysis Phase

Work on this phase started on March 10, 1997 and finished on May 9, 1997.

The Requirements Analysis phase had two objectives:

- The definition of X-Array hardware and software changes required for the implementation of an interface to a standard EG&G Linescan 110.
- The definition of X-Array hardware and software changes required to improve X-Array reliability.

This phase resulted in a document entitled, "X-Array Upgrade Requirements Specification", which was delivered with PR2. This specification forms the basis for the work done during subsequent phases of the project.

The Requirements Analysis Phase was conducted as two parallel tasks: the analysis of the interface between the EG&G and X-Array and the analysis of X-Array software and hardware malfunctions.

2.1.1 Interface Analysis

Array determined that two independent interfaces would be required between the X-Array and the EG&G Linescan machine:

- A Small Computer Systems Interface (SCSI) to transfer image data from the EG&G Linescan 110 to the X-Array.
- A CANBus interface to transfer command and control data from the X-Array to the EG&G Linescan.

The CANBus interface hardware was ordered in late April 1997 and was received on June 17, 1997. The design and implementation of the control and command interface are discussed in section 2.2 and section 2.3.

2.1.1.1 SCSI Interface

Following detailed technical discussions with manufacturer's sales representatives and technical personnel, Array identified the Verisys SCSI Analyzer as the board best suited to our application. Array ordered a board on a no charge evaluation basis, and received it on April 4, 1997.

It was quickly determined that the Verisys SCSI Analyzer was not a suitable interface between the EG&G and the X-Array for the following reasons:

- It was not capable of receiving and storing data from the EG&G at the required rates.
- It was not capable of transferring stored (captured) data from its own on-board memory to the Personal Computer (PC) memory.
- It was not easily interfaced to the X-Array software, and expected to be controlled by its own PC host program. The operation of the PC host program precluded operation of the X-Array software.

On May 15, 1997, the Verisys SCSI Analyzer was returned.

The Verisys board did permit a more detailed analysis and definition of the interface requirements between the EG&G and the X-Array (see the X-Array Upgrade Requirements Specification, delivered with PR2). Based on these requirements, a Fujitsu SCSI Protocol Controller card was ordered from Insight Electronics on April 21, 1997. Despite frequent communications with this supplier, the card was never delivered, and Array cancelled the order in late October 1997.

2.1.1.2 Interface to Hiemann Machine

In parallel with the analysis of the interface and the definition of interface related requirements, Array investigated the development of an interface to the Hiemann X-Ray scanning machine. The investigations were carried out at Array's expense, at a cost of approximately $4 000. They showed that the development of an interface to the Hiemann is possible.

2.1.2 Software and Hardware Analysis

The original X-Array hardware and software were analyzed to determine if changes unrelated to the interface could improve X-Array reliability. As a result of the investigations, Array 'ported' the existing X-Array software to a single board, Pentium PC platform running under Windows. This 'port' was successful and demonstrated the feasibility of such an implementation. The 'port' was done at Array's expense, at a cost of approximately $10 000.

2.2 Design Phase

The Design Phase commenced on May 1, 1997 and ended on November 1, 1997. The Design phase had three objectives:

- Design of the image transfer interface.
- Design of the command and control interface.
- Design of X-Array software and hardware changes required to improve reliability.

Design of the image transfer interface is not complete. During this reporting period:

- Array cancelled the order of the Fujitsu interface card. The card had been on order for over six months at the time of cancellation, and the supplier was not willing to guarantee a delivery date.
- Array investigated the use of the IPC-8500 SCSI analyzer manufactured by I-Tech Corporation. Close inspection of the card's specification manual, obtained on loan from the supplier, indicated that the card could not be used with the X-Array system compiler and library. This card was not therefore, a feasible option.

Array completed the design of the command and control interface. The interface can be implemented using a standard off-the-shelf interface card and the standard CANBus command protocol.

Array completed the design of X-Array software and hardware changes required to improve reliability. Array identified a number of X-Array software and logic errors. Refer to section 2.3 for more information.

Array has documented the X-Array design that will allow a full port of X-Array software from the current hardware platform to a Pentium platform running under Windows NT (see the X-Array Design Changes Document, delivered with PR2). There were three key issues involved in the design of the 'port':

- Maintaining the current X-Array detection performance.
- Maintaining or improving the current X-Array real-time processing rate.
- Ensuring that device drivers (mouse, screen, disks, etc.) are properly 'ported'.

2.3 Implementation Phase

The Implementation Phase commenced on July 2, 1997 and ended on November 1, 1997. The implementation phase had three objectives:

- Implementing the image transfer interface.

- Implementing the command and control interface.
- Implementing of X-Array software and hardware changes required to improve reliability.

Owing to our failure to find a suitable interface card, we were not able to implement the image transfer interface. We were similarly unable to complete the command and control interface, using the CANBus card and protocol.

Implementation of the X-Array software and hardware changes related to the ‘port’ to the Pentium platform has started and is currently about 75 percent complete. Array has spent approximately $4 000 to date.

Minor upgrades to X-Array hardware have been implemented. In particular, the 80486 PC has been replaced with a Pentium PC. This Pentium PC uses the PPU used by the previous PC. As well, the X-Array monitor has been replaced by a 17 inch, touch screen monitor. Neither of these changes has resulted in X-Array software changes.

In addition to the above, Array has implemented a number of X-Array code changes. Array identified a number of software programming errors that were responsible for most, if not all, of the observed X-Array malfunctions. Array corrected these bugs at our own expense, in parallel with the project work. Identified bugs include:

- A PPU coding error, causing PPU failures after processing a certain number of bags. The number of bags processed prior to the failure is high (over 100) and is dependent on bag size. Array corrected this error.
- A logic error in the code that determines where one bag ends and where the next bag starts. This error was responsible for a number of operational errors, including the incorrect segmentation of bags, bags scrolling off the screen without first pausing, and occasional X-Array software crashes. Array corrected this error.
- A coding error in the handling of operator inputs during the analysis of a bag. This error resulted in program crashes when the operator commands the EG&G belt to stop during bag analysis. Array corrected this error.
- A coding error in the detection of very large guns, causing them to be detected as opaques. Array corrected this error.

2.4 Test Phase

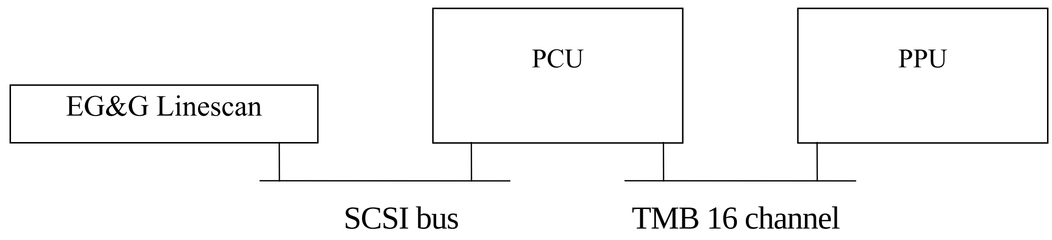
The Test Phase started on September 29, 1997 and ended on November 18, 1997. The test phase objective was to prove that the X-Array product meets the requirements stated in the X-Array Upgrade System Requirements Specification, delivered with PR2.

The results of the testing are documented in the X-Array Test Report (Appendix A).

3.0 APPARATUS

The system hardware consists of an IBM PC compatible computer and an off-the-shelf PPU. We refer to the computer as the Personal Computer Unit (PCU). Figure 1 shows the configuration of the current CAXSS system.

FIGURE 1. Overview of X-Array System



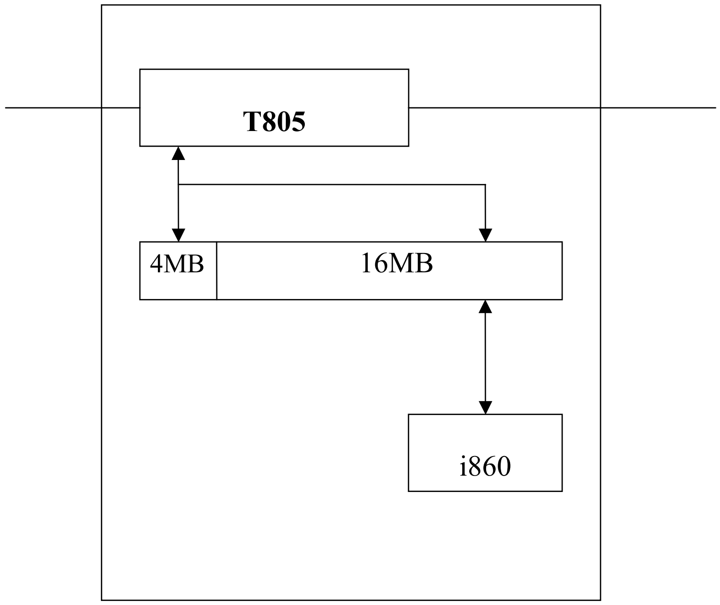
3.1 PCU Hardware

The PCU contains an Intel Pentium 100MHz CPU, 16 MB RAM, 1.9 GB SCSI hard drive, a Matrox local bus graphics accelerator (Impression), and a TMB16 interface card to facilitate communication with the PPU. The mother board of the PCU has a VESA local bus for the graphics card and a SCSI card to interface the PCU to the EG&G Linescan.

3.2 PPU Hardware

The PPU is housed in a ‘pizza-box’ unit called the Transtech Parastation. This contains a Transtech Motherboard (TMB24) which may be fitted with up to four Transtech Transputer Module (TTM200) daughter boards. The TTM200s consist of a 50 MHz i860 CPU, a T805 transputer and 20 MB RAM. Figure 2 shows the logical organization of the components of a TTM200.

FIGURE 2. Logical Representation of a TTM200 Module.



The RAM in the TTM200 is organized so that the T805 transputer has access to the whole memory address space, while the i860 CPU has access to only 16 megabytes of this address space. Each transputer has four serial communication links that can be connected to other transputers on adjacent TTM200s. Each transputer acts as a communications processor and data manager for its local i860. Data transfer between the T805 and the i860 occurs through the use of the shared memory. Semaphores and triggers handle the data access control.

The transputer in the PPU that is directly connected to the TMB16 interface card in the PCU is referred to as the global master processor. The global master processor is directly connected to the other two TTM200 transputers in the PPU.

3.3 Software

The X-Array software used was version 1.0, running under Microsoft Windows[1] 3.11.

[1]. Trademark of Microsoft Corporation.

4.0 TESTS

The Test Phase started on September 29, 1997 and finished on November 18, 1997.

The purpose of the Test Phase was to show that the X-Array reliability is sufficient to allow airport trials. The airport trials will take place using the original X-Array to EG&G interface. Prior to the airport trials, Transport Canada will be invited to witness a re-test of the X-Array under the X-Array Field Trial Project.

Appendix A contains the results of the Test Phase.

5.0 RESULTS

The following sub-sections summarize the results of the X-Array Upgrade project.

5.1 Image Transfer Interface

Array evaluated two interface cards and determined that neither was suitable for this application.

Array waited over six months for delivery of an interface card. This card was never delivered, so we cancelled the order. Obviously this card was not evaluated.

5.2 Command and Control Interface

Array tested the interface card by developing a stand-alone test program. This showed that the PC can control the EG&G machine belt remotely via the interface card. Changes to the X-Array software and integration of the interface hardware with the X-Array hardware were not done. A new command and control interface is only required if a new image transfer interface is implemented.

5.3 Software Port

A proof-of-concept ‘port’ of the software to a Windows NT platform was completed at Array’s expense. Array has documented changes required to the X-Array system (including software, hardware, and configuration) that will allow a real-time implementation of the X-Array on a Pentium PC platform running Windows NT. The document was delivered with PR2.

Array started ‘porting’ to the Windows NT platform. The ‘port’ is approximately 75 percent complete, and the current version of the Windows NT program can analyze stored bag images.

5.4 Bug Fixes

Array identified and corrected several X-Array software bugs at our own expense. Array will continue to correct bugs as they are discovered.

6.0 ANALYSIS OF RESULTS

6.1 Image Transfer Interface

The design and implementation of an image interface is a high risk item. Array has been unable to identify a suitable interface card.

6.2 Command and Control Interface

Implementation of this interface is of low risk. Internal demonstrations of the interface proved its ability to meet the project needs. However, this interface is required only if a new image transfer interface is implemented.

6.3 Software Port

Completion of this item is a low risk. Risk areas identified include:

- Implementing a new interface to the EG&G machine. The Windows NT version of the X-Array cannot be used with the existing EG&G interface.
- Ability of the system to run at real time rate. The current platform, a 100MHz Pentium, may have to be replaced with a 200 MHz Pentium.

Successful completion of the X-Array 'port' to the Pentium/Windows NT platform offers the following advantages:

- Windows NT is a more reliable hardware platform.
- Windows NT is much more reliable than Windows 3.1.
- A more easily upgradeable and expandable X-Array system. Windows NT is anticipated to be the real-time operating system of choice for many years. As PC technology continues to improve, the processing power of the X-Array can be increased at low cost
- Easier development of interfaces to other scanning machines (the Hiemann for example).
- The aging PPU is no longer required.

6.4 Field Trial Readiness

Array made significant improvements to the X-Array reliability during the course of and in parallel to this project work. Array believes that the X-Array, using the original EG&G custom interface and the original PPU hardware, is ready for field trials. Array has prepared a cost estimate for conducting field trials, and has completed internal formalized robustness and capability testing of the X-Array.

7.0 CONCLUSIONS

Array performed significant work towards the objectives of the X-Array Upgrade Project:

- Array made numerous improvements to the operation and reliability of the X-Array. The X-Array is now ready for field trials.
- Array was not successful in developing a new interface with the EG&G machine. Significant funds have been spent but it now seems unlikely that a low cost, off-the-shelf solution is possible.

8.0 RECOMMENDATIONS

Array has two recommendations:

a) On successful completion of the field trial, Transport Canada should consider funding the development of an interface to the Hiemann machines.

b) On successful completion of the field trial, there should be an investigation into further improvements to the X-Array's detection capabilities.

List of Acronyms

ARRAY	Array Systems Computing Inc.
CAXSS	Computer Assisted X-ray Screening System
CPU	Central Processing Unit
DPU	Display Processing Unit
FAA	Federal Aviation Administration
GB	Gigabyte
MB	Megabyte
MHz	Megahertz
PC	Personal Computer
PCU	Personal Computer Unit
PPU	Parallel Processing Unit
PR1	Progress Report Number 1
R&D	Research and Development
RAM	Random Access Memory
SCSI	Small Computer Systems Interface
TDC	Transportation Development Centre

APPENDIX A

Appendix A contains the X-Array Upgrade Project Report.

Document ID: ASC_XRAYUP_007
Version No: 1.0
Version Date: November 25, 1997

ARRAY SYSTEMS COMPUTING INC.

Test Report

for the

X-ARRAY UPGRADE PROJECT

Prepared for:
Transportation Development Centre
Safety and Security,
Transport Canada.

Prepared by:
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1120 Finch Avenue West, 8th Floor
North York, Ontario, Canada M3J 3H7

ARRAY SYSTEMS COMPUTING INC.

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Test Report

for the

X-ARRAY UPGRADE PROJECT

Author: for Terry Stewart — Nov 25/97 Date

Project Manager: Jane Cunningham — Nov 25/97 Date

Quality Assurance: FOR: Iris Buchan — Nov. 25/97 Date

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Test Report

for the

X-ARRAY UPGRADE PROJECT

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1.0	November 25, 1997	TS	Initial release

Table of Contents

1.0 Introduction

[1] Array Systems Computing Inc. (Array) has developed a computer-assisted threat detection system for airport security. This project (supported by the TDC and the FAA) is known as the X-Array. The technology was demonstrated successfully to the aviation security community at the ITS booth at AVSEC World ‘95.

[2] X-Array is a relatively inexpensive addition to existion airport X-ray machines and provides valuable assistance to the operators. Some of the advantages of X-Array:

- greater operator efficiency
- improved consistency
- reduced stress levels and work breaks
- provides critical extra time for operators to detect more serious but less obvious threats

[3] This document reports the results of the X-Array reliability and operability testing performed by Array at the conclusion of the X-Array Upgrade project.

1.1 Identification

[1] This Test Report (TR) documents the X-Array test procedures and results. These tests demonstrate that the X-Array is ready for field trials.

1.2 Document Overview

[1] Section 1 is the Introduction

[2] Section 2 describes the tests and their results

2.0 Testing and Results

[1] Reliability testing ensures that the X-Array system can accept a high throughput of bags for extended periods of time without crashing, or otherwise decreasing the functionality of the system.

[2] Reliability testing follows two strategies:

a) autonomous testing

b) interactive testing

2.1 Autonomous Reliability Testing

[1] Autonomous testing uses a separate program to send commands to the X-Array software. This removes the need for long periods of human supervision, without requiring modifications to the source code under test.

[2] Testing consists of scanning a single bag repeatedly by running it forward and backward through the X-Ray scanner. After every scan the system saves a copy of the image to disk, and a log file keeps track of every event that occurs during the trial. We tested the reliability of three features over extended periods of time:

a) consistent identification of standard test objects (a knife and a grenade)

b) capture of scanned images to disk

c) control of the EG&G Linescan 110 X-Ray scanner

[3] The tests produced the following results:

a) The system never failed to identify standard test objects. In other words, the image analysis code did not fail to function.

b) The system never failed to capture scanned images to disk.

c) Control of the X-Ray scanner failed. After a period of time, the software crashed and the computer needed a complete restart to restore its functionality. The amount of time that elapsed before a crash was highly variable. The shortest time before a system crash was 30 minutes, while the longest time was 12 hours. The average time was two hours.

2.2 Interactive Reliability Testing

[1] We subjected the X-Array system to six extreme circumstances. The observations are explained in Sections 10.2.1 to 2.2.6.

2.2.1 Frequent Restarting of the Software Component

[1] After initializing the X-Array system the operator pressed the ‘Escape’ key to exit from the software, then re-run the software component immediately.

[2] This always caused a full software crash of Windows and the system needed a hardware reset.

2.2.2 Random Pressing of Buttons and Controls

[1] After initializing the X-Array system the operator spent 30 minutes:

a) Pressing on-screen buttons randomly

b) Pressing keyboard keys randomly

[2] No failures were observed. The system performed within specifications at all times.

2.2.3 Low Disk Space

[1] The operator filled the hard drive to within 2MB of capacity, then ran the X-Array system.

[2] The system crashed when it attempted to save an image to the completely filled drive and could not recover without a full re-boot of the PC. No other problems were observed.

2.2.4 Disconnecting and Reconnecting Communications Cables

[1] The operator disconnected and reconnected the cable between the X-Array system and the X-Ray scanner at various times.

[2] There were no failures if the X-Array was not scanning a bag when the operator disconnected or reconnected the cable. However, if the system was scanning a bag at the time, the X-Ray scanner became unresponsive to commands from the X-Array system and to direct commands from its built -in control panel. Resetting the X-Ray scanner solved this problem.

2.2.5 Resetting the Hardware Component

[1] The operator reset the X-Ray scanner while the X-Array system was running.

[2] If the X-Ray scanner was reset once, the X-Array system could not communicate with it. However, resetting the X-Ray scanner when the X-Array system was in this uncommunicative state restored all functionality.

2.2.6 Long Bags

[1] Scanning long bags (twice or three times the length of normal bags).

[2] The detection software failed when presented with long bags. For example, if the bag is too long the software may not detect any blade threats. This affects bags that have a length approximately twice the width of a normal suitcase.

2.3 Operability Testing

[1] The following features of the original X-Array system were examined in order to show that the functionality of the original interface has been maintained in the current version:

a) **Conveyor Controls -** These are fully functional, as defined in the documentation.

b) **Optional Conveyor Stop Mode -** still has problems with closely spaced bags (by the time it has detected the bag and told the conveyor to stop, the next bag has already been partially scanned). This problem existed in the original X-Array system. Otherwise, this is fully functional, as defined in the documentation.

c) **Image Display Selection** (normal, inverse, contrast, color) **-** This is fully functional, as defined in the documentation.

d) **Image Zoom -** This is fully functional, as defined in the documentation.

e) **Display of Threats and Threat Levels -** This is fully functional, as defined in the documentation. There is the added ability to turn off the display of threats and to display what the image analysis code identified as a threat.

f) **Recall of Recent Bags -** This is fully functional, as defined in the documentation.

g) **Storage of Bags onto the Hard Disk -** This is fully functional, as defined in the documentation with the added ability to automatically store all bags.

h) **Ability to Use Previously Saved Bags -** This is fully functional, as defined in the documentation.

i) **User Selection and Creation of Bag Areas -** This is fully functional, as defined in the documentation.

j) **Touch-Screen Controls -** This is fully functional, as defined in the documentation.

k) **Logging of Events -** This is fully functional, as defined in the documentation.

l) **Configuration of Alert Levels -** This is fully functional, as defined in the documentation.

m) **Enabling/Disabling Detectors -** This is fully functional, as defined in the documentation.

2.4 Performance Testing

[1] The performance of the image analysis portion of the X-Array system was tested by analyzing a set of 318 bags. Detection rates and False Alarm rates are tabulated in the following three configurations:

a) All detectors active (Knife, Gun, Opaque, Grenade)

b) Knife detector only

c) Gun detector only

[2] For each configuration data were analyzed on a per threat basis and on a per bag basis. For the configurations where only one detector was active, statistics are given on how a simple post-detection threshold algorithm could improve the false alarm rate. This thresholding algorithm examines the feature values for each dark-connected-region (the potential threat). If these values fall outside a certain range the system discards them. For example, if the size threshold is 40000 and the dark-connected-region has a value of 50000, the system would not call this object a threat. The system uses a different set of threshold values for the gun and knife detectors

[3] With the system configured to detect only single threats, false alarms were defined as the analysis software indicating one type of threat, when in fact it was another. For example, indicating that a gun was a knife was considered a false alarm.

2.4.1 All Detectors Active

2.4.1.1 Analysis by Bag

[1] Number of Bags: 318

[2] Number of Bags Without Threats: 138 (43.4%)

[3] Number of Bags With Threats: 180 (56.6%)

[4] Number of Bags Falsely Alarmed: 79 (24.8%)

[5] Number of Bags With Missed Threats: 3 (0.9%)

2.4.1.2 Analysis by Threat

[1] Number of Real Threats: 266

[2] Number of Falsely Identified Threats: 240

[3] Number of Missed Threats: 7

2.4.2 Knife Detector Only

2.4.2.1 Analysis by Bag

[1] Number of Bags: 318

[2] Number of Bags Without Threats: 284 (89.3%)

[3] Number of Bags With Threats: 34 (10.7%)

[4] Number of Bags Falsely Alarmed: 120 (37.7%)

[5] Number of Bags With Missed Threats: 4 (1.3%)

2.4.2.2 Analysis By Threat

[1] Number of Real Knives: 47

[2] Number of Falsely Identified Knives: 184

[3] Number of Falsely Identified Knives Eliminated by Thresholding: 66

[4] Number of Missed Knives: 8

[5] Number of Missed Knives due to Opaque Blocking: 3

2.4.3 Gun Detector Only

2.4.3.1 Analysis by Bag

[1] Number of Bags: 302

[2] Number of Bags Without Threats: 203 (67.2%)

[3] Number of Bags With Threats: 99 (32.8%)

[4] Number of Bags Falsely Alarmed: 49 (16.2%)

[5] Number of Bags With Missed Threats: 10 (3.3%)

2.4.3.2 Analysis By Threat

[1] Number of Real Guns: 108

[2] Number of Falsely Identified Guns: 99

[3] Number of Falsely Identified Guns Eliminated by Thresholding: 84

[4] Number of Missed Guns: 10

[5] Number of Missed Knives due to Opaque Blocking: 7

APPENDIX B

The following table shows the software and hardware procured for the X-Array Upgrade Project.

Item	Description	Quantity
1	Pentium 120MHz PC	2
2	Goldstar 76i monitor with Touch-screen and controlling software	1
3	Microsoft Windows NT 4.0	2
4	Microsoft Visual C++ 5.0 Pro	2
5	KTM4X32L 16 MB EDO Memory module	4