INTERNATIONAL LABOUR ORGANIZATION

Seafarers' Identity Documents Convention (Revised), 2003 (No. 185)

ILO Seafarers' Identity Documents Biometric Testing Campaign Report

Part I

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ILO Seafarers' Identity Documents Biometric Testing Campaign Report Part 1

Executive Summary

The International Labour Organization (ILO), a Specialized Agency of the United Nations (UN), is a tripartite organization, in which representatives of Governments, Employers and Workers take part with equal status. In June 2003, the ILO adopted the Seafarers' Identity Documents Convention (Revised), 2003 (Convention No. 185) to prevent acts of terrorism that threaten the security of passengers and crews and the safety of ships. ILO Convention No. 185 will be a binding, international treaty for all Members that ratify it. This Convention will come into force on February 9, 2005.

Implementation of ILO Convention No. 185 will represent the world's first internationally interoperable biometric verification system. In March 2004, the ILO Governing Body adopted the technical standard, ILO SID-0002 Finger Minutiae-Based Biometric Profile for the Seafarers' Identity Documents, which will be used to enable global interoperability of Members' implemented systems (as specified in ILO Convention No. 185). The biometric storage format described in ILO SID-0002 was based on draft ISO standards dated October 2003, but minor modifications were made to satisfy the requirements of storing two fingerprint templates on a two-dimensional PDF417 barcode. No manufacturers were known to have products that supported these draft ISO standards; consequently, modifications to commercial products were necessary. In addition, fingerprint biometric products have not been tested using a test population of seafarers, who have diverse backgrounds, occupational categories, age, and gender distributions in their professional environments. Because no biometric systems had heretofore been tested on seafarers for compliance to the standard adopted by the ILO Governing Body, the International Labour Office (the secretariat of the Organization) commissioned the ILO SID Biometric Testing Campaign to develop a list of compliant biometric products for Members to use when implementing ILO Convention No. 185.

The ILO took measures to ensure that interested biometric algorithm and sensor vendors had the opportunity to participate in the test. The vendors were assured anonymity, consequently, the seven biometric products that are referenced in this report are referred to as Products A through G. All seven products discussed herein passed initial conformance tests and were tested onboard a ship at sea using a Seafarer test population. Onboard tests included genuine comparisons and impostor comparisons to determine False Reject Rates (FRRs) and False Accept Rates (FARs), respectively, for each native product. Interoperability performance was also investigated by processing templates created by one product with each of the other products to determine non-native FRRs.

Only Products A and F met the ILO's stated performance objectives of 1% FRR (or less) at 1% FAR. Products A and F are also the best performing combination of two products with a mean FRR of less than 1% (at 1% FAR) under ideal operating conditions. Several other two-product combinations exhibited acceptable performance in some operating conditions, however these products did not meet the performance objectives (1% FRR at 1% FAR) and did not perform as well as the combination of Products A and F. The error rates for all combinations of 3, 4, 5, and 6 products did not meet the ILO's performance requirements.

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The ILO would like to express its appreciation to the authors of the report, Cynthia Musselman and Valoria S. Valencia (Authenti-Corp, USA) and John Campbell (Bion-Biometrics, Canada) for their painstaking efforts in the preparation and conduct of the test as well as for the preparation of this report.

Foreword

The International Labour Organization (ILO), established in 1919, is a Specialized Agency of the United Nations (UN). It is a tripartite organization, in which representatives of Governments, Employers and Workers take part with equal status. In June 2003, the ILO adopted the Seafarers' Identity Documents Convention (Revised), 2003 (Convention No. 185). The revision of the earlier Convention of 1958 was prompted by discussions held in the International Maritime Organization (IMO) reviewing measures and procedures to prevent acts of terrorism that threaten the security of passengers and crews and the safety of ships. ILO Convention No. 185 will be a binding, international treaty for all Members that ratify it. This Convention will come into force on February 9, 2005.

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The ILO Biometric Testing Campaign consisted of two phases. In the first phase, several biometric algorithm and sensor pairs (referred to as biometric products) underwent preliminary evaluation to determine which systems should be included in the second phase of testing. Seven products were included in the second phase, which was conducted onboard a seafaring vessel. The experimental procedures, results, and analysis are included in this document, *ILO SID Biometric Testing Campaign Report – Part 1*, wherein the tested systems are referred to as Products A through G. Recommendations from the test team for the ILO-Compliant Biometric Products List and a key to the anonymous acronyms used in this report are divulged to the ILO under a separate report, *ILO SID Biometrics Testing Campaign Report – Part 2*.

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1 Introduction

The International Labour Organization (ILO), a Specialized Agency of the United Nations (UN), adopted the Seafarers' Identity Documents Convention (Revised), 2003 (Convention No. 185) in June 2003. The revision of the earlier Convention of 1958 was prompted by discussions held in the International Maritime Organization (IMO) reviewing measures and procedures to prevent acts of terrorism that threaten the security of passengers and crews and the safety of ships. The Seafarers' Identity Documents Convention (Revised), 2003 (ILO Convention No. 185), which is available on the ILO website[1], specifies requirements for a new Seafarers' Identity document, or SID. The specifications for the biometric component of the SID are defined in ILO SID-0002 *Finger Minutiae-Based Biometric Profile for the Seafarers' Identity Documents*, the biometric technical standard adopted by the ILO Governing Body in March 2004, which is also available on the ILO website[2].

The SID will play a vital role in enhancing international port security while facilitating transit, transfer, and shore leave of seafarers in the normal conduct of their profession. For the first time in history, biometric technology will be employed internationally (by ratifying Members of ILO Convention No. 185) in support of a professional identity document.

It is critical that, as governments begin to deploy systems for issuing SIDs to their own seafarers and for verifying other seafarers at their ports of entry, the global network of SID issuance and verification systems be interoperable. This is particularly true for the biometric technology, since it is the primary means by which a seafarer can be verified as the legitimate owner of the SID that is presented as proof of Seafarer identity.

In the SID, two minutiae-based fingerprint templates shall be contained in a single biometric interchange record (BIR), which is itself contained in the payload of a two-dimensional PDF 417 barcode. The format of this ILO SID BIR is specifically defined in ILO standard given by ILO SID-0002 *Finger Minutiae-Based Biometric Profile for the Seafarers' Identity Document*. The minutiae-based templates defined in ILO SID-0002 were derived from a draft international standard for data interchange, ISO/IEC[3] CD 19794-2 – *Biometric Data Interchange Formats – Part 2: Finger Minutiae Data* (ISO/IEC JTC 1 SC37 N 340, dated 2003-10-07), which is designed to allow interoperability among finger minutiae-based biometric vendors, but has never been formally tested.

The fingerprint templates on each card will be used to verify that the person presenting the SID for verification of identity is, in fact, the Seafarer to whom the SID was originally issued. It is important to note that seafarers work in harsh environments that may affect not only the skin of their fingers but also the fingerprint equipment onboard ships and in ports around the world. No fingerprint biometric test has heretofore been conducted on a seafarer population.

As such, the ILO has commissioned a Biometric Testing Campaign to address some of the unknowns that could affect successful deployment of the biometric component of the ILO SID. The ultimate goal of the Campaign was to develop a list of compliant biometric products for Members to use when implementing ILO Convention No. 185.

Performing third-party, independent testing of biometric products from several vendors for both enrollment and verification of seafarers will provide a high level of assurance that systems using biometric

[1] http://www.ilo.org/ilolex/cgi-lex/convde.pl?C185
[2] http://www.ilo.org/public/english/dialogue/sector/papers/maritime/sid0002.pdf
[3] ISO (the International Organization for Standardisation) and IEC (the International Electrotechnical Commission) have a joint technical committee that deals with all standardization in the area of information technologies (including biometrics).

technology will be able to verify seafarers' identities accurately, provided their SIDs were created with another successfully tested biometric technology.

To this end, the Biometric Testing Campaign was partitioned into three primary components:

- The ***conformance*** component of the test determined if the biometric products generate minutiae-based templates that conform to the ILO's requirements. More specifically, the test verified that when given the appropriate demographic fields, the biometric software can enroll two fingers and generate the biometric interchange record (BIR) component of the payload for the SID 2D PDF417 barcode as described in ILO SID-0002.
- The ***performance*** component of the test determined, for each biometric system tested, the false accept rate and false reject rate for identity verification using real seafarers in a realistic seafaring environment over reasonable time periods. If a particular biometric technology is unable to effectively enroll seafarers, or to, successfully verify a seafarer's identity then it is unsuitable for use with the ILO SID.
- The ***interoperability*** component of the test determined if the BIRs generated by one biometric product can be used to verify seafarers using other vendors' biometric products. This test also determined if each biometric product can verify seafarers using BIR generated by other vendors' biometric products. It is vital that global interoperability be achieved among ILO SIDs issued by different governments.

This Technical Report, *ILO Seafarers' Identity Documents (SID) Biometric Testing Campaign Report – Part I*, provides the results of these tests as conducted by the ILO Test Team on real seafarers on a ship at sea.

The ILO SID Biometric Testing Campaign was conducted in two phases. The first phase of the test was performed in a laboratory environment with a limited, non-seafaring test population to determine if the biometric system was conformant to the required BIR format and to perform initial interoperability tests. Only those products that satisfactorily completed the first phase of the test were included in the second phase of the test, which was conducted onboard a seafaring vessel from 25 September 2004 through 7 November 2004 with a test population comprised of 126 actual seafarers, including men and women from 30 countries, a broad distribution of ages, and a diverse set of seafaring job categories. Each Seafarer paid three visits to the test site for biometric verification and data collection. The biometric systems tested in this report are referred to as Biometric Systems A through G as agreed to by the ILO and the vendors participating in the test. The test timeline was tightly constrained by the ILO's requirement for reported results in mid-November 2004.

The ILO Biometrics Testing Campaign is the first test of biometric interoperability of fingerprint minutiae-based biometric templates. Consequently, the results of the Campaign reported in the technical report will be important not only to the ILO and its member nations but also to the international biometrics community. The Test Preparation, Methodology, Results, and Analyses are discussed in detail in the following sections of this report. Analyses targeting any group of seafarers based on age, gender, or ethnicity are specifically outside the scope of this Technical Report.

2 Biometric Product Solicitation

Participation in the ILO Biometric Testing Campaign was open to all biometric vendors. An open solicitation for biometric products compliant with ILO Convention No. 185 and ILO SID-0002 was announced in June 2004. Because ILO Convention No. 185 will be implemented in up to 148 countries, it was important to include as many biometric products in the ILO Biometric Testing Campaign as possible to ensure global access to solution providers. The announcement for the Campaign (provided in Annex A) was posted on the ILO's website and on the public Biometric Consortium Listserv. In the announcement, the ILO's intention to create a list of biometric systems that have successfully satisfied the objectives of the test for use by ratifying Members of ILO Convention No. 185 was explained. The announcement also explained how interested vendors could participate in the ILO's Virtual Bidders' Conference.

Ratification of and implementation of ILO Convention No. 185 will affect up to 148 countries: some of which are developing countries, some transitioning economy countries, and some more prosperous countries. The Convention will apply equally to all countries that ratify it. It was felt that travel costs to attend a traditional meeting format for a bidders' conference in Geneva, Switzerland, would have been cost prohibitive for some interested Member States and biometric vendors. As such, a Virtual Bidders' Conference was held, where communication with interested parties took place via electronic mail to eliminate geographic advantage based on travel costs to any potential participants that a physical meeting might engender.

The virtual bidders' conference was conducted from June 13, 2004 through June 19, 2004. The ILO's Biometric Testing Campaign Announcement invited interested parties to send an email with point of contact details to an ILO email account. Vendors were allowed to ask questions for clarification based on the ILO Test Campaign Announcement and determine their commitment to making the indicated product modifications in advance of the Test Campaign. A total of 18 vendors were added to the global distribution list during the virtual bidders' conference. Questions by the vendors were emailed to the designated ILO email account. Responses to all questions were distributed to the global distribution list. The list of questions and responses is presented in Annex B of this document.

All vendors interested in participating in the test were provided with a detailed description of the test plan and the requirements for their products in advance of the test. Vendors were asked to commit to providing products for inclusion in the Biometric Testing Campaign via email to the designated ILO email account by not later than June 20, 2004.

Participating vendors were asked to provide two fingerprint capture devices and two copies of a software module, or more specifically a Biometric Service Provider (BSP) module. Because the hardware and software provided were evaluated as a single combined biometric product, each BSP vendor was encouraged to select the fingerprint capture device that they believed would be most advantageous to them (for a seafaring population onboard a ship) for the purposes of the test. The BSP performed fingerprint capture and matching, and generated the BIR component of the barcode payload as specified in ILO SID-0002.

3 Protecting the Privacy of the Volunteer Seafarers

In addition to the biometric products, volunteer seafarers were needed to perform the requisite testing. Great lengths were taken to protect the personal information of the seafarers, such as names and fingerprint data.

The first line of protection was the "Personal Information Release Form for Participants of the ILO Biometric Test," which is shown in Annex C. This document, which was signed by all volunteer seafarers, explicitly requires the ILO Test Group to hold confidential all personally identifying data including, but not limited to, name, age, gender, other demographic information, and biometric images and templates. During the shipboard data acquisition and report writing periods, the Release Forms were physically protected by the ILO Test Group. The forms were then sent to Geneva for secure storage by the ILO.

During shipboard data acquisition, which was performed in a client-server IT environment, the client computer transferred all information to the server immediately following each biometric enrollment or verification on a particular sensor. The client software did not retain information locally and thus the only repository of seafarers' personal information was on a single password protected database on a single computer. The database was backed up daily onto a pair of external USB-2.0 hard drives that were protected physically when not in use. Two additional copies of the database were made on individual computers for data analysis purposes during the writing of this report; these temporary copies were deleted prior to the publication of this report. Care was taken to ensure that no backup copies were made of these temporary databases and that they were completely erased.

The server PC containing the database was also reconfigured so that a blank database was sent to Geneva for possible demonstrations of the biometric systems by the ILO. This left only two backup copies of the database, both of which are retained in secure storage in Geneva by the ILO. They will only be used if further testing is required to better understand the biometric requirements of the ILO SID or to perform offline impostor testing of additional products seeking inclusion in the list of compliant biometric products.

All copies of the Seafarer data, including paper copies and primary and backup electronic media will be destroyed by the ILO on or before 30 November 2009. Until that date, each seafarer may request a report identifying the specific personal information related to them that is being held by the ILO in Geneva.

4 Test Environment

The test environment for both the laboratory (Phase 1) and onboard (Phase 2) tests are described below. The Test Methodology, Test Results, and Data Analysis are presented in Sections 5, 6, and 7, respectively. As noted above, Test Phase 1 was conducted in a laboratory environment with a limited non-seafaring test population, and Test Phase 2 was conducted onboard a seafaring vessel with 126 actual seafarers. Only those products that passed Test Phase 1 were included in Test Phase 2. Test Phase 1 was designed to eliminate nonconforming products from the tests to be included in the onboard test phase, thereby, minimizing the time required of each test subject.

4.1 Laboratory Testing Environment

Phase 1 of the test assessed biometric product ***conformance***, which determined if the biometric products generate minutiae-based templates that conform to the ILO's requirements. More specifically, this phase of the test verified that the biometric service provider (BSP) software module could enroll two fingers and generate the biometric interchange record (BIR) component of the payload for the SID 2D PDF417 barcode as described in Annex B of ILO SID-0002. Some basic interoperability tests were also performed during this test phase.

Three personal computers running Microsoft Windows XP SP1 and version 1.1 SP1 of the .NET Framework were used to conduct the conformance test. One of these PCs was configured as the server to store the results of each biometric test. The other two were configured as clients to host the tested products. Three of the tested products used the same BSP with different biometric sensors. The sensor device driver was tightly coupled to this BSP, which meant that only one of these three products could be installed on a single client PC at a time. These experiments were performed in an office environment with ambient temperature and indirect lighting.

4.2 Onboard Testing Environment

Phase 2 of the ILO Biometric Test was conducted aboard the Crystal Harmony cruise ship. Biometric data was collected from seafarers with a variety of jobs in a real seafaring environment so that a reasonable cross section of realistic seafarer skin conditions and fingerprint qualities was represented in the test data.

Seven of the submitted systems passed conformance testing and were accepted for inclusion in the onboard test. This test phase included three visits of each Seafarer, an initial enrollment and verification visit and two subsequent verification visits, which were separated by roughly two weeks. The two week interval was selected to study how the performance of the biometric systems change over time; two weeks is a reasonable time cycle for changes in human skin. Initial timing estimates indicated that two test teams would need to work in parallel to process the all of the Seafarer test subjects within the allotted onboard test duration, roughly six weeks.

The test team consisted of five members; one **Experimenter** and two test teams with one **Administrator** and one **Operator** each. The Experimenter was responsible for the overall management of the test, such as scheduling the seafarers' visits, ensuring consistency in the guidance provided to the seafarers, and reviewing test results on an ongoing basis to ensure integrity. The Operator explained to each Seafarer the purpose of the test and how it would be conducted by reading the test scripts, which are provided in Annex D, guided each Seafarer through the enrollment and verification visits, and filled out the Data Log forms, which are illustrated in Annex E. The Administrator ensured that the test system functioned properly, entered Seafarer personalization information, recorded test details such as finger used, enrollment results, and verification results, and generated performance reports. The Operator and Administrator verbally corroborated results before they were entered into the database to mitigate any potential data collection errors.

It is important to note that the testing performed here only compared live fingerprints with BIRs stored in the test harness database. Conformance, performance, and interoperability testing of the SID PDF417 barcode was beyond the scope of the Biometric Test Campaign. Seafarer biometric identification (one-to-many) matching was also beyond the scope of this Biometric Test.

Physical Environment

The test suite was assembled in one of the ship's staterooms, which was on the Starboard side of Deck 9 aft. The testing area's dimensions were 9 feet wide by 15 feet deep. Entry to the room was gained through a hallway 31 inches wide by 76 inches long. The light sources in the test suite included two ceiling lights, a fluorescent light in the entryway to the suite, two light fixtures attached to a mirror over a desk, and a sliding glass door to the balcony. The drapes to the balcony were often pulled closed to minimize the impact of the sun on the temperature and lighting of the test suite. On those occasions that the drapes were pulled open (for example, when the sun was on the opposite side of the ship) sheer curtains ensured that the light was diffuse. No light source shed direct light on any of the fingerprint sensors.

Two folding tables were set up in opposite corners of the test area. One table supported two of the test laptop computers (ILO-1 and ILO-2) and one set of six biometric sensors (products A, B, C, D, E, and F). This table was 72 inches wide, 29 inches deep and 30 inches high. The second table supported two test laptop computers (ILO-3 and ILO-4) and the D-Link wireless router and a second set of six biometric sensors (products A, B, C, D, E, and F). This table was 72 inches wide, 35 inches deep and 30 inches high. The sensors were aligned to the right of the 2 laptops and positioned 12 inches from the edge of the table when not in use. The test team Operator positioned the sensors in front of the test subject as directed by the test team Administrator, who operated the computerized test harness. These sensors were cleaned with a dry Kleenex roughly twice a day or when visibly dirty. Two FireWire hubs and one USB hub were setup on each table behind the 2 laptops. A temperature/humidity gauge was placed on each table and readings were recorded on commencement of each Seafarer visit.

The stateroom desk was 32 inches wide, 20 inches deep and 30 inches high. The desk supported a fifth laptop computer (ILO-5) and one of the biometric sensors (product G). This laptop was also the server in the client/server configuration and was shared between the 2 teams to test product G. The sensor was positioned 12 inches from the edge of the desk when not in use and was held in the Seafarer’s hand during testing. Six dining room chairs and one desk chair were positioned for testers and Seafarers. The chairs were 17" in height.

Only 2 electrical outlets were available with 110V. Several power strips were utilized to power the computers, sensors, hubs, and router.

IT Environment

A client-server architecture was implemented on five Toshiba Satellite A70-TS1 laptop computers. The IT testing environment consisted of the following software components:

- Microsoft Windows XP Professional SP1 on ILO-5
- Microsoft Windows XP Home SP1 on ILO-1, ILO-2, ILO-3, and ILO-4
- Microsoft SQL Server 2000 on ILO-5 only
- Microsoft .NET Framework 1.1 SP1
- BioAPI 1.1 reference implementation written in C++
- BioAPI 1.1 C# Wrapper written by H. Kaiser Yang (http://sourceforge.net/projects/boiapi-dt/)
- custom test tool written in C# on the Microsoft .NET framework (see *Test Software Design Document for Biometric Systems for use with International Labour Organization Seafarers’ Identity Documents*)

Test Harness

The test harness managed a Graphical User Interface (GUI) for the Seafarers and Administrators and made all BioAPI calls to the different vendors' biometric software. The required BioAPI calls that were used to support the test included:

- BioAPI_Init
- BioAPI_Terminate
- BioAPI_EnumModules
- BioAPI_ModuleLoad
- BioAPI_ModuleUnload
- BioAPI_ModuleAttach
- BioAPI_ModuleDetach
- BioAPI_Enroll
- BioAPI_Verify

The database used by the test harness was hosted on Microsoft SQL Server 2000 SP3 and stored all pertinent enrollment and verification test data, seafarer demographics, fingerprint templates, and raw fingerprint images. The database table definitions and relationships are presented in Annex F. The SQL views used for programmatic data analysis and reporting are also presented in Annex F.

5 Test Methodology

The test methodology for the ILO Biometric Testing Campaign was designed to determine whether the products submitted for testing satisfy the biometric-related requirements of ILO Convention No. 185 and ILO SID-0002. To determine whether products meet the ILO's requirements, two primary biometric functions were performed: enrollment and verification. For enrollment, a live fingerprint is presented to a product's sensor, and the product's Biometric Service Provider (BSP) software module creates an enrollment template, or more specifically a Biometric Interchange Record (BIR). The test harness saves the BIR, along with other identifying information for the test subject, in a database. During verification, a live fingerprint is again presented to a sensor, and the BSP compares the live fingerprint with an enrolled BIR that has been retrieved from the database. The BSP then outputs a binary match/no-match decision and a FARAchieved Score, as required by BioAPI.

During operational enrollment, a Seafarer has up to three attempts each to enroll a primary and a secondary finger. The Seafarer is considered enrolled if both a primary and secondary finger are enrolled. If necessary, the Seafarer can try up to all ten fingers to get two fingers enrolled.

During operational verification, the Seafarer has up to three attempts to verify their primary finger. If this fails, the Seafarer has three attempts to verify their secondary finger. The Seafarer is considered verified if either finger is matched.

During verification testing, two types of tests are run: ***genuine comparisons***, where the test subject attempts to match their own BIR, and ***impostor comparisons***, where a test subject attempts to match a different test subject's BIR.

The following sections describe 1) the test methodologies employed to demonstrate the primary test components of the ILO Biometric Testing Campaign, 2) the biometric test functions – enrollment, genuine verification, and impostor verification testing, and 3) details of the initial and subsequent Seafarer visits.

5.1 Test Components

The test methodologies for the primary components of the Biometric Testing Campaign: Conformance, Performance, and Interoperability, are discussed in Sections 5.1.1, 5.1.2, and 5.1.3, respectively.

5.1.1 Conformance

The objective of the Conformance component of the ILO Biometric Test Campaign was to ensure that products submitted for evaluation generate and store fingerprint biometric templates, or more specifically, BIRs, as defined in Annex B of ILO SID-0002. Each biometric system that produced a template with the defined format was advanced to full performance and interoperability testing as described in the following sections. The defined format stores two fingerprint minutiae templates from a seafarer's primary and secondary finger in the BIR, along with personal identification data pertaining to the seafarer. The BIR will be encoded into the SID's two-dimensional PDF417 barcode. The conformance of the personal identification data to the defined format and of the encoding of the BIR into a two-dimensional barcode was outside the scope of these tests.

One notable aspect of the defined template format is that each fingerprint template shall be truncated at 52 minutiae, which was required because of the limited storage space in the PDF417 barcode. While some fingers have less than 52 minutiae, some fingers may have more. The truncation is required to enable interoperability of seafarer templates across SID biometric products that the seafarer may encounter around the world.

The conformance test component included 1) an integration test, 2) three enrollment tests, 3) three verification tests, and 4) a basic interoperability test.

Integration Test

For the integration test, each BSP was tested for compliance with BioAPI, as detailed in Section 4.2 of the BioAPI Specification version 1.1 (ANSI/INCITS 358-2002) for the Verification BSP type. In addition, each BSP was integrated into the test harness software as specified in the "Test Software Design Document for Biometric Systems for use with International Labour Organization Seafarers' Identity Documents," which was distributed to all product vendors. Once successfully integrated into the test harness, each vendor's BSP was evaluated for stability, excessive crashing, and destabilization of other BSPs or applications in the test harness.

Enrollment Tests

Three enrollment tests were performed on those products that passed the Integration Test.

Enrollment Test #1 was designed to ensure that each vendor's BSP conformed to the following defined enrollment procedures (adherence to bullets 2, 3, and 5 was mandatory for procedural conformance):

(1) Appropriate procedural prompts for placement of current finger by name

(2) Prompts for all ten fingers in the correct order. Specifically:
 Right Index
 Left Index
 Right Thumb
 Left Thumb
 Right Middle
 Left Middle
 Right Ring
 Left Ring
 Right Little
 Left Little

(3) The option to select another finger for enrollment (finger not available)

(4) Visual feedback of the fingerprint image in the BSP GUI

(5) Prompts for next finger if repeated capture attempts cannot create an image of sufficient quality for enrollment (system uses quality metrics)

(6) Prompts in the GUI to indicate what was wrong with the fingerprint if the quality was poor

To evaluate conformance to these procedures, the tester deliberately prevented enrollment by placing fingers incorrectly on each sensor. Fingers were deliberately placed on the sensor too far down, too far up, too far left and too far right, and one finger was deliberately placed too hard thus forcing the ridges on the fingerprint together. If a fingerprint was captured successfully during this test, the test was aborted and executed again. After each finger was rejected for poor quality, the next finger was presented until the BSP cycles through all fingers. No BIRs were created in this test since no fingers were successfully enrolled (intentionally).

Enrollment Test #2 was designed to ensure that the BIR written to disk conformed to ILO SID-0002 Annex B data format conformance requirements. The specific items verified by the conformance testing software were as follows:

(1) ENROLL.BIR Byte Size = 56 to 566
(2) Length in Bytes header field matches file size
(3) BioAPI_BIR_VERSION = 0x01
(4) BioAPI_BIR_DATA_TYPE = 0x01010203
(5) BioAPI_Quality = 0 to 100
(6) BioAPI_BIR_PURPOSE = 0x02
(7) BioAPI_BIR_AUTH_FACTORS = 0x00000008
(8) Format Identifier = 0x464D5200
(9) Version Number = 0x20313100
(10) Length of Record = 40 to 550
(11) X Resolution >=196

(12) Y Resolution >=196
(13) Number of Fingers = 0x01
(14) Number of Finger Views = 0x00
(15) Finger Position = 0x01 to 0x0A
(16) View Number = 0x0
(17) Impression Type = 0x0 or 0x8 according to Module table
(18) Finger Quality = 0 to 100 (0x00 to 0x64)
(19) Number of Minutiae = 1 to 52 (0x01 to 0x34)
(20) Finger Position = 0x01 to 0x0A
(21) Impression Type = 0x0 or 0x8 according to Module table
(22) Finger Quality = 0 to 100 (0x00 to 0x64)
(23) Number of Minutiae = 1 to 52 (0x01 to 0x34)

To verify conformance to these requirements, which were all mandatory, the tester attempted to successfully enroll the right and left index fingers as the primary and secondary fingers, respectively.

Enrollment Test #3 was designed to ensure that the BIR written to disk conformed to ILO SID-0002 Annex B, as with Enrollment Test #2, except that the tester attempted to capture the left thumb and left ring fingers as the primary and secondary fingers, respectively.

Verification Tests

Three verification tests were performed. Verification Test #1 was designed to ensure that the BSP provided the following (adherence to bullets 3, 4, and 6 was mandatory):

(1) appropriate procedural prompts for placement of primary and secondary enrolled fingers by name

(2) visual feedback of the fingerprint image

(3) correct identification of the primary finger as the right index and the secondary finger as the left index

(4) a maximum of three capture/match attempts for each finger enrolled

(5) an automatic prompt for the secondary finger if the primary finger cannot match

(6) a non-match indication after three attempts for each finger

During this test, the tester deliberately attempted to fail to match the BIR created during Enrollment #2.

Verification Test #2 was designed to ensure that the BSP provided the following:

(1) the option of indicating that the primary finger is not available for verification

(2) automatic prompting for the correct secondary finger (left index) if the primary finger not available option is selected

(3) a successful match indication

During this test, the tester attempted to successfully verify the secondary finger (left index) created during Enrollment #2. Adherence to all three bullets was mandatory.

Verification Test #3 was designed to ensure that the BSP provided the following:

(1) prompts for placement of primary finger (left thumb)

(2) once the finger not available button has been selected, prompts for the secondary finger (left ring)

(3) a successful match indication

During this test the tester attempted to successfully verify the secondary finger (left ring) enrolled during Enrollment #3. Again, adherence to all three bullets was mandatory.

Basic Interoperability Test

Each vendor's product was tested for basic interoperability by attempting to successfully verify at least one of the primary or secondary fingers against the BIRs enrolled (from Enrollment Test #2) on each of the other products whose BIRs passed the data format conformance test described in Enrollment Test #2.

For a given product to pass this basic interoperability test, a successful verification had to occur against 50% of the BIRs (1 per product other than the product being tested), and 50% of the other products had to successfully match against the given product's BIR.

For example, with 7 total products, the BIR from Product 1 containing the right and left index fingers generated in Enrollment Test #2 was used to attempt a successful verification on each of the Products 2-7. Similarly, the tester attempted a successful verification on Product 1 against the Enrollment Test #2 BIRs from each of Products 2-7. For Product 1 to be considered interoperable, 50% of 6, or 3 of these 6 verification tests had to pass for each portion of the test.

5.1.2 Performance

The objective of the Performance component of the ILO Biometric Test Campaign was to determine false reject and false accept rates for biometric verification using real seafarers in a realistic seafaring environment over reasonable time periods for each biometric product tested.

This component seeks to demonstrate that the biometric technologies being offered in the marketplace are able to provide sufficient accuracy to be reliable for the seafaring population given. The goal, as specified in ILO SID-0002 is to achieve a false non-match rate of less than 1% with a false match rate also less than 1%.

The false reject rate is determined by comparing each seafarer's live fingerprint with the BIR created for that seafarer during enrollment, which is stored in the test harness database. (A detailed description of the database design is found in Annex F.) If the comparison fails to match, it is considered a false reject or non-match. This is particularly important for seafarers and ship owners, since failure of the biometric to be verified at a port of entry will likely cause significant delays.

The false accept rate is determined by comparing each seafarer's live fingerprint with a BIR created for a different seafarer. If the comparison matches, it is considered a false accept or match. This is known as impostor testing. The BIR for the different seafarer was selected randomly by the test harness. This is important for the security of the ship and of the port country.

As stated above, performance was tested in three separate visits by each seafarer to the test center. The performance testing methodology is presented in Section 5.2, where the details of each test visit are discussed.

5.1.3 Interoperability

The objective of the Interoperability component was to demonstrate that BIRs created by one system can be used as reference BIRs for verification of samples captured by different biometric products. For example, a template created when a seafarer placed his or her finger on Product A should positively match (verify) against a reference template that was created upon enrollment by a different biometric product (in this case, Product B, C, D, E, F, or G). This is called non-native verification. Our test included three non-native verifications on each product for each seafarer at each of three visits. Time constraints prevented more exhaustive testing. At each verification, the three non-native products were randomly selected by the test harness to ensure a near-even distribution of testing combinations. Interoperability testing is representative of a real port-based seafarer verification scenario. The Interoperability testing methodology is presented in following section, where Enrollment, Verification, and Impostor testing are fully explored.

5.2 Biometric Test Functions

Performance and interoperability were tested in three separate visits by each seafarer to the test center. The first covered both the enrollment and first verification visits, and each of the next two was for verification only.

5.2.1 Enrollment Testing

The biometric products tested were required to demonstrate that they could generate minutiae-based templates that conform to the ILO's requirements. More specifically, they needed to verify that the biometric software could enroll two fingers and generate the biometric identification record (BIR) component of the payload for the SID 2D PDF417 barcode as described in ILO SID-0002. Seafarers were enrolled in accordance with requirements stated in ILO Convention No. 185, Article 3, paragraph 8 and in ILO SID-0002. Seafarer enrollment procedures are summarized below.

A fingerprint was captured from the index finger of each hand[4] when possible. Three placements of a finger were attempted before recording a failure to enroll. The placements were counted by the test operator who noted the number of times the finger was lifted off of a sensor. If the index fingerprint was missing or damaged to the extent that a reliable fingerprint either could not be created or could not be enrolled due to poor quality, the test team attempted to enroll a fingerprint from another finger or thumb such that operational consistency, operational efficiency, and Seafarer convenience were maximized. If the BSP failed to acquire a fingerprint template, the administrator would request placement of the next finger. The test team did not inspect Seafarer fingers to determine whether or not they were clean, damaged, or scarred, but relied on the BSP to determine whether or not to accept a finger. The standard presentation order of fingers for enrollment, as defined in ILO SID-0002, Section 5.1.1, is:

- right index finger,
- left index finger,
- right thumb,
- left thumb,
- right middle finger,
- left middle finger,
- right ring finger,
- left ring finger,
- right little finger,
- left little finger.

The test team administrator specified which fingers were enrolled at the time of biometric enrollment and this information was recorded in the biometric system's BIR as defined in ILO SID-0002, Annex B. All BIRs were written to and stored in the test harness.

The administrator depended on the BSP to determine whether a fingerprint was of sufficient quality to successfully enroll and to record success/fail indicators. The administrator entered the following data using the test harness GUI: temperature, humidity, finger unavailable, failure to enroll, and number of placement attempts. The administrator also provided finger placement and quality guidance, such as moistening the finger if it was too dry, during enrollment and during the 3rd verify visit.

The operator recorded the following data during the enrollment visit: seafarer's name and Test ID number, date, temperature and humidity, the number of placement attempts for each successful enrollment or a failure to enroll indication, and comments as indicated. A sample operator Enrollment Data Log Form is shown in Annex E. The administrator and operator verbally compared notes to mitigate potential data collection errors.

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[4]Fingerprints from two fingers are acquired to improve the reliability and robustness of the system. The index finger is chosen for the primary fingerprint because in most cases, the index finger is most easily placed on the fingerprint capture device, thus providing maximum convenience to the seafarer (ILO Convention No. 185, Article 3, paragraph 8, Precondition 1).

5.2.2 Verification Testing

Verification testing involved both **performance** testing to measure native False Reject Rate (FRR) and False Accept Rate (FAR) values, and **interoperability** testing to measure non-native FRR values. In each of these different tests, the Seafarer's primary and secondary fingerprints were compared to corresponding primary and secondary fingerprint templates allowing up to three placements per finger. The biometric products were required to demonstrate that they could capture minutiae-based templates and compare them to previously-enrolled templates to support verification of Seafarer identity.

The stated performance test objectives of the ILO are a 1% FAR and a 1% FRR. A FRR of 1% implies that the odds of a legitimate Seafarer not matching either of the templates stored on his or her SID are 1 in a 100. A FAR of 1% implies that the odds of an impostor matching either of the fingerprint templates stored on a legitimate SID that an imposter has found or stolen are 1 in 100.

To measure native performance FRR values, a Seafarer's live fingerprint captured with one biometric product was compared against a template previously generated during enrollment by that same biometric product for that same finger of that same Seafarer (**genuine comparisons**).

To measure native performance FAR values, a Seafarer's live fingerprint captured with one biometric product was compared against a template previously generated during enrollment by that same biometric product for that same finger of a randomly-selected different Seafarer (**imposter comparisons**).

To measure non-native interoperability FRR values, a Seafarer's live fingerprint captured with one biometric product was compared against a template previously generated by a different biometric product for that same finger of that same Seafarer. As time on the ship to conduct the testing was limited, interoperability impostor comparisons were not performed.

5.3 Test Visits

During Visit 1, the Seafarers were enrolled, verification attempts were performed for native and non-native template-product combinations, and impostor attempts were performed for native template-product combinations. During Visits 2 and 3, additional sets of verification attempts were performed for native and non-native template-product combinations, and impostor attempts were performed for native template-product combinations. Details of these visits are provided below.

5.3.1 Visit 1

During Visit 1, the Seafarers enrolled on all seven systems where templates from two fingers could be successfully captured. Scripts were read to each Seafarer at the beginning of the enrollment session, immediately before they used each biometric system, and at the beginning of the verification session. The scripts were used to minimize the impact of tester bias on the performance of each biometric system. In addition to reading the scripts, the test operator demonstrated one correct finger placement on each system to the Seafarer immediately before they began their enrollment or verification tests on that system. This was deemed to be reasonable, since in the real world the Seafarer would have guidance during enrollment and would probably become somewhat familiar with the fingerprint products after the first few verifications.

Each Seafarer was given up to three attempts to place each of their primary and secondary fingers for the two-finger enrollment. A placement was generally considered to be any positioning of the finger on the sensor. Lifting and replacing a finger on the sensor was considered to terminate the current placement and begin the next one. If a finger was not enrolled after three attempts, it was entered as a failure to enroll for that finger by the test staff, but the biometric system was still allowed to try and generate an enrollment template by requesting that the Seafarer proceed to the next finger in the ordered list specified in ILO SID-0002 and in Section 5.2.1 above. If two fingers could not be enrolled from all ten fingers, then that seafarer was recorded as being unable to enroll on that biometric system. That Seafarer could not participate in genuine comparison tests on that product during subsequent verification visits, although the Seafarer could still participate in impostor comparison tests and in interoperability tests on that product.

If two fingers were successfully enrolled, then the BIRs were written to the test harness database, along with critical returned information such as the number of attempts for each finger, the time and date of enrollment, the finger minutiae template quality for each enrolled finger, etc. Demographic data such as birthdate, gender, job type onboard the ship, and nationality were also recorded.

After completing enrollment or failing to enroll on all seven systems, each Seafarer attempted to verify each of their primary and secondary fingers (usually the right and left index fingers, respectively) against all seven systems (genuine comparisons). Each Seafarer also attempted to verify each of their primary and secondary fingers against a randomly selected BIR from another Seafarer enrolled on the same system on all seven systems (impostor comparisons). To test interoperability for each of the seven systems, the Seafarers attempted to verify their live-captured fingerprints against their templates generated during enrollment on three of the six other products included in the test.

The tests described above were performed in random order so that the Seafarer could not predict whether or not a match or a non-match response was expected. If every sensor correctly matched or failed to match every finger placement, 98 finger placements would be required. In the worst case scenario where all comparisons fail, 210 finger placements would be required. The order of the products on which the Seafarer was both enrolled and verified was also randomized to prevent products used later in the visit, when the Seafarers were more familiar with how to place their fingers, from gaining an unfair advantage.

5.3.2 Visit 2 – Seafarer Verification

The Seafarers were scheduled to return for the second visit approximately two weeks following the first visit. Ten tests for each of the seven sensors were performed during this visit with each test allowing up to three finger placements. These ten tests consisted of a genuine comparison of each of the Seafarer's primary and secondary fingers, an imposter comparison of each of their primary and secondary fingers, and a genuine interoperability comparison of each of their primary and secondary fingers against templates enrolled from three of the other six systems. The scripts for Visit 2 are provided in Annex D. The Administrator told the Operator and the Seafarer which sensor to use and which finger to present to that sensor. During this second visit, the operator demonstrated finger placement on each sensor, but no other guidance was given to the Seafarer except for which finger and sensor to use and when to place his or her finger on the sensor.

The tests described above were performed in random order such that the Seafarer could not predict whether or not a match or a non-match response was expected. The order of the products was also randomized so that no product benefited from the Seafarer's increasing familiarity with fingerprint placements as the visit progressed.

5.3.3 Visit 3 – Seafarer Verification

Approximately two weeks after the second verification visit, each seafarer returned and repeated the verification portion of the test just as they did in the previous visit. During this visit, the Seafarer was given a demonstration of correct finger placement and sensor operation. In addition, the Administrator provided guidance for finger placement and pressure based on the BSP feedback. Such feedback is suggested for use of biometric products in an operational Seafarer biometric verification environment so that Seafarers can be verified as efficiently as possible. As such, Visit 3 is referred to as the Key Visit in the remainder of this report as it represents supervised operating conditions (which means that Seafarer guidance was provided by a system operator, if the initial finger placement failed to verify the Seafarer) with a realistic time lapse since the fingers were enrolled.

Again, the tests described above were performed in random order, such that the Seafarer could not predict whether or not a match or a non-match response was expected and the order of the products used was also randomized.

6 Test Results

Test results for the Conformance, Performance, and Interoperability test components are presented in the following sections. The results are divided into two parts, the laboratory-based test results and the onboard test results.

6.1 Laboratory-Based Conformance and Basic Interoperability Test Results

The results of the conformance and basic interoperability tests, as described in Section 5.1.1, are summarized in Table 1 on the following page for those products that advanced to onboard testing.

Seven products passed the laboratory-based Conformance testing and were advanced to onboard Performance and Interoperability testing.

Table 1. Conformance and Basic Interoperability Results

		A	B	C	D	E	F	G
Integration Test		**Pass**	**Pass[1]**	**Pass**	**Pass**	**Pass[1]**	**Pass**	**Pass[1]**
Enrollment Test #1								
	1	**Pass**	**Pass**	**Fail[2]**	**Pass**	**Pass**	**Pass**	**Pass**
Mandatory	2	**Pass**	**Pass**	**Pass[4]**	**Pass[8]**	**Pass**	**Pass[7]**	**Pass**
Mandatory	3	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	4	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Mandatory	5	**Pass[6]**	**Pass**	**Pass**	**Pass[9]**	**Pass**	**Pass**	**Pass**
	6	**Pass**	**Pass**	**Pass[3]**	**Pass[3]**	**Pass**	**Pass[3]**	**Pass**
Enrollment Test #2 and #3								
Mandatory	1a	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1b	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1c	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1d	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1e	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1f	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1g	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1h	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1i	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1j	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1k	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1l	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1m	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1n	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1o	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1p	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1q	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1r	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1s	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1t	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1u	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1v	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	1w	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Verification Test #1								
	1	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	2	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Mandatory	3	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Mandatory	4	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
	5	**Pass**	**Pass**	**Fail[5]**	**Fail[5]**	**Pass**	**Fail[5]**	**Pass**
Mandatory	6	**Pass**	**Pass**	**Pass[5]**	**Pass[5]**	**Pass**	**Pass[5]**	**Pass**
Verification Test #2								
Mandatory	1	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Mandatory	2	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Mandatory	3	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Verification Test #3								
Mandatory	1	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Mandatory	2	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Mandatory	3	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Interoperability Tests								
Verification Sensor								
A		**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
B		**Pass**	**Pass**	**Pass**	**Fail**	**Pass**	**Pass**	**Pass**
C		**Pass**	**Pass**	**Pass**	**Fail**	**Pass**	**Pass**	**Fail**
D		**Pass**	**Fail**	**Pass**	**Pass**	**Pass**	**Fail**	**Pass**
E		**Pass**	**Pass**	**Pass**	**Fail**	**Pass**	**Pass**	**Pass**
F		**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
G		**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Overall Result		**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**

Reference Notes:

1) a. Can't support more than one device on one laptop.

   b. Causes some instability, with occasional crashes of other BSP's or the test application. Therefore testers must exit the application after each round of tests.

   c. License requires a new license key whenever the windows' network connections change such as enabling a wireless network.

2) Uses finger number (instead of name) after Right Index.
3) Limited prompts. Essentially only indicated low quality.
4) If BSP cycles through all 10 fingers without a successful enroll, it crashes and next time you try to access BSP, application locks up. Therefore testers must exit application after this occurs.
5) BSP declares a non-match after three failed attempts on whichever finger (primary or secondary) is being tested and relies on the application to request the other finger.
6) BSP allows unlimited attempts, but shows quality, and relies on user to activate "Cancel" button if too many low quality captures occur. Then it prompts for next finger.
7) BSP allows cycling through all 10 fingers using Finger Not Available but if any 2 fingers have 3 capture attempts where quality is insufficient, no more fingers are prompted for. This will be a challenge for seafarers' with difficult to enroll fingers.
8) Finger Not Available button cycles through fingers. Clicking Next button has unpredictable behavior. Particularly, if Left Little finger not available, must use Cancel, not Next or Finger Not Available.
9) Quality metrics do not appear to be correlated to visible image quality on screen.

6.2 Onboard Performance and Interoperability Test Results

As explained in Section 5, for each comparison between a newly acquired fingerprint and a previously enrolled fingerprint template (BIR), each BSP module outputs a binary decision, match or non-match, as determined by the vendors' original BSP threshold setting. In addition, each BSP module outputs a FARAchieved score for each comparison.

In an operational scenario, both the primary and secondary fingers will be attempted, if needed, to verify the identity of the seafarer. As such, the most operationally meaningful performance data looks at those cases where either the primary or secondary finger successfully matched, indicating that the seafarer was verified.

The false accept and false reject performance for the key visit (Visit 3) and for all three visits combined are summarized in Figure 1 using the binary decision output by each BSP for each product. The vertical axis reports the FAR and FRR percentages achieved for each of the seven tested products.

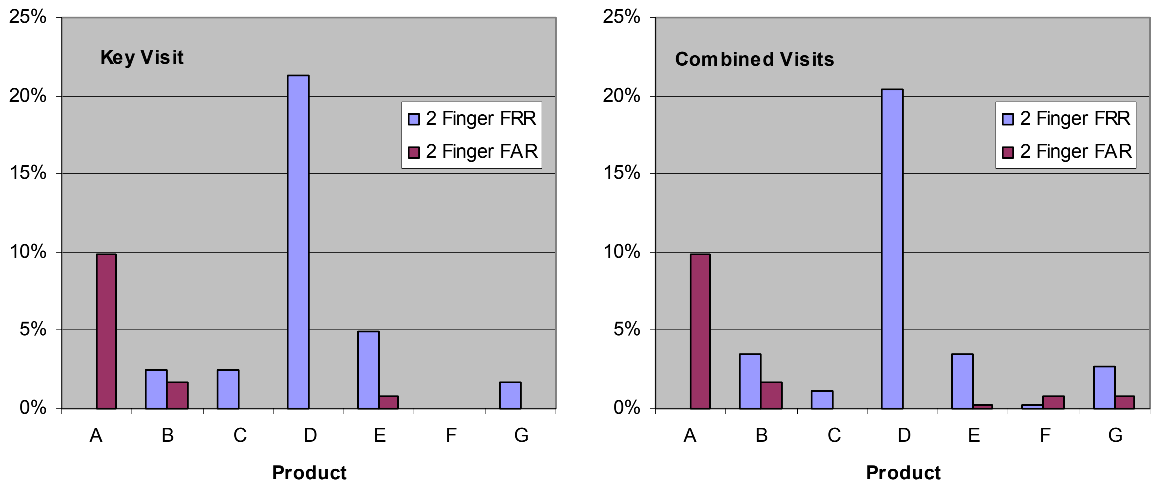


Figure 1. Decision-Based FAR and FRR for Key Visit and Combined Visits

Figure 1 shows that Product A has a high (10%) FAR (poor performance) but no false rejects (good performance), and Product D has a very high (>20%) FRR (poor performance), but no false accepts (good performance). The performance is slightly different for all three visits combined compared to the key visit. This is expected since direct finger presentation guidance was not provided during verification visits 1 and 2 but was provided during the 3rd "key" visit.

The FRR interoperability performance using the binary decision output by each BSP for each product is summarized in Tables 2 and 3 for the key visit and all visits combined, respectively. The values in these tables illustrate FRR performance when templates (BIRs) created from one product are processed by the other products. For example, how does a template enrolled by Product A perform when seafarers present their fingerprints to Products A through G? The tables also illustrate FRR performance when a product (sensor and BSP) processes templates created by the other products. For example, how does Product A's sensor and BSP perform with seafarers whose templates were enrolled using Products A through G? The shaded values on the diagonal are the native FRR scores presented in Figure 1.

As one example, Table 2 shows that low FRRs are achieved when Product A's sensor and BSP process templates created with other products (Column A). However, for templates created with Product A that are processed by other products' sensors and BSPs (Row A), a wide variety of performance is observed, from 1.6% FRR for Template A – Product F comparisons up to 56.5% FRR for Template A – Product B comparisons.

Table 2. Interoperability Decision-Based FRR for Key Visit

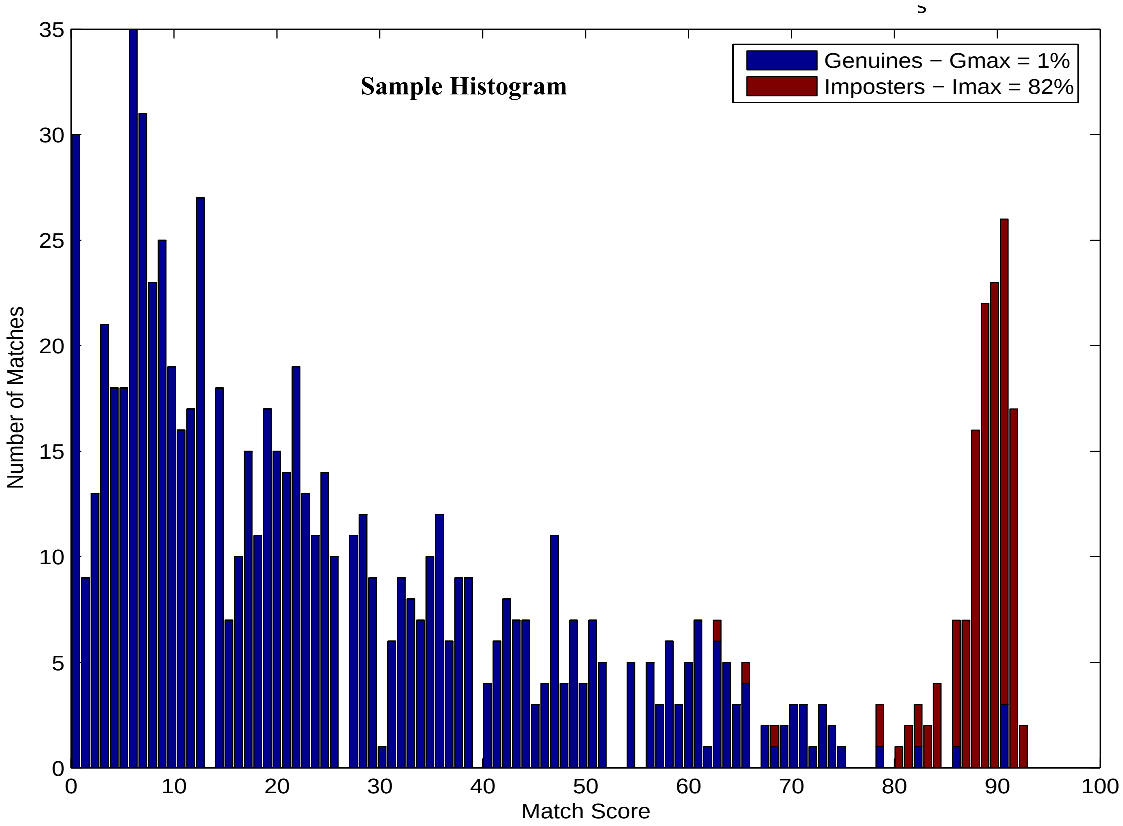
		Product (Sensor and BSP)						
		A	B	C	D	E	F	G
Template	A	0.0%	56.5%	4.0%	20.0%	53.1%	1.6%	45.3%
	B	1.6%	2.5%	7.8%	59.0%	12.5%	1.6%	6.3%
	C	0.0%	6.3%	2.5%	40.6%	5.5%	68.5%	6.3%
	D	0.0%	1.6%	59.4%	21.3%	52.7%	28.6%	39.3%
	E	0.0%	4.7%	14.1%	73.4%	4.9%	3.5%	3.6%
	F	0.0%	45.8%	7.8%	65.6%	43.8%	0.0%	38.6%
	G	1.6%	4.7%	79.3%	67.2%	6.3%	20.3%	1.6%

Table 3. Interoperability Decision-Based FRR for Combined Visits

		Product (Sensor and BSP)						
		A	B	C	D	E	F	G
Template	A	0.0%	51.9%	8.5%	35.5%	51.0%	2.9%	54.2%
	B	2.3%	3.5%	11.9%	64.7%	9.0%	8.2%	6.8%
	C	0.0%	9.3%	1.1%	56.1%	7.5%	73.1%	8.8%
	D	5.2%	45.0%	59.2%	20.4%	57.1%	33.1%	42.9%
	E	0.7%	3.1%	14.9%	71.7%	3.5%	7.3%	5.5%
	F	0.0%	41.4%	10.1%	63.0%	45.1%	0.3%	42.8%
	G	1.8%	6.8%	74.3%	72.5%	12.7%	21.3%	2.7%

This data, based on the binary decision of each BSP, provides initial indications of native and interoperability performance by the tested products. However, since each product's BSP used a different threshold setting, this data does not represent performance at similar operating (FAR) points. In fact, Figure 1 illustrates that native FARs varied from 0% to 10%. To address this issue, the FARAchieved scores can be used to estimate each product's performance at specific FARs of interest. This score-based analysis is described in Section 7.

Histograms showing the FARAchieved scores for genuine and impostor comparisons for each of the products for the key visit and for all visits combined are presented in Annex G. An example is illustrated on the following page. The FARAchieved scores (called Match Score in the figures) are indicated on the horizontal axis and the number of those scores that were measured (called Number of Matches in the figures) is shown on the vertical axis. Scores generated from genuine comparisons are indicated in blue, while scores generated from impostor comparisons are indicated in red. Ideally, a threshold score exists where all impostor comparisons fall above the threshold and all genuine comparisons fall below the threshold (in the scoring scale used here). If this were the case, a product could achieve 0% FAR and 0% FRR. In reality, as shown in the graphs, the best that can be achieved is to select an operating point that provides the best compromise between false accepts and false rejects for the given application.

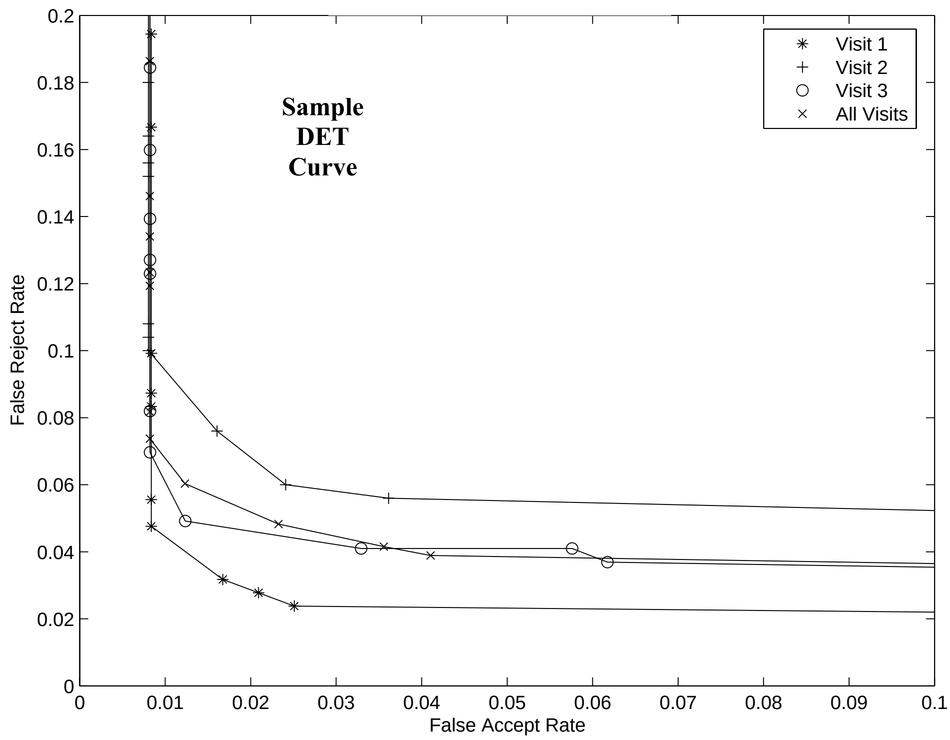


Using the score data plotted in Annex G, single-finger and two-finger Detection Error Tradeoff (DET) curves were generated for each of the seven products. As the most relevant analysis is focused on the operational scenario where the seafarer can attempt to match two fingers, the two-finger DET curves are shown in Annex H[5].

To generate a single-finger DET, all unique scores output by the BSP are placed in numerical order for the genuine score data set and for the impostor score data set. (Recall that a zero score is a perfect match for the score schema used here and by BioAPI.) Each score is then individually considered a threshold score. For the genuine score data set, the number of scores that occurred above the selected threshold score represent verification attempts that should have matched but will be rejected and thus determine an FRR value. For the impostor score data set, the number of scores below that same threshold score represent verification attempts that should have been rejected but would be accepted as matches, and thus determine a FAR value. These two values becomes one point on the DET curve. The process is then repeated for all other scores. To compute two-finger DET curves, the calculations accounted for the fact that each seafarer provided two scores, one for the primary finger and one for the secondary finger, and if either one of these was below the selected threshold score, a match would be determined to have occurred. Essentially this means that a two-finger DET curve could be computed in exactly the same manner as a single finger DET curve, provided that the minimum of the FARAchieved scores from each seafarer's primary and secondary fingers was used.

[5] DET curves are commonly plotted on log-log scales, however the DET curves presented in this report are plotted on linear scales.

An example of a two-finger DET graph is shown below. The four curves represent the DET curves for each of the three verification visits individually and the DET curve resulting from the combined visits (All Visits). Recall that Visit 3 is the Key Visit. The DET curves indicate that, as expected, the FAR increases as the FRR decreases, and vice versa. In general, the lower the FARs and FRRs, the better the overall performance of the product. As noted above, an operating point that provides the best compromise between FAR and FRR must be selected for any given application. For some applications a low FRR may be more important. For other applications a low FAR may be more important. For the data analysis, presented in Section 7 below, FAR operating points of 1% and 2% (0.01 and 0.02 in the DET curve below) were used.



For all of the DET curves presented in Annex H, Visit 2 shows the poorest performance (the highest FAR and FRR values), as expected, since no finger presentation guidance was provided to the Seafarers during this visit and about two weeks had passed since the Seafarers had last used the products. For most products, Visit 1 shows the best performance (lowest FARs and FRRs). This is expected since Visit 1 occurred immediately following enrollment, where the Seafarers were trained to use the products and guided through correct finger presentation. In a few cases, Visit 3 performance improved over Visit 1 performance. Operationally, Visit 3 is representative of the suggested use of the products in the field; where Seafarers are expected to be coached to achieve optimum finger presentation.

In summary, Visit 3, or the Key Visit, represents ideal operating conditions, where the Seafarer is given guidance by a human for each finger placement attempt. The Combined Visits, in comparison, represent less than ideal operating conditions, because human guidance was not provided on every finger placement attempt.

7 Data Analysis

To determine which products, and which combinations of products, best satisfy the requirements of ILO Convention No. 185 and ILO SID-0002 biometric profile, it is necessary to evaluate the performance of the products at similar operating points. As mentioned in Section 6.1 above, the binary match/non-match decisions output by each BSP were based on the vendors' original threshold scores, which are different and thus represent different operating points. To adequately compare the performance of individual products and of combinations of products, the FRRs must be derived at common operating points, in this case corresponding to specific FAR values.

Native Performance

For each of the seven products, FRR values were determined by interpolating between points on the DET curves in Annex H at specific FARs of interest, specifically 1% and 2%. The FRR performance at these FARs for the key visit and for all three visits combined are summarized in Table 4 and illustrated in Figure 2 by rank from best performing product (Rank 1, lowest FRR) to worst performing product (Rank 7, highest FRR). The observed (binary decision based) FRR values are included in Table 4 and Figure 2 for comparison.

Table 4. Ranked Product Performance

	Key Visit FRR			Combined Visits FRR		
	1% FAR	2% FAR	Observed	1% FAR	2% FAR	Observed
Rank 1 Products						
Product	A and F	A and F	A and F	F	F	A
FRR	0.0%	0.0%	0.0%	0.3%	0.3%	0.0%
Rank 2 Products						
Product	-	-	-	A and G	B	F
FRR	-	-	-	1.9%	1.49%	0.3%
Rank 3 Products						
Product	G	G	G	-	G	C
FRR	1.6%	1.6%	1.6%	-	1.53%	1.1%
Rank 4 Products						
Product	C	C	B	C	A	G
FRR	1.7%	1.7%	2.46%	2.4%	1.9%	2.7%
Rank 5 Products						
Product	E	B	C	E	C	E and F
FRR	4.9%	2.1%	2.48%	3.2%	2.2%	3.5%
Rank 6 Products						
Product	D	E	E	D	E	-
FRR	21.1	4.9%	4.9%	20.2%	3.2%	-
Rank 7 Products						
Product	B	D	D	B	D	D
FRR	-	20.9%	21.3%	-	11.5%	20.4%

Table 4 indicated that Products A and F meet the ILO's stated performance objectives of 1% FRR (or less) at 1% FAR for the Key Visit. No other products meet these objectives.

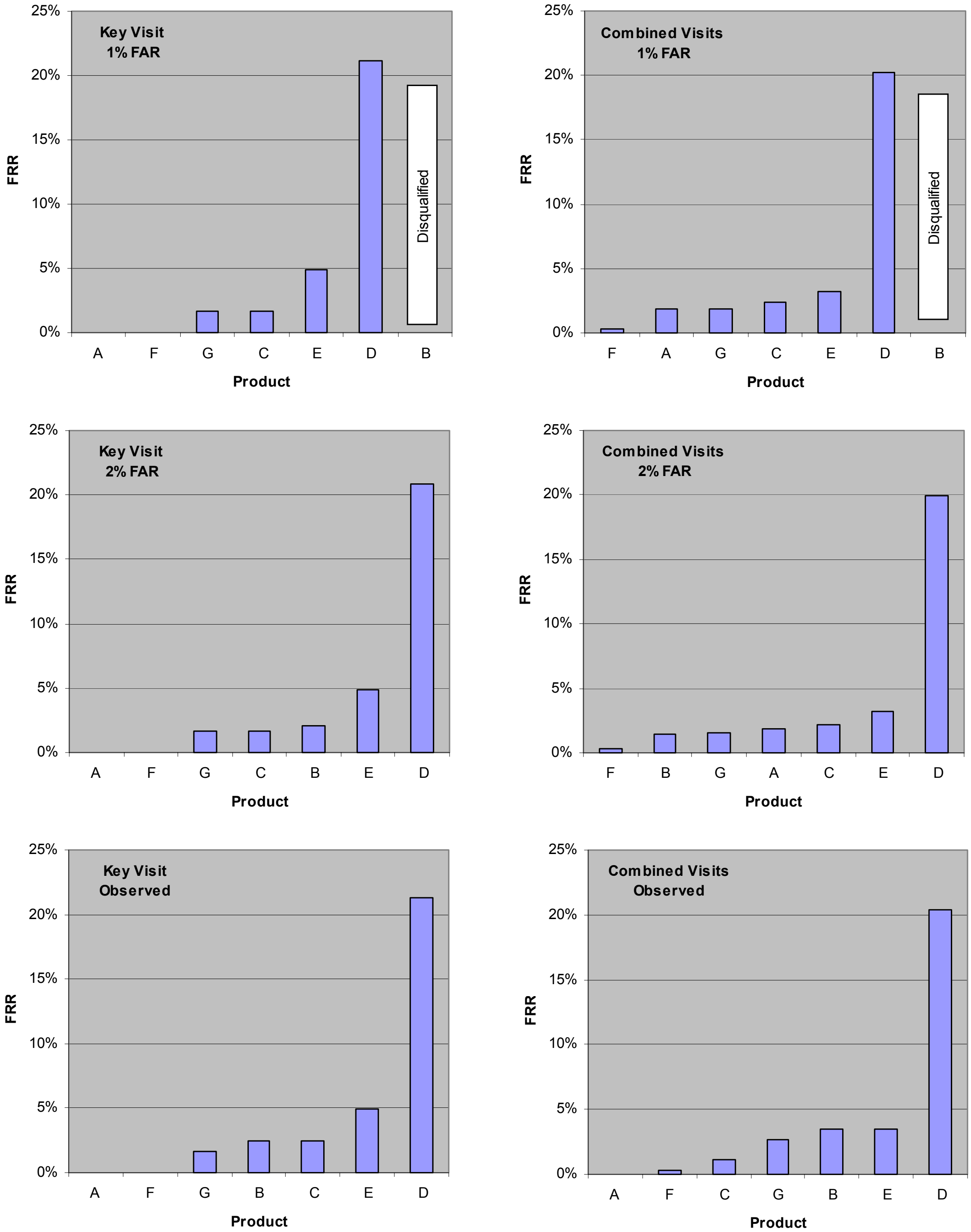


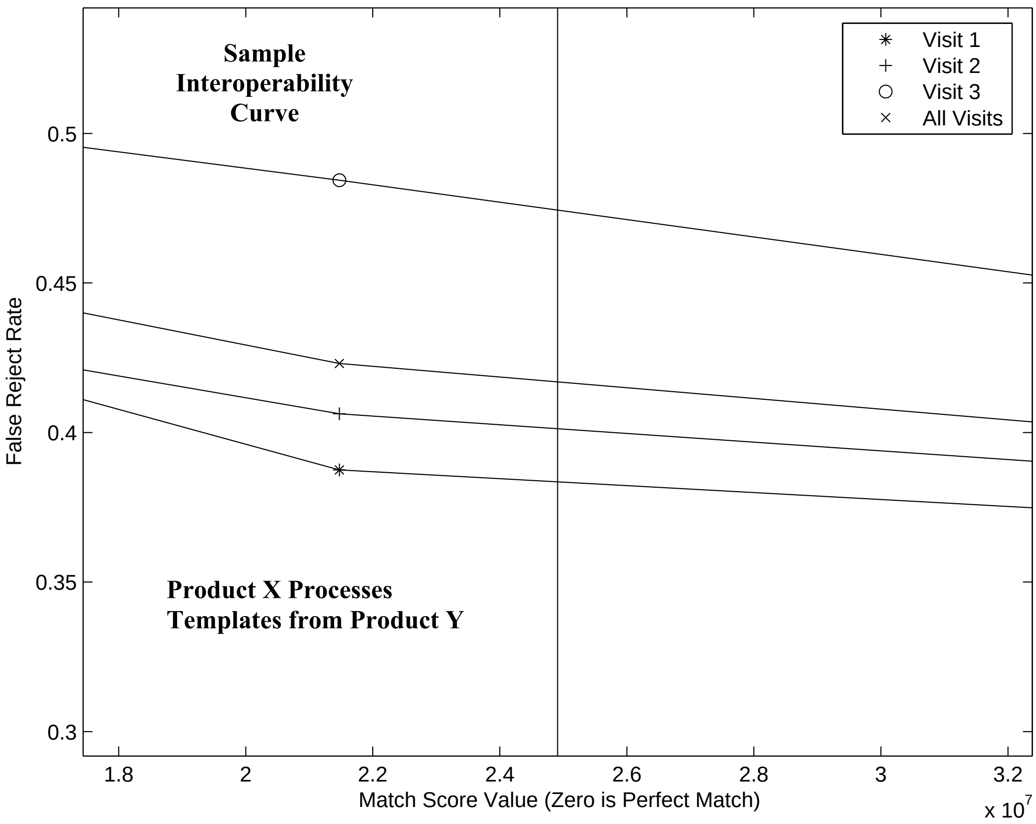
Figure 2. Ranked FRR for Key Visit and Combined Visits

Figure 2 shows that Product D has roughly a 20% FRR in all cases. This performance is clearly unacceptable, and this product was dropped from consideration. The remaining products have FRRs nominally below 5%, except Product B, which was unable to achieve at a 1% FAR. Overall, Products A and F have the lowest FRRs (best native performance) compared to the other products.

Interoperability Performance

Next the performance of combinations of products, or interoperability performance, must be evaluated. While impostor tests were performed for each native product-template combination (for example, Product A processes templates created with Product A), impostor tests for non-native product-template combinations (for example, Product A processes templates created with Product B) were not performed due to time constraints. Without non-native impostor tests, interoperability DET curves cannot be generated and thus cannot be used to directly calculate FRRs for nonnative product-template combinations at specific FAR values.

To estimate FRRs at specific FARs for nonnative combinations, the FARAchieved Scores (Match Score Values) were plotted versus FRR for each of the nonnative product-template combinations. To generate these curves, all unique scores output by a given product-template combination were placed in numerical order. Each score was then considered a threshold score. The number of scores that occurred above the threshold score determined the FRR value at that score. An example of a two-finger interoperability graph is illustrated below.



The match scores corresponding to 1% and 2% FAR on each product's DET curve in Annex H were computed and then located on the interoperability curve for the same processing product (indicated by the vertical line in the sample interoperability curve). For example, the score at 1% FAR from Product X's DET was about $2.45x10^7$. Locating this score in the interoperability curve for Product X processing a template created by Product Y, gives a FRR value on each of the four interoperability curves at this score that can be assumed to correspond to the original FAR. For example, for Visit 3 in the graph above, the FRR is about 0.475 (47.5%) at an FAR of 1%.

The results of this analysis, which allows comparison of native and nonnative product-template FRRs at common (inferred) FARs for all of the products tested, are presented in Tables 5-8 below.

Although the FAR values for the nonnative FRR values presented in Tables 5 – 8 are estimates, it is likely that the assumptions used in the calculations will, if anything, overestimate the FAR values. Thus actual performance should equal or better these estimates. Each BSP processes and stores minutiae slightly differently than do other BSPs. In addition, each BSP is tuned to achieve optimal performance when processing its own templates. When a BSP processes a template created by a different BSP, performance may be as good as with a native template, but it likely will not be better. As such, it is expected that in most cases, the FRR for non-native product-template comparisons will increase, or at best be the same, compared to FRR for native comparisons. In the same vein, FAR is expected to decrease for non-native comparisons. It is typically harder for a BSP to match a template generated by another BSP, which makes false accepts even less likely.[6]

Table 5. Interoperability Score-Based FRR for Key Visit at 1% FAR*

	Product (Sensor and BSP)									Aggregate Mean	
Template		A	C	D	E	F	G	Mean			
	A	0.0%	3.6%	19.8%	52.0%	1.6%	40.6%	19.6%		A	11.1%
	C	0.0%	1.7%	40.2%	5.5%	59.4%	3.0%	18.3%		C	17.7%
	D	9.4%	40.4%	21.1%	49.7%	22.2%	37.0%	30.0%		D	38.8%
	E	1.9%	6.3%	72.7%	4.9%	1.8%	3.6%	15.2%		E	20.9%
	F	0.0%	4.9%	65.0%	41.9%	0.0%	27.3%	23.2%		F	20.1%
	G	4.3%	46.6%	66.6%	6.3%	17.0%	1.6%	23.7%		G	21.3%
	Mean	2.6%	17.2%	47.6%	26.7%	17.0%	18.9%	21.7%			

*Product B removed since unable to produce FAR of 1%

Table 6. Interoperability Score-Based FRR for Combined Visits at 1% FAR*

	Product (Sensor and BSP)									Aggregate Mean	
Template		A	C	D	E	F	G	Mean			
	A	1.9%	7.0%	34.2%	41.7%	1.4%	49.6%	22.6%		A	13.0%
	C	0.0%	2.4%	53.8%	2.5%	65.0%	4.8%	21.4%		C	19.0%
	D	7.1%	38.1%	20.2%	43.6%	25.1%	40.8%	29.1%		D	40.5%
	E	4.1%	5.8%	70.6%	3.2%	2.8%	2.4%	14.8%		E	18.4%
	F	3.0%	5.6%	62.8%	31.5%	0.3%	36.9%	23.4%		F	21.0%
	G	3.6%	40.7%	69.4%	9.4%	17.5%	1.9%	23.8%		G	23.2%
	Mean	3.3%	16.6%	51.8%	22.0%	18.7%	22.7%	22.5%			

*Product B removed since unable to produce FAR of 1%

[6] In a personal communication with Dr. V. S. Valencia on 13 November 2004, Dr. J. L. Wayman claimed that theoretical computations support the general trend that FAR decreases and FRR increases for non-native product-template comparisons compared to native product-template comparisons. However, the theoretical computations also show that the comparison distributions broaden, which indicates that in some outlying cases the assumptions made here may not be valid.

Table 7. Interoperability Score-Based FRR for Key Visit at 2% FAR												
		Product (Sensor and BSP)									Aggregate Mean	
Template		A	B	C	D	E	F	G	Mean			
	A	0.0%	54.4%	3.3%	19.6%	45.5%	1.6%	40.6%	23.6%		A	12.9%
	B	3.1%	2.1%	5.9%	57.8%	10.2%	4.5%	3.6%	12.5%		B	17.2%
	C	0.0%	5.6%	1.7%	39.8%	5.5%	56.5%	2.0%	15.9%		C	14.9%
	D	7.6%	41.1%	37.5%	20.9%	37.4%	22.1%	33.0%	28.5%		D	38.6%
	E	1.9%	4.0%	6.3%	72.0%	4.9%	1.8%	3.6%	13.5%		E	17.0%
	F	0.0%	41.5%	4.7%	64.3%	35.9%	0.0%	23.1%	24.2%		F	19.4%
	G	3.1%	4.7%	37.9%	65.9%	4.8%	16.2%	1.6%	19.2%		G	17.3%
	Mean	2.2%	21.9%	13.9%	48.6%	20.6%	14.7%	15.4%	19.6%			

Table 8. Interoperability Score-Based FRR for Combined Visits at 2% FAR												
		Product (Sensor and BSP)									Aggregate Mean	
Template		A	B	C	D	E	F	G	Mean			
	A	1.9%	49.1%	7.0%	33.8%	38.3%	1.4%	40.7%	24.6%		A	13.6%
	B	2.7%	1.5%	7.8%	59.0%	4.2%	4.5%	2.7%	11.8%		B	16.1%
	C	0.0%	5.9%	2.2%	53.2%	2.4%	53.0%	2.0%	17.0%		C	15.7%
	D	5.8%	41.0%	37.2%	20.0%	38.1%	22.4%	33.9%	28.3%		D	40.4%
	E	2.7%	2.4%	5.4%	69.9%	3.2%	2.4%	2.0%	12.6%		E	15.1%
	F	3.0%	38.3%	5.4%	62.2%	29.1%	0.3%	25.9%	23.4%		F	18.8%
	G	2.7%	4.7%	36.1%	68.7%	8.1%	14.6%	1.5%	19.5%		G	17.5%
	Mean	2.7%	20.4%	14.4%	52.4%	17.6%	14.1%	15.5%	19.6%			

As with Tables 2 and 3 above, Tables 5 – 8 illustrate FRR performance 1) when templates (BIRs) created from one product are processed by the other products, and 2) when a product (sensor and BSP) processes templates created by the other products. The shaded values on the diagonals are the native FRR scores presented in the Figure 2 bar charts. The average FRRs of templates created by Product X and processed by all other products are indicated in the Mean column. The average FRRs of Product X processing templates created by all other products are indicated in the Mean row. The Aggregate Mean is the average of these two values for each Product.

The average interoperable performance expected for all products is shown in the Mean/Mean cell in red lettering. As expected, the average FRR is lower at 2% FAR than at 1% FAR. Allowing more successful impostor attempts (higher FAR) serves to facilitate more successful genuine attempts (lower FRR).

For the key visit at 1% FAR (Table 5), the average interoperability FRR is 21.7%, however it is important to note that a wide variety of FRR performance is observed. For example the Template C-Product A pair has 0% FRR, while the Template G-Product D pair has a very high 66.6% FRR. Clearly, Products A and C work well together while Products D and G do not under these operating conditions. Similar trends can be observed in Tables 6-8. The next task, then, is to identify which combinations of products achieve optimal performance and best satisfy the requirements of the ILO Convention No. 185.

Optimal Product Combinations

To determine optimal product combinations, interoperability tables were generated for all possible combinations of two, three, four, five and six products for the various operating conditions. The best performing combinations (lowest mean FRR) for the 1% and 2% FAR cases for the key and combined visits are presented in Annex I. Also included in Annex I, for comparison, are the best performing product combinations using the observed (binary decision based) FRR values. The format of the tables in Annex I is identical to the format of Tables 5-8. The results presented in Annex I are summarized in Table 9 below and presented graphically in Figure 3.

Table 9. Summary of Best Performing Product Combinations

	Key Visit FRR			Combined Visits FRR		
	1% FAR	2% FAR	Observed	1% FAR	2% FAR	Observed
Best Combinations of 2 Products						
Products	A-F	A-F	A-F	A-F	A-F	A-F
Mean FRR	0.4%	0.4%	0.4%	1.6%	1.6%	0.8%
Max Non-Native FRR (Product-Template)	1.6% (F-A)	1.6% (F-A)	1.6% (F-A)	3.0% (A-F)	3.0% (A-F)	2.9% (A-F)
Min Non-Native FRR	0.0%	0.0%	0.0%	1.4%	1.4%	0.0%
Best Combinations of 3 Products						
Products	A-C-F	B-E-G	B-E-G	A-C-E	B-E-G	B-E-G
Mean FRR	7.9%	4.4%	5.2%	7.6%	3.4%	6.0%
Max Non-Native FRR (Product-Template)	59.4% (F-C)	10.2% (E-B)	12.5% (E-B)	41.7% (E-A)	8.1% (E-G)	12.7% (E-G)
Min Non-Native FRR	0.0%	3.6%	3.6%	0.0%	2.0%	3.1%
Best Combinations of 4 Products						
Products	A-C-E-G	B-C-E-G	B-C-E-G	A-C-E-F	B-C-E-G	A-B-C-E
Mean FRR	11.4%	6.5%	10.5%	11.1%	5.8%	11.1%
Max Non-Native FRR (Product-Template)	52.0% (E-A)	37.9% (C-G)	79.3% (C-G)	65.0% (F-C)	36.1% (C-G)	51.9% (B-A)
Min Non-Native FRR	0.0%	2.0%	3.6%	0.0%	2.0%	0.0%
Best Combinations of 5 Products						
Products	A-C-E-F-G	A-B-C-E-G	A-B-C-E-G	A-C-E-F-G	A-B-C-E-G	A-B-C-E-G
Mean FRR	11.4%	10.2%	13.2%	13.8%	9.5%	14.1%
Max Non-Native FRR (Product-Template)	52.0% (E-A)	45.5% (E-A)	79.3% (C-G)	65.0% (F-C)	40.7% (G-A)	74.3% (C-G)
Min Non-Native FRR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Best Combinations of 6 Products						
Products	-	A-B-C-E-F-G	A-B-C-E-F-G	-	A-B-C-E-F-G	A-B-C-E-F-G
Mean FRR	-	12.3%	15.6%	-	11.5%	16.8%
Max Non-Native FRR (Product-Template)	-	56.6% (F-C)	79.3% (C-G)	-	53.0% (F-C)	74.3% (C-G)
Min Non-Native FRR	-	0.0%	0.0%	-	0.0%	0.0%

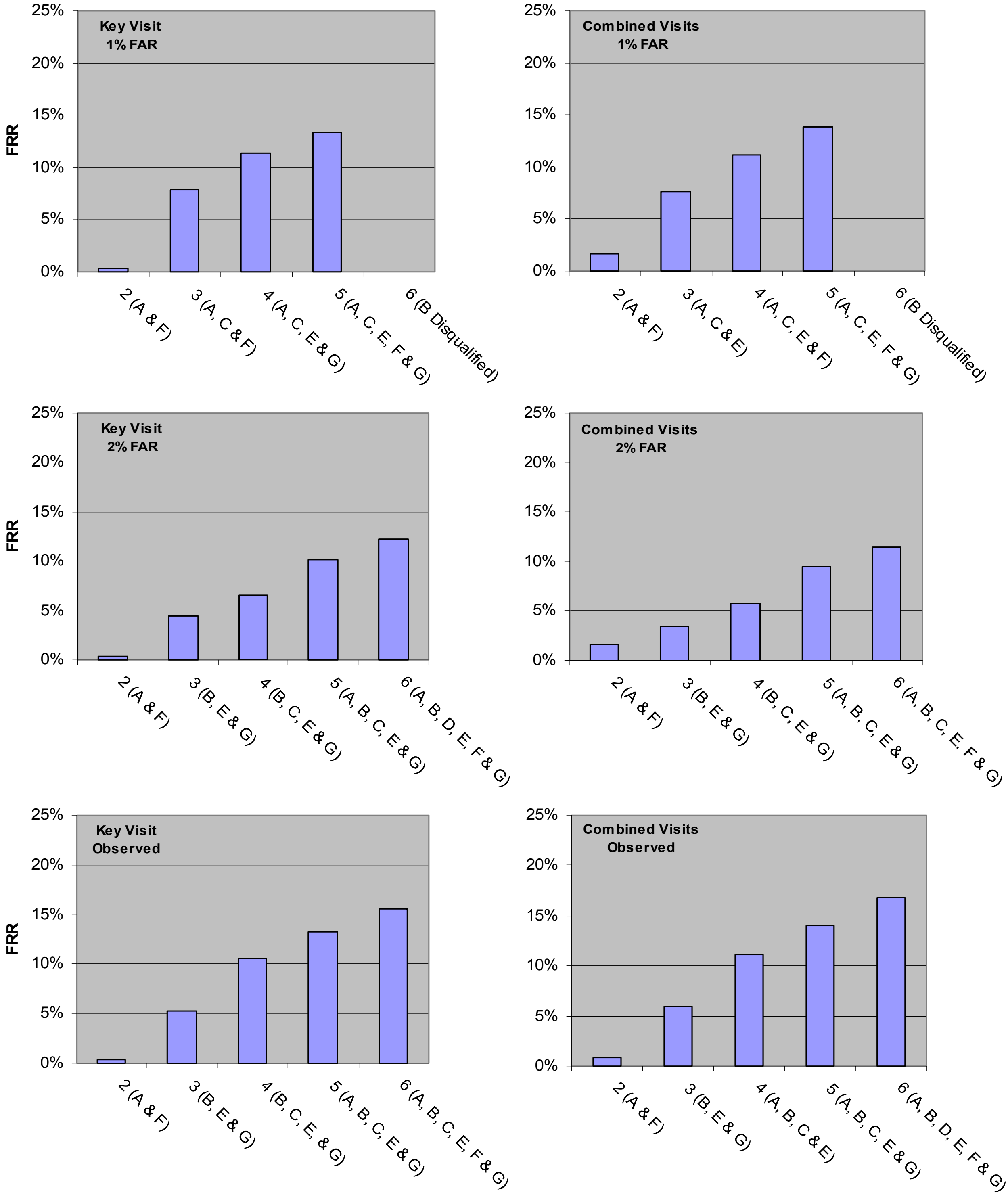


Figure 3. Ranked Best Performing Product Combinations

In Table 9 we observe that the best performing combination of two products is A and F, regardless of the operating conditions. The maximum non-native FRR for this pair 1.6% for the key visit and 3.0% for the combined visits. This is acceptable interoperability performance for field operation.

The best performing combination of three products depends on the operating conditions. For 1% FAR, Products A, C, and F achieve a mean FRR of 7.9% for the key visit, while for 2% FAR, Products B, E, and G achieve a mean FRR of 4.4% for the key visit.

The native FRR performance for Products A, C, and F at 1% FAR are 0.0%, 1.6%, and 0.0%, respectively. To use this combination, the ILO would have to relax the native FRR requirement to 1.6%. The mean FRR of 7.9% for Products A, C, and F means that for every 100 Seafarers that use the system, about 8 of them will fail to be biometrically verified. More important, however, is the non-native FRR of 59.4% when Product C templates are processed by Product F. If one country uses Product C to create the SID templates (the BIRs stored in the PDF-417 barcode that is printed on the SID), and a different country uses Product F to verify Seafarers, then over half of the Seafarers will fail to be biometrically verified. This performance is clearly not acceptable.

If 2% FAR is an acceptable operating point (for every 100 impostors that attempt biometric verification, 2 will succeed), then Products B, E, and G with 4.4% mean FRR for the key visit are an option, however when Product B templates are processed by Product E, the failure rate will be about 10% (10.2% FRR). This is probably unacceptable performance for a fielded system; roughly 1 out of 10 biometric verifications would fail for the Template B-Product E combination. The key-visit native FRR's for Products B, E, and G are 2.1%, 4.9%, and 1.6%, respectively at 2% FAR, which are all above the ILO requirement of 1% FRR.

The best performing combinations of four products depend highly on operating conditions. However, the native and non-native failure rates associated with all of these combinations are too high to be operationally feasible. The same is true for combinations of five and six products.

Combinations of two products deserve additional analysis, as some of these combinations, though not as highly performing as the Product A and Product F combination, may exhibit acceptable performance if the ILO is willing to relax the native FRR and FAR requirements of 1%. Performance for the top five two-product combinations for the various operating conditions are presented in Annex J and summarized in Table 10 on the following page. As observed in Table 10, performance depends significantly on operating conditions. A critical performance metric is the maximum non-native FRR. We have plotted this metric for four operating conditions of interest in Figure 4 (see page 34), which indicates the relative expected performance for the best performing two-product combinations. While the combination of Products A and F clearly outperform the other two-product combinations, this chart can be used to evaluate the degradation in performance that will result from using other combinations.

The bars in Figure 4 have a width to indicate that there is some uncertainty in the values we have measured. A full statistical analysis should be performed to adequately predict the statistical significance of the data presented herein. However, if we make crude binomial distribution approximations, we can estimate, for example, that a measured 1% FRR could actually range roughly from 0% to 2% FRR and a measured 6% FRR could actually range roughly from 4% FRR to 8% FRR. The width of the bars in Figure 4 are not to scale and are intended only to indicate that some uncertainty in the measured values does exist.

Table 10. Summary of Best Performing Two-Product Combinations						
	Key Visit FRR			Combined Visits FRR		
	1% FAR	2% FAR	Observed	1% FAR	2% FAR	Observed
Rank 1						
Products	A-F	A-F	A-F	A-F	A-F	A-F
Mean FRR	0.4%	0.4%	0.4%	1.6%	1.6%	0.8%
Max Non-Native FRR (Product-Template)	1.6% (F-A)	1.6% (F-A)	1.6% (F-A)	3.0% (A-F)	3.0% (A-F)	2.9% (A-F)
Min Non-Native FRR	0.0%	0.0%	0.0%	1.4%	1.4%	0.0%
Rank 2						
Products	A-C	A-C	A-C	A-C	B-G	A-C
Mean FRR	1.3%	1.2%	1.6%	2.8%	2.6%	2.4%
Max Non-Native FRR (Product-Template)	3.6% (C-A)	3.3% (C-A)	4.0% (A-C)	7.0% (C-A)	4.7% (B-G)	8.5% (A-C)
Min Non-Native FRR	0.0%	0.0%	0.0%	0.0%	2.7%	0.0%
Rank 3						
Products	E-G	B-G	B-G	C-E	A-C	B-E
Mean FRR	4.1%	3.0%	3.8%	3.5	2.8%	4.8%
Max Non-Native FRR (Product-Template)	6.3% (E-G)	4.7% (G-B)	6.3% (B-G)	5.8% (C-E)	7.0% (C-A)	9.0% (B-E)
Min Non-Native FRR	3.6%	3.6%	4.7%	2.5%	0.0%	3.1%
Rank 4						
Products	C-E	E-G	E-G	E-G	B-E	B-G
Mean FRR	4.6%	3.7%	4.1%	4.2%	2.8%	5.0%
Max Non-Native FRR (Product-Template)	6.3% (C-E)	4.8% (E-G)	6.3% (G-E)	9.4% (E-G)	4.2% (E-B)	6.8% (B-G/G-B)
Min Non-Native FRR	5.5%	3.6%	3.6%	2.4%	2.4%	6.8%
Rank 5						
Products	F-G	C-E	B-C	E-F	C-E	E-G
Mean FRR	11.5%	4.6%	4.8%	9.4%	3.3%	6.1%
Max Non-Native FRR (Product-Template)	27.3% (G-F)	6.3% (C-E)	7.8% (B-C)	31.5% (E-F)	5.4% (C-E)	12.7% (G-E)
Min Non-Native FRR	17.0%	5.5%	6.3%	2.8%	2.4%	5.5%

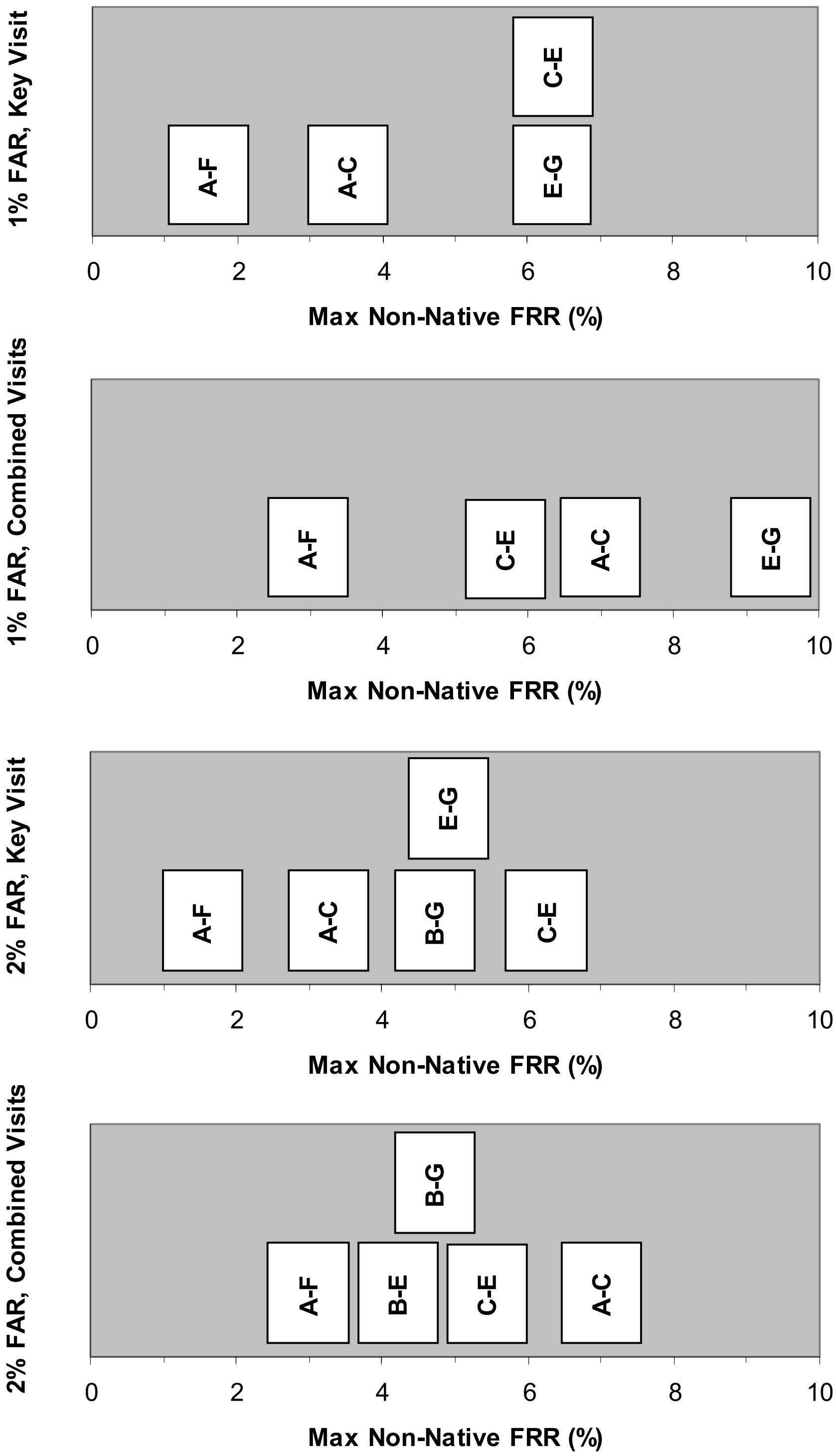


Figure 4. Ranked Performance for Two-Product Combinations

8 Summary

Seven biometric products passed initial conformance tests and were tested onboard a ship at sea using a Seafarer test population. Onboard tests included genuine comparisons and impostor comparisons to determine False Reject Rates (FRRs) and False Accept Rates (FARs), respectively, for each native product. Interoperability performance was also investigated by processing templates created by one product with each of the other products to determine non-native FRRs.

Only Products A and F met the ILO's stated performance objectives of 1% FRR (or less) at 1% FAR. Products A and F are also the best performing combination of two products, with a mean FRR of less than 1% at 1% FAR under ideal operating conditions. Several other two-product combinations exhibited acceptable performance in some operating conditions, however these products did not meet the ILO's performance objectives (1% FRR at 1% FAR) and did not perform as well as the combination of Products A and F. The error rates for all combinations of 3, 4, 5, and 6 products did not meet the ILO's performance requirements.

9 Additionally Indicated Analyses

Several important analyses that could influence the use and operation of the biometric component of the ILO SID were not addressed in the report due to the extreme urgency of publishing the report immediately following the data collection. These topics should be addressed in a timely manner:

- A methodology for testing additional products for expansion of the product list over time should be developed and swiftly implemented.

  Such a methodology will enable the ILO to quickly respond to inquiries from international vendors interested in providing the biometric component of the SID for each Member nation that ratifies ILO Convention No. 185.

- An analysis needs to be performed on the enrollment and verification data to document performance-critical information, such as the number of attempts for each finger; failure to acquire rates; time, date, temperature and humidity for enrollment and verification attempts; finger minutiae template quality for each finger; etc. In addition, distributions need to be reported for performance-relative demographic data such as birthdate, gender, and onboard job type.

  Understanding how performance is influenced by these parameters will allow the ILO to implement the ILO SID to achieve optimum performance.

- A statistical analysis should be performed on the data collected for this test. A statistical analysis would, to the extent possible with existing models, determine the uncertainties in the data analysis performed here, such as error bars and confidence intervals.

  A statistical analysis of the existing data will enable the ILO to be more confident in the expected performance of the ILO SID biometric component in an operational environment and potentially reduce costs associated with including additional products on the list of compliant biometric products in the future.

- Correlations between sensor resolution, sensor size, and sensor type and performance should be fully investigated.

  If the types of sensors that provide optimal performance are well understood, the ILO can potentially minimize future testing with live seafarers, which is very time consuming and expensive.

- The robustness of fingerprint quality assurance algorithms within each product's software module should be investigated.

  Quality algorithms profoundly influence the ultimate performance of biometric products in a fielded environment.

- Finally, the impact of minutiae truncation on biometric performance needs to be fully explored. Both native and interoperability performance may be significantly influenced by minutiae truncation. This influence can be studied using the data taken during this test. While analysis was not performed on truncation affects, the raw data suggests that potentially 24% of the enrolled fingerprint templates, ranging from 3% for Product A to 40% for Product D, were truncated.

  Understanding whether minutiae truncation influences performance will allow the ILO to make appropriate recommendations and take corrective measures, if necessary, to improve the performance of the ILO SID.

References

Normative References

a) ILO Convention No. 185

b) ILO SID-0002 – Finger Minutiae-Based Biometric Profile for Seafarers' Identity Documents (ILO SID-0002)

c) ISO/IEC CD 19794-2 – Biometric Data Interchange Formats – Part 2: Finger Minutiae Data (ISO/IEC JTC 1 SC37 N 340, dated 2003-10-07)

Informative References

d) ICAO Document 9303 – Machine Readable Travel Documents (Part 1, 5th Edition, 2003; Part 3, 2nd Edition 2002)

Glossary

An attempt has been made to harmonize the definitions and terms used in this report with common industry practice and with the various reference standards listed above. Specific relevant terms are defined below for the reader's convenience.

Administrator

Person performing the testing or enrollment.

Attempt

Submission of one (or a sequence of) biometric samples to the system.

NOTE 1: An attempt results in a matching score (or scores), or possibly a 'failure to acquire'.

NOTE 2: Many biometric systems collect and process a sequence of samples in a single attempt, for example:

(a) collecting samples over some fixed period, and scoring the best matching sample;

(b) collecting samples until either a match is obtained or the system times out;

(c) collecting samples until one of sufficient quality is obtained, or the system times out;

(d) collecting a second sample when the score from the first sample is very close to the decision threshold.

Biometric

Pertaining to the field of biometrics, used as an adjective.

Biometric information record (BIR)

A data structure containing a BDB, information identifying the BDB format, and possibly further information such as whether the BDB is digitally signed or encrypted.

Biometric verification/biometrically verify

Validate that a biometric sample matches the previously-stored processed biometric sample associated with the subject's claimed identity by comparing the templates, generating a score, and comparing the score with the threshold.

Biometric enrollment

The process of collecting one or more biometric samples from a subject and the subsequent preparation and storage of one or more processed biometric samples and associated data representing that subject's identity.

Detection error tradeoff curve (DET curve)

Curve which plots error rates on both axes (false positives on the x-axis and false negatives on the y-axis), which is usually plotted using logarithmic axes.

NOTE 1: DET curves can be used to plot matching error rates (false non-match rate against false match rate), decision error rates (false reject rate against false accept rate), open-set identification error rates (false negative identification rate against false positive identification rate). In this last case, the curves will depend on (a) the number of users enrolled in the database, and (b) the number of identifiers returned (per attempt) by the identification system.

Experimenter

Person responsible for defining, designing, and analyzing the test.

Failure-to-acquire rate (FTA)

Expected proportion of attempts for which the system is unable to capture or locate an image or signal of sufficient quality.

Failure-to-enroll rate (FTE)

Expected proportion of the population for whom the biometric system is unable to generate repeatable biometric samples (for the purpose of this document, templates).

NOTE: Regardless of the accuracy of the matching algorithm, the performance of a biometric system is compromised if an individual cannot enroll or if they cannot present a satisfactory image at a later attempt.

False Accept Rate (FAR)

Expected proportion of verification transactions with wrongful claims of identity (in a positive identification system) or non-identity (in a negative identification system) that are incorrectly confirmed by the biometric system.

False Reject Rate (FRR)

Expected probability that a biometric verification system will incorrectly not match a person's biometric sample to his/her biometric reference data (in a positive identification system) or incorrectly match a person's biometric sample to someone else's biometric reference data (in a negative identification system); thereby denying truthful claims of identity.

NOTE 1: See clause 4.3.2 for further details.

NOTE 2: In this document, biometric reference data are finger minutiae-templates as described in ILO SID-0002, Annex II.

Genuine attempt

Single good-faith attempt by a user to match their own biometric reference data.

NOTE: In this document, biometric reference data are finger minutiae-templates as described in ILO SID-0002, Annex II.

Operator

Test staff member recording test data.

Script

A script utilized by a test administrator in the direction of a test subject during enrollment and verification sequences.

Score

Measure of the similarity between features derived from a sample and stored biometric reference data, or a measure of how well these features fit a user's reference model.

NOTE 1: A match or non-match decision may be made according to whether this score exceeds a decision.

NOTE 2: As a presented sample becomes closer to the stored template, similarity scores will increase.

NOTE 3: In this document, biometric reference data are finger minutiae-templates as described in ILO SID-0002, Annex II.

Template

User's stored reference measure based on features extracted from enrollment samples.

NOTE: In this document, the template consists of minutiae data and other information for a single fingerprint as described in Annex B of ILO SID-0002 as either the 1st Fingerprint or 2nd Fingerprint Sections within the BIR.

User

Person presenting biometric sample to the system.

Annex A – Seafarers' Identity Document Biometric Technology Test Announcement Summer 2004

The International Labour Organization (ILO) is a tripartite organization in which representatives of governments, employers, and workers participate with equal status. It is a specialized agency of the United Nations that was created in 1919 and currently consists of 177 member States. In June 2003 the International Labour Conference adopted a new international labour Convention, the Seafarers. Identity Document (SID) Convention (Revised) 2003 No. 185 which is available on the ILO website[1]. This Convention provides for States to issue SIDs to their national or permanently-resident Seafarers with enhanced security measures over the existing Seafarers' identification documentation. ILO Convention No. 185 is a significant, comprehensive and effective response to security concerns in the modern world, including the necessary safeguards for individual rights. The objective of the Convention is to ensure that a Seafarer's identity can be verified positively and minimize Seafarer hardship as a result through enhanced security combined with the necessary freedom of movement in the normal conduct of their profession.

In March 2004, the ILO Governing Body decided on the biometric standard that will be incorporated in ILO Convention No. 185-compliant SIDs. That standard is given by the finger minutiae-based biometric profile for the ILO SID (ILO SID-0002) which is also available on the ILO website[2]. While this standard was based on draft ISO standards dated October 2003, modifications were made to ensure template interchangeability between minutiae-based biometric vendors and enable global interoperability for templates stored on the ILO SID two-dimensional PDF417 barcode. Consequently, modifications to commercial products will most likely be necessary.

The ILO will conduct a biometric technology test beginning August 16, 2004 to ensure compliance of biometric technology to both ILO Convention No. 185 and the biometric standard decided upon by the Governing Body in March 2004. This test will be open to biometric vendors and integrators of biometric systems. There will be three primary objectives of the biometric technology test; namely:

- Determine if the biometric products generate minutiae-based templates that conform to the ILO.s requirements. More specifically, verify that when given the appropriate demographic fields, the biometric software can enroll two fingers and generate the biometric identification record (BIR) component of the payload for the SID 2D PDF417 barcode as described in ILO SID-0002. This is the conformance component of the test.

- Determine if the biometric products generate BIR components of the barcode payloads that can be used to verify seafarers by themselves and by other vendors' biometric products. Also, determine if each product can verify seafarers using BIR components of the barcode payloads generated by other vendors' biometric products. This is the interoperability component of the test.

1 Go to www.ilo.org/public/english/dialogue/sector/index.htm and follow the links or directly at www.ilo.org/ilolex/cgi-lex/convde.pl?C185

2 Go to www.ilo.org/public/english/dialogue/sector/index.htm and follow the links or directly at www.ilo.org/public/english/dialogue/sector/papers/maritime/sid0002.pdf

• For each biometric product tested, determine the false accept rate and false reject rate for identity verification using real seafarers, in a realistic seafaring environment over reasonable time periods. This is the performance component of the test.

Biometric products that are determined to successfully meet the requirements of the test will go on an ILO list of products for use by countries implementing next generation SIDs for the purposes of Convention No. 185. Participating vendors will be provided with a detailed description of the test plan and the requirements for their products in advance of the test, although it will not be possible to provide quantitative success criteria for all parts of the test until after the test is completed.

Each vendor will be requested to provide two fingerprint capture devices and two copies of a software module. The hardware and software provided will be evaluated as a single combined product, thus each algorithm vendor should select the fingerprint capture device which they believe will be most advantageous to them in this test. The software module will perform fingerprint capture and matching, as well as generate the particular BIR component of the barcode payload format for the output specified in ILO SID-0002. A test control module will manage a GUI for the test subjects and operators and will make all calls to the different vendors' software. In general, these calls will be facilitated using the C# wrapped BioAPI written by H. Kaiser Yang, but certain additional calls may be required. Details will be provided to those vendors participating in the test.

A virtual bidders' conference will be conducted from June 14, 2004 through June 18, 2004 to allow vendors to ask questions for clarification and determine their commitment to making product modifications, as indicated, in advance of the ILO SID biometric technology test which is scheduled to begin on August 16, 2004. Interested vendors should send an email with point of contact details to g4marit@ilo.org. All vendors expressing interest will be added to the global distribution list. Questions for clarification on either of the referenced compliance documents can be emailed to g4marit@ilo.org. Responses to all questions will be distributed to vendors on the global distribution list. By not later than June 21, 2004, vendors prepared to commit to providing products for inclusion in the ILO SID biometric technology test should send an email to the g4marit@ilo.org. Products to be tested must be received by the ILO-designated test lab by July 16, 2004. Note that vendors on the global distribution list will not be informed of vendor intent to participate in the test. All communications with vendors will be treated as confidential. Particular care will be taken to ensure that technical details, as well as the hardware and software provided for testing, will be disclosed only to persons, under obligations of confidentiality, who are involved in the testing and only to the extent necessary for the testing. The hardware and software will be returned after testing.

The ILO SID program will be the first implementation of biometric technology on a global scale that will address biometric template interoperability. Members of the international standards community are keenly interested in the results of this test. We look forward to vendor participation in the project. Our collective goal should be to realize the objective of ILO Convention No. 185, which is to ensure that a Seafarer's identity can be verified positively and minimize Seafarer hardship as a result through enhanced security combined with the necessary freedom of movement in the normal conduct of their profession.

Annex B – Seafarers' Identity Document Biometric Technology Test Virtual Bidder's Conference Summary - Summer 2004

Forward:

Questions and Answers are ordered from most recently received to the earliest received. Question 1 was the first question received.

Thank you for your participation. The ILO would like to ensure that each of you has time to review the answers to all of the questions posted during the Virtual Bidders' Conference; therefore, please declare your intention to submit products for testing under the ILO SID Biometric Technology Test by so stating in an email addressed to g4marit@ilo.org by **not later than Wednesday, June 23, 2004.**

Question #33: The ILO has requested that vendor's declare by June 21st their intention to submit product for testing. Will ILO consider extending this deadline until one or two days after all Q's&A's have been distributed?

Answer #33: (sent 20040620) The ILO will move the deadline for intent to submit products for testing to Wednesday, June 23, 2004 to give vendors/integrators sufficient time to review the responses to the questions from the bidders' conference.

Question #32: In reference to previous response that no less than five other member States have indicated their intention to ratify Convention 185 soon: Which countries are among the five referenced?

Answer #32: (sent 20040620) Nigeria has publicly stated their intention to ratify. The ILO Office would need to consult with the other four member states before identifying them as we do not know if they have made their intentions publicly known yet.

Question #31: It is stated "In general, these calls will be facilitated using C# wrapped BioAPI, but certain additional calls may be required". Should certain additional calls be implemented with C# or C in the software module we provide?

Answer #31: (sent 20040619) No calls will be required which are not part of BioAPI, but the BSP is required to produce extra information such as writing raw files to the disk. Details are specified in the test SW design documents referenced in answer #1.

Question #30: Am I reading question #15 & #14 correctly that this test only requires the integrator to provide an BIO complaint BSP and that there is no deliverable application that requires biometric searches, printing of bar code, or bar code reading with biometric verification of cards/documents such as passport and ID cards.

Answer #30: (sent 20040619) Correct, biometric-based searches, bar code printing and bar code reading are outside the scope of this technology test. See answers #1 and #22 for more information.

Question #29: In reference to previous response indicating that "the ILO will use the biometric technology test to determine which biometric algorithm and sensor pairs meet the ILO's biometric requirements for the SID. It won't make sense to test the same system twice.", is it an accurate interpretation that a "system", as referenced above, is defined as the algorithm and sensor pair typically produced by a biometrics vendor? If such is the case and given that ILO is not interested in duplicating tests of the same system, is there a scenario under which ILO would test the same sensor/algorithm pair submitted for testing by multiple integrators? What value-added, if any, would an integrator need to add to a sensor/algorithm pair such that the ILO would view multiple systems as distinct even if they are based on the same sensor/algorithm pair?

Answer #29: (sent 20040619) Integrators may select any sensor/algorithm pair that is on the approved list of products in response to member state implementation opportunities. The ILO hopes that several sensor/algorithm pairs will successfully test and be placed on the ILO approved product list to maximize flexibility for member states and their integrators. Also, see Answers #16 and #23.

Question #28: In reference to the previous response indicating that 62 countries have already ratified Convention No. 108, and these countries can issue Convention No. 185 SIDs in accordance with Article 9 of Convention No. 185: Which countries are among the 62 referenced?

Answer #28: (sent 20040619) As of 2004-06-18, the following countries have ratified Convention 108: Algeria, Angola, Antigua and Barbuda, Azerbaijan, Barbados, Belarus, Belize, Brazil, Bulgaria, Cameroon, Canada, Cuba, Czech Republic, Denmark, Djibouti, Dominica, Estonia, Fiji, Finland, France, Ghana, Greece, Grenada, Guatemala, Guinea-Bissau, Guyana, Honduras, Iceland, the Islamic Republic of Iran, Iraq, Ireland, Italy, Kyrgyzstan, Latvia, Liberia, Lithuania, Luxembourg, Malta, Mauritius, Mexico, Republic of Moldova, Morocco, Norway, Panama, Poland, Portugal, Romania, Russian Federation, Saint Lucia, Saint Vincent and the Grenadines, Seychelles, Slovenia, Solomon Islands, Spain, Sri Lanka, Sweden, Tajikistan, Tanzania Tanganyika, Tunisia, Ukraine, United Kingdom, Uruguay. Source: http://www.ilo.org/ilolex/cgi-lex/ratifce.pl?C108 **)**

Question #27: In reference to options for vendors that fail to complete the test and obtain certification: What recourse is available to vendors that are not successful in the August 16, 2004 test? Will ILO allow re-testing and/or subsequent testing opportunities? What would be the earliest date that an unsuccessful vendor could apply for a follow-on test and subsequent certification?

Answer #27: (sent 20040619) See Answer #20 and note that the specific date for a follow-on test has not been determined at this point.

Question #26: In reference to test support expected from vendors/integrators: Subsequent to the deadline for submitting equipment for testing, will ILO require support from the participating vendors/integrators? If support is required, what is expected to be the nature of such support, e.g.: remote support, on-site support, test application development support?

Answer #26: (sent 20040619) The Test Laboratory selected by the ILO may require remote or on-sight support to ensure that the product is given the best possible chance during the test. Test application development support should not be required.

Question #25: In reference to the July 16, 2004 deadline for submission of equipment to be tested: It is understood, based on clarification previously provided, that the August 16, 2004 test date cannot be delayed. With a view to allowing vendors sufficient time to review ILO's responses (including the software design and test methodology documents received on 16 June) and to implement necessary software revisions, will ILO consider moving back the July 16, 2004 deadline for submission of equipment to be tested?

Answer #25: (sent 20040619) No, the ILO will not move this deadline. See Answer #20.

Question #24: In reference to application of certification awarded to vendors that successfully complete test: Please clarify how the certification will be applied - i.e..: is it only the equipment tested that will be certified? Will the biometric vendor and/or integrator that supply the approved equipment be "certified" as an approved provider? If an integrator adds value to an independent biometric vendor's technology for purposes of the test, is the biometric vendor's equipment certified separate from the integrator's added value or is the certification applied only to the integrated "solution"?

Answer #24: (sent 20040619) The actual equipment tested will be put on the ILO's approved list of equipment that member states (countries) can use to implement ILO Convention No. 185. If a biometric vendor's product has been modified by the biometric vendor or by an integrator and that product successfully completes the test, then that modified product (or solution) will be put on the ILO's approved list of equipment. Neither the biometric vendor nor the integrator will be put on a list.

Question #23: With regards to the July 16th deadline for submitting Software and Hardware for the test; When will the final, detailed description of the test plan and requirements for the products be provided for the participants?

Answer #23: (sent 20040619) See Answer #1.

Question #22: Does the ILO have test bar codes (2D PFD417) that hold real minutia-templates that we can use for test purposes?

Answer #22: (sent 20040619) No, the ILO does not have test bar codes that hold real minutia-templates to be used for vendor test purposes. See Question and Answer #14 noting that bar code printing and reading will not be included in the ILO SID Biometric Technology Test that is scheduled to begin August 16, 2004.

Question #21: A possible visit to Geneva: We would be pleased, during for instance our products delivery, to visit you in Geneva, in order to have round talks regarding your project and the testing procedures. Could you please confirm whether that possibility would be acceptable?

Answer #21: (sent 20040619) Vendors will be encouraged to visit the ILO Test Laboratory to ensure product integration with the test suite prior to the test. The ILO Test Laboratory has not been selected yet and may not be in Geneva. See Answer #1.

Question #20: Could I send our biometric product after 16th July? If I can, until when should I send it? We may possibly not be able to send our product by 16th July.

Answer #20: (sent 20040619) Products to be included in the ILO SID Biometric Technology Test that is scheduled to begin on August 16, 2004 need to be received by July 16, 2004. Consideration will be given to ways in which modified products could undergo appropriate testing at a later date with a view to inclusion in the ILO list of compliant products.

Question #19: Could I cancel our application after your acceptance? If I can, until when should I make cancellation? We are still discussing whether we will join or not. We need make a consensus of our company.

Answer #19: (sent 20040619) Yes, products not received by the Test Laboratory by July 16, 2004 will not be included in the ILO SID Biometric Technology Test.

Question #18: Will you give responses and time to react if the BIR shows non-conformance?

Answer #18: (sent 20040619) There is no time for product modification built into the test plan. It may be possible for minor adjustments to be made to products in the course of testing, to the extent that the persons responsible for testing consider that there would be sufficient time for such adjustments to be made. The results of a products performance will be made available to the vendor/integrator submitting the product for test and consideration will be given to ways in which modified products could undergo appropriate testing at a later date with a view to inclusion in the ILO list of compliant products.

Question #17: With which OS should the software module submitted for testing be compatible (e.g.: Windows, Linux)? What type of processor will be employed for testing purposes?

Answer #17: (sent 20040618-1) The test platform will use the Microsoft Windows XP Professional SP1 operating system and run on a Intel Pentium M Processor 1.4GHz or better.

Question #16: If ILO's requirement is for a BioAPI compliant Library only, and in view of the fact that such Library is the competency of the biometrics vendor, what, under this scenario, would be the role of an integrator in the test process?

Answer #16: (sent 20040618-1) Some biometric vendors may not have the capacity to participate in the ILO's SID biometric technology test. In the case that a biometric vendor does not have the capacity or will to participate then it would be up to an interested integrator to sponsor the work necessary to have that vendor's product participate in the technology test.

Question #15: Please clarify whether the software module to be provided is a Library or a functional application.

Answer #15: (sent 20040618-1) Vendors shall provide a BioAPI compliant Biometric Service Provider (BSP) as detailed in section 4.2 of the BioAPI specification, version 1.1. (ANSI/INCITS 358-2002) Wherever possible, vendor's BSPs should be statically linked to avoid DLL conflicts with other vendor's BSPs on the same test machine.

Question #14: Specifically for the purposes of this test, is the vendor/integrator responsible for outputting only the 566 bytes of biometric data for the ILO to compile the bar code, or should the vendor output a complete 686-byte SID bar code? Is the reading/writing of this data from/to a PDF417 bar code part of the test or is the reading of and writing to the bar code up to the ILO?

Answer #14: (sent 20040618-1) It is mandatory to provide an ILO SID-0002 compliant BioAPI BIR -- bar code writing and reading is outside the scope of the ILO SID technology test. Thus, the vendor/integrator is only responsible for outputting 566 bytes of data. All implementing integrators will be responsible for system testing including the PDF417 bar code printing and reading.

Question #13: Are the BioAPI required calls to be high level, low level, or both? What are the specific BioAPI calls required?

Answer #13: (sent 20040618-1) Testing software will use all the BioAPI operations required for conformance to the Verification BSP type specification. Particularly, those calls indicated as required in Section 4.2 of the BioAPI specification, version 1.1 are required.

Question #12: Could you kindly give us some more information regarding the way you will proceed to evaluate the interoperability of the different tested systems?

Answer #12: (sent 20040618-1) See Answers #1, #7, and #8.

Question #11: Why does the ILO need to know what biometric algorithm and sensor pair we intend to submit for inclusion in the test?

Answer #11: (sent 20040618) The ILO will use the biometric technology test to determine which biometric algorithm and sensor pairs meet the ILO's biometric requirements for the SID. It won't make sense to test the same system twice. We hope to test multiple combinations to generate as large a list of approved biometric products as we can. This will give integrators maximum flexibility in their system design and implementation strategies. The ILO will need to know which biometric algorithm and sensor combinations will be submitted for testing by the deadline for expression of interest, June 21, 2004. The ILO will not use the biometric technology test to select integrators for implementation. System integrators may support biometric vendor preparation for the test and may influence sensor/algorithm pairing.

Question #10: What is the time schedule for the complete test? When the three test cases shall take place?

Answer #10: (sent 20040618) The Seafarers' Identity Document Biometric Technology Test is schedule to begin on August 16, 2004. The procurement announcement for submission of a Proposal for a Testing Laboratory for the ILO Seafarers' Identity Document (SID) Biometric Technology has been posted by the ILO. While the testing laboratory will determine the exact date that each of the three components of the test shall begin and the schedule for completion (working in conjunction with the ILO and the test subjects), the estimated test duration is 8 weeks.

Question #9: Could you specify a more detailed test procedure? What will be the size of the test population?

Answer #9: (sent 20040618) See answer #1.

<u>Question #8</u>: Will we get a test implementation of the mentioned C# BioApi by Kaiser Yang a week before July 16, 2004?

<u>Answer #8:</u> (sent 20040618) The complete source-code for the BioAPI C# wrapper is available from http://www.kaiseryang.com/CSharp/BioAPI/.

<u>Question #7</u>: Which version of the draft ISO Standards are applicable - the lastest or the standard versions documented in ILO SID0002.pdf?

<u>Answer #7</u>: (sent 20040618) To quote from Annex B of ILO SID-0002: "Because this fingerprint storage format was developed in accordance with draft ISO standard documents, **this document will take precedence for the Seafarers' ID** should evolution of either of these draft standards create any perceived inconsistency. The current committee draft that this document is based on is in flux. Where differences between this document and the Committee Draft are know to exist they will highlighted. Copies of the two draft conformance standards; namely, ISO WD 19794-2 – Biometric Data Interchange Formats – Part 2: Finger Minutiae Data (ISO/IEC JTC 1 SC37 N 340, dated 2003-10-07) and ISO WD 19794-4 – Biometric Data Interchange Formats – Part 4: Finger Image Based Interchange Format (ISO/IEC JTC 1 SC37 N 341, dated 2003-10-07), are provided in Annex C and Annex D, respectively."

<u>Question #6</u>: Would you be so kind and specify the test equipment? Which PC - type, which operating system shall be used? Will there be an USB input on the test PC?

<u>Answer #6</u>: (sent 20040618) See Answer #1 below.

<u>Question #5</u>: ILO requests vendors' commitments to make product modifications to comply with convention 185. Vendors are commercial entities with need to balance investment in product modifications against revenue opportunities. Requiring vendors to invest in product modifications in advance of Convention 185 ratification creates significant investment risk based on uncertainty about the success and timing of ratification. In consideration of vendors' legitimate business concerns, ILO is requested to consider delaying compliance testing until ratification of Convention 185 is a certainty.

<u>Answer #5</u>: (sent 20040618) Convention No. 185 has already been ratified by France and no less than five other member States have indicated their intention to ratify soon. It is also important to note that 62 countries have already ratified Convention No. 108, and these countries can issue Convention No. 185 SIDs in accordance with Article 9 of Convention No. 185.

Six months after the second ratification, the Convention will enter into force.

It should also be pointed out that, irrespective of ratification, many countries are likely to insist on production of the SID. They need to feel secure about authentication of Seafarer's identities in order to allow port entry and seafarer transit and the SID is, at the moment, the only international scheme in existence to provide the required level of assurance in the wake of September 11, 2001. Furthermore, the scheme is deemed to be a good one, by at least one important verifying country (the US). Access to foreign ports for shore leave and transit is an absolute necessity; however, the US have a deadline for positive verifiable identification of July 1, 2004 and have indicated to the Office that they were of the view that the SID would help grant access to US ports and would help implement obligations under the IMO's ISPS Code and that the absence of a SID would most likely be an impediment to shore leave or access to US ports.

The ratification of an ILO Convention, which is an international treaty, is a somewhat complex and lengthy procedure, which involves parliaments and relevant governments' ministries. These government agencies want to know, in any case before they ratify, that they will be able to comply with and implement the Convention's requirements.

All these bodies have heavy agendas, and cannot simply place our issues on the top of the pile. However, the whole procedure leading to the adoption of Convention No. 185 has been remarkably rapid. These are clear indications that the SID is seen as indispensable for the access to ports as well as for shore leave of the 1.2 million seafarers that serve the merchant fleets of the world. For these reasons the ILO is not in a position to consider delaying compliance testing until the Convention has entered into force.

Question #4: ILO requests vendors' commitments to make product modifications to comply with convention 185. Vendors are commercial entities with need to balance investment in product modifications against revenue opportunities. Given that convention 185 is not yet ratified, vendors may have reasonable concerns about the timing of a return on investment in product modifications specific to ILO's requirements. Please provide specific information on the status of the ratification process and the estimated timing of definitive adoption. To assist vendors in defining their business cases/ financial justifications with respect to investment, please indicate the likely adoption time frame of the SID by ILO member countries. Please indicate the expected size of the Seafarers ID market in terms of # of cards to be issued, # of issuance stations, # of verification stations.

Answer #4: (sent 20040618) See Answer #5.

Question #3: Participating vendors are to be provided a detailed description of the test plan and the requirements for their products in advance of the test... The test plan and the product requirements are critical drivers of vendors' decision to invest in the product modifications necessary to comply with ILO's standards. Given that such test plan and product requirements have not been issued by the current date (15 June 2004), vendors are in an extremely difficult position to make a business decision, allocate resources, and implement product changes by the August 16th test date. ILO is requested to consider moving back the test date such that vendors are given reasonable time to review the product and test requirements, decide a business strategy and then implement product modifications.

Answer #3: (sent 20040618). See Answer #5, together with Answer #1.

Question #2: With respect to the following phrase: “Vendor biometric must interoperate via certain additional calls to be determined”, please specify and describe the additional calls with which vendors' biometric must interoperate.

Answer #2 (sent 20040618): See Answer #1 below.

Question #1: With respect to the following phrase: “Vendor application must interoperate via C# wrapped BioAPI written by H. Kaiser Yang”, please specify and describe the exact set of BioAPI interfaces that are required by the ILO for both the testing and deployment of the SID.

Answer #1 (sent 20040618): The ILO has released a procurement notice to potential laboratories interested in performing the evaluation. The “Test Software Design Document" within that notice, specifically section 3 "Vendor BSP Requirements” should provide you with more details. The link for these documents is ftp://ftp.ilo.org/RFP_11_2004.zip.

Annex C – Participant Release Form

Personal Information Release Form for Participants of the ILO Biometric Test

This form officially gives consent for:

____,

hereinafter known as the ***seafarer,*** to release personal information to the International Labour Organization through its appointed biometric technology test team, hereinafter collectively known as the ***ILO test group***. This data is to be used exclusively for the purpose of testing to support the International Labour Organization Seafarers' Identity Document.

The data covered by this consent form will be collected during the testing period from **September through November 2004**. All personally identifying data including, but not limited to, name, age, gender, other demographic information and biometric images and templates, will be held confidentially by the ***ILO test group*** for a data retention period of five years, terminating on November 30, 2009. The information will not be shared with any person or entity outside the ***ILO test group*** and will be used only for the purpose of testing systems related to issuing and inspecting seafarers' identity documents. On or prior to the expiry of the five year data retention period, all copies of the data, including paper copies and primary and backup electronic media will be destroyed. Reports derived from this data that contain no personally-identifying information, such as biometric performance curves derived from a particular sub-group of seafarers, may be published and will not be destroyed at the end of the data retention period.

During the data retention period, the ***seafarer*** may request a report identifying the specific personal information related to them is being held by the ***ILO test group***. He or she can do this by sending a signed letter requesting this information to the ***ILO test group*** at the address given below and providing a return mailing address. Upon verifying that the ***seafarer***'s signature matches the signature on this release, the ***ILO test group*** will send a summary of the data currently retained to the mailing address provided. Due to the private nature of this information, electronic information requests and responses will not be permitted.

The ILO appreciates seafarer participation in this test which is designed to support implementation of ILO Convention No. 185.

The ***Seafarer*** acknowledges that he/she has read this Form and has been informed about the nature and purpose of the ILO Biometric Testing Campaign and the work of the ILO Test Group and agrees, by signing below, that he/she consents to the ILO's data retention as defined above. Please complete the reverse side of this form and remit to the ***ILO test group***.

I agree to participate in the ILO SID Testing Campaign and the tests carried out by the ILO test group, as described above.

Signed: the Seafarer: ____

Print Name: ____

Date: __________

ILO test group
4405 E. Baseline Road, Suite 118
Phoenix, AZ 85206
USA

Back side of Consent Form

Participant Demographic Information		
Name		Check one: ☐ Female ☐ Male
Birthplace (City, Country)		Birth Date (mm/da/yr):
Citizenship		
Position on board		

Back side of Consent Form

Annex D – Test Scripts

Enrollment Visit

Using the information from the release forms, we have created a record for each seafarer participating in the trial. This record will be used to identify that seafarer in each subsequent visit. My colleague [name] will read the information from your record aloud and ask you to verbally verify it.

Administrator reads all demographic data and allows seafarer to correct if necessary.

You will be asked to to place a primary finger and then a secondary finger, usually the left and right index fingers, on each sensor when you enroll on that sensor. Enrollment is the process of capturing an image of your fingerprint and converting it to the standardized minutiae template that will be used with the ILO Seafarers' Identity Document. This minutiae template contains only a map of the critical points from your fingerprint and not an image of the fingerprint. For the purposes of this test we are also recording the images of the fingerprints, but all of the matching is done only using the minutiae based templates.

We will tell you when to place the finger on each sensor and when to remove it. If the sensor has difficulty measuring that fingerprint, it will allow up to 3 attempts with the same finger before asking for another. Our goal is to enroll you on all of the sensors, so you may have to try several fingers. We have found that the left and right index fingers work best for most people, so we will start with those.

Are you ready to begin?

Operator now answers any last minute questions and then moves to first sensor as instructed by the administrator. The operator will place each sensor in front of the seafarer.

During enrollment, the administrator may provide guidance to the seafarer to achieve better fingerprint quality during the second and third attempts if appropriate.

The individual scripts for each sensor are not included here as the tested products might be identifiable from the specific scripts.

First Verification Visit

We are now going to try to recognize your fingers against the templates we just created during enrollment. We will ask you to place your fingers on each of the sensors several times.

Some of these tests will compare your finger against your own templates from the same sensor. These should match easily.

Some of the tests will compare your finger against your own template from other sensors. These should match, but depending on the compatibility of the different sensors and templates they may or may not match.

Some of the tests will compare your finger against templates from other seafarers we have enrolled. These should not match.

To make the test fair, the order of the tests is randomized, so some attempts to match your finger will succeed and some will fail. This is an intended part of the test and does not mean there is anything wrong with your fingerprints or with the technology we are testing.

As during enrollment, we will tell you which sensor and finger to use, when to place the finger on the sensor, and when to remove it. Are you ready to begin?

Operator now answers any last minute questions and then moves to first sensor as instructed by the administrator. The operator will place each sensor in front of the seafarer.

During verification, the administrator may NOT provide any guidance to the seafarer.

Second Verification Visit

We are going to try and match your fingers against the templates we created during your enrollment.

You will be asked to place your fingers on each of the sensors several times. There will be 10 tests on each of the seven sensors. The order of the tests is randomized, so you may find that some attempts to match your fingers succeed and some fail. This is an intended part of the test and does not mean there is anything wrong with your fingerprints or with the technology we are testing.

We will demonstrate finger placement on each sensor and <administrator name> will tell you which finger to use, when to place the finger and when to remove it. Please do not move your finger once it is touching the glass and do not lift your finger until you are told to do so.

Do you have any questions before we begin?

Operator now answers any last minute questions and then moves to first BSP as it appears on the screen.

During verification, the administrator may NOT provide any guidance to the seafarer.

Third Verification Visit

Used script for second verification visit

During verification, the administrator may provide guidance to the seafarer to achieve better fingerprint quality during the second and third attempts if appropriate.

.

Annex E – Enrollment and Verification Data Log Forms

Enrol Phase, Visit 1

Date: ____________________

Temperature (ºC): ________

Rel. Humidity (%): ________

Seafarer ID: ________

First Name: ____________________

Last Name: ____________________

Comments:

Test Results:	Right Index	Left Index	Right Thumb	Left Thumb	Right Middle	Left Middle	Right Ring	Left Ring	Right Little	Left Little	Quality 1	Quality 2
A												
B												
C												
D												
E												
F												
G												

Blank = Not Tested
n/a = Not Available
F = Failed / Unsuccessful
1 = Enrolled on First Attempt
2 = Enrolled on Second Attempt
3 = Enrolled on Third Attempt

Verify Phase, Visit X

Date: ____________________________ Seafarer ID: ___________

Temperature (ºC): ___________ First Name: ____________________________

Rel. Humidity (%): ___________ Last Name: ____________________________

Comments:

TEMPLATE

Test Results:

DEVICE		A		B		C		D		E		F		G	
		1	2	1	2	1	2	1	2	1	2	1	2	1	2
A	1:1 & Interop.														
	False Match			B		C		D		E		F		G	
B	1:1 & Interop.														
	False Match	A				C		D		E		F		G	
C	1:1 & Interop.														
	False Match	A		B				D		E		F		G	
D	1:1 & Interop.														
	False Match	A		B		C				E		F		G	
E	1:1 & Interop.														
	False Match	A		B		C		D				F		G	
F	1:1 & Interop.														
	False Match	A		B		C		D		E				G	
G	1:1 & Interop.														
	False Match	A		B		C		D		E		F			

Blank = Not Tested
n/a = Finger Not Available
1 = Match on First Attempt
2 = Match on Second Attempt
3 = Match on Third Attempt
F = Failed to Match after Three Attempts
U = Finger Undetected

Annex F – Test Harness Database Schema

Table Definitions

Module			
Persists all data related to each vendor's BioAPI BSP/sensor combination.			
	Column Name	**Data Type**	**Description**
PK	ID	tinyint	Primary Key
	Sequence	tinyint	used by test software to sequence interop. Tests
	bspDescription	varchar	used to link Module with BioAPI device schema
	Swipe	bit	0 = Live Scan Plain, 1 = Swipe
	FAR	bigint	BioAPI RequestedFAR as indicated by vendor
	bspVendor	varchar	name of vendor/sensor displayed in test software
	bspName	varchar	name of DLL used to link module with BioAPI when bspDescription fails
	bspPath	varchar	not used
	bspDeviceId	int	not used
	AlgorithmVersion	varchar	not used
	CreatedDateTime	datetime	default to INSERT date/time

Seafarer			
Stores demographic and visit data for all individual seafarers participating in the test.			
	Column Name	**Data Type**	**Description**
PK	ID	smallint	Primary Key
	FirstName	varchar	seafarer's first name
	LastName	varchar	seafarer's last name
	Nationality	char	2-character Nationality code
	DateOfIssue	datetime	default to INSERT date/time
	PlaceOfBirth	varchar	city or place of birth
	DateOfBirth	datetime	birthdate
	Gender	char	m, f, x (unspecified)
	PlaceOfIssue	varchar	not used
	JobClassification	varchar	seafarer's job or title on ship
	Temp1	tinyint	room temperature on first visit
	Temp2	tinyint	room temperature on second visit
	Temp3	tinyint	room temperature on third visit
	Humidity1	tinyint	% relative humidity on first visit
	Humidity2	tinyint	% relative humidity on second visit
	Humidity3	tinyint	% relative humidity on third visit
	CommentsEnrol	varchar	comments at time of enrolment
	CommentsVerify1	varchar	comments at time of first verification
	CommentsVerify2	varchar	comments at second verification visit
	CommentsVerify3	varchar	comments at third verification visit
	InteropSeed1	tinyint	starting Module Sequence number for interop tests on Visit 1
	InteropSeed2	tinyint	starting Module Sequence number for interop tests on Visit 2
	IntersopSeed3	tinyint	starting Module Sequence number for interop tests on Visit 3

Enrollment

Stores all test data and BIR fingerprint templates for each two-finger enrolment transaction.

	Column Name	Data Type	Description
PK	SeafarerID	smallint	Foreign Key to Seafarer
PK	ModuleID	tinyint	Foreign Key to Module
	EnrolDateTime	datetime	default to INSERT date/time
	EnrolStart	datetime	used to calculate total enrolment duration
	EnrolEnd	datetime	used to calculate total enrolment duration
	BIR	image	BIR generated by vendor BSP
	Conform	bit	1 if BIR is SID-0002 Conformant, 0 = not conformant
	ComformStatus	varchar	indicates BIR fields that failed conformance testing
	BioAPI_Quality	smallint	0 - 100
	Primary_Finger	tinyint	primary finger enrolled
	Primary_Quality	tinyint	0 - 100
	Primary_Minutiae	tinyint	0 - 52
	Alt_Finger	tinyint	alternate finger enrolled
	Alt_Quality	tinyint	0 - 100
	Alt_Minutiae	tinyint	0 - 52
	RightIndex	tinyint	0 = not tested, 1= not available, 11,12,13 = successful in 1,2, or 3 attempts, 2 = failed
	LeftIndex	tinyint	same as above
	RightThumb	tinyint	same as above
	LeftThumb	tinyint	same as above
	RightMiddle	tinyint	same as above
	LeftMiddle	tinyint	same as above
	RightRing	tinyint	same as above
	LeftRing	tinyint	same as above
	RightLittle	tinyint	same as above
	LeftLittle	tinyint	same as above
	RawPrimary	image	BMP image of primary finger if available
	RawAlternate	image	BMP image of alternate finger if available

Verfication

Stores all test data and BIR fingerprint templates for each single-finger verification transaction.

	Column Name	Data Type	Description
PK	Visit	tinyint	verification visit 1, 2, or 3
PK	SeafarerID	smallint	Foreign Key to Seafarer
PK	ModuleID	tinyint	Foreign Key to Module
PK	EnrolmentModuleID	tinyint	Foreign Key to Module
PK	EnrolmentFinger	tinyint	corresponds to the primary or alternate finger in the enrolment BIR
PK	EnrolmentSeafarerID	smallint	Foreign Key to Seafarer (same as SeafarerID, except for False Match tests)
	VerifyDateTime	datetime	default to INSERT date/time
	VerifyStart	datetime	used to calculate total verification duration
	VerifyEnd	datetime	used to calculate total verification duration
	BIR	varbinary	BIR generated by vendor BSP
	Conform	bit	1 if BIR is SID-0002 Conformant, 0 = not conformant
	ComformStatus	varchar	indicates BIR fields that failed conformance testing
	Match	bit	0 = No Match, 1 = Match
	Attempts	tinyint	placement attempts recorded by administrator (0 = all placements undetected)
	Score	int	BioAPI FARAchieved returned by vendor BSP
	Quality	tinyint	0 - 100
	Minutiae	tinyint	Number of Minutiae in Verification BIR
	BioAPI_Quality	smallint	0 - 100
	RawBMP	image	BMP image of verified finger if available

Config

Stores global configuration variables used by the test software. One record only.

	Column Name	Data Type	Description
	InteropTests	tinyint	specifies number of two-finger interoperability tests to be run per sensor per seafarer per visit
	LastTemp	tinyint	indicates the last temperature recorded by an administrator
	LastHumidity	tinyint	indicates the last humidity recorded by an administrator

Country

Lookup table for seafarer nationalities or counties of origin.

	Column Name	Data Type	Description
	Code	char	ISO country code
	FullName	varchar	full name of country

Gender

Lookup table for seafarer gender.

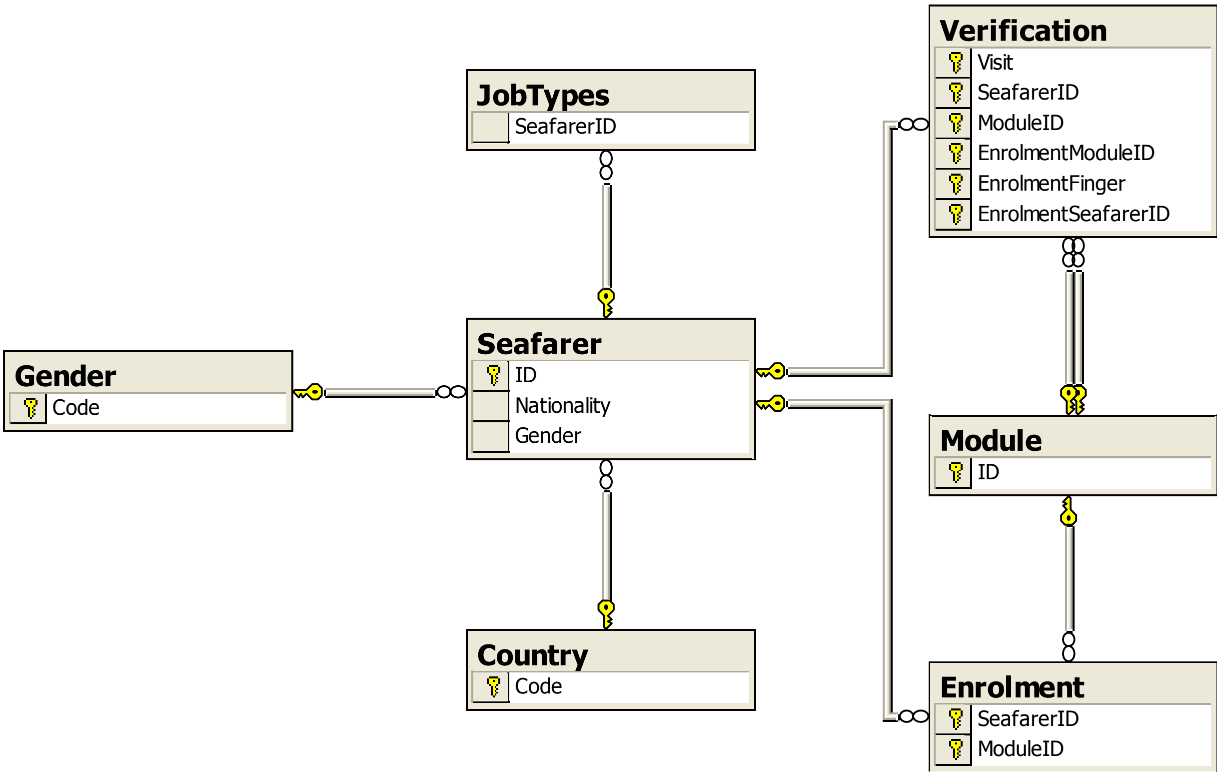
	Column Name	Data Type	Description
	Code	char	m = Male, f = Female, x = unspecified
	FullName	varchar	Male, Female, unspecified

JobTypes

Used for correlating test results with job types which may adversely affect fingerprint quality.

	Column Name	Data Type	Description
	SeafarerID	smallint	Foreign Key to Seafarer
	JobType	smallint	1, 2, 3, or 4

Primary / Foreign Key Relationship Diagram



MS-SQL Views

dbo.ReportVerify

```
CREATE VIEW dbo.ReportVerify
AS
SELECT Visit, ModuleID, EnrolModuleID, SeafarerID, EnrolSeafarerID, EnrolFinger,
[Match], Score, Attempts, BioAPI_Quality, Quality, Minutiae, EnrolQuality,
EnrolMinutiae FROM dbo.ReportVerifyPrimary
UNION ALL
SELECT Visit, ModuleID, EnrolModuleID, SeafarerID, EnrolSeafarerID, EnrolFinger,
[Match], Score, Attempts, BioAPI_Quality, Quality, Minutiae, EnrolQuality,
EnrolMinutiae
FROM dbo.ReportVerifyAlt
```

dbo.ReportVerifyPrimary

```
CREATE VIEW dbo.ReportVerifyPrimary
AS
SELECT TOP 100 PERCENT dbo.Verification.Visit,
dbo.Verification.ModuleID,dbo.Verification.EnrolmentModuleID AS EnrolModuleID,
dbo.Verification.SeafarerID, dbo.Verification.EnrolmentSeafarerID AS EnrolSeafarerID,
dbo.Verification.EnrolmentFinger AS EnrolFinger, dbo.Verification.[Match],
dbo.Verification.Score, CASE WHEN [Match] = 0 AND Attempts <> 0 THEN 3 ELSE
Attempts END AS Attempts, dbo.Verification.BioAPI_Quality, dbo.Verification.Quality,
dbo.Verification.Minutiae, dbo.Enrolment.Primary_Quality AS EnrolQuality,
dbo.Enrolment.Primary_Minutiae AS EnrolMinutiae
FROM dbo.Verification INNER JOIN dbo.Enrolment ON
dbo.Verification.EnrolmentModuleID = dbo.Enrolment.ModuleID AND
dbo.Verification.EnrolmentSeafarerID = dbo.Enrolment.SeafarerID AND
dbo.Verification.EnrolmentFinger = dbo.Enrolment.Primary_Finger
WHERE (dbo.Verification.FingerAvailable = 1)
ORDER BY dbo.Verification.SeafarerID, EnrolSeafarerID,
dbo.Verification.EnrolmentFinger
```

dbo.ReportVerifyAlt

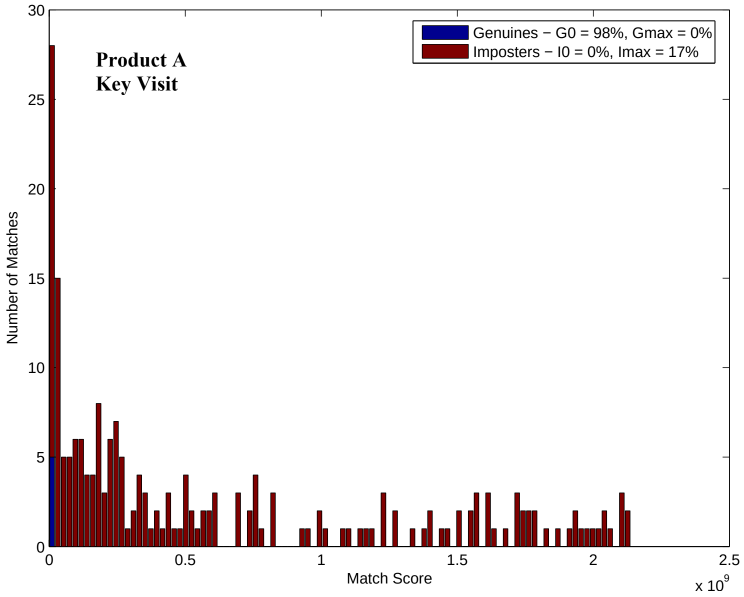
```
CREATE VIEW dbo.ReportVerifyAlt
AS
SELECT          TOP 100 PERCENT dbo.Verification.Visit, dbo.Verification.ModuleID,
dbo.Verification.EnrolmentModuleID AS EnrolModuleID, dbo.Verification.SeafarerID,
dbo.Verification.EnrolmentSeafarerID AS EnrolSeafarerID,
dbo.Verification.EnrolmentFinger AS EnrolFinger, dbo.Verification.[Match],
dbo.Verification.Score, CASE WHEN [Match] = 0 AND Attempts <> 0 THEN 3 ELSE
Attempts END AS Attempts, dbo.Verification.BioAPI_Quality, dbo.Verification.Quality,
```

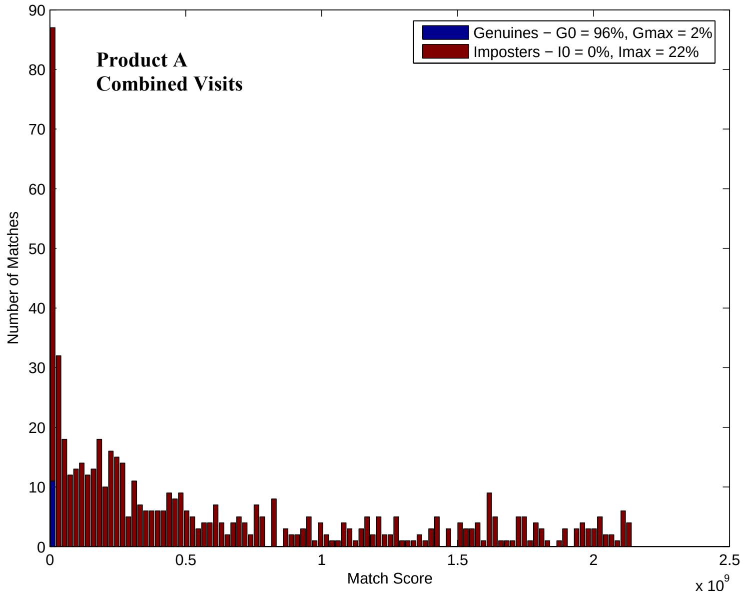
```
dbo.Verification.Minutiae, dbo.Enrolment.Alt_Quality AS EnrolQuality,
dbo.Enrolment.Alt_Minutiae AS EnrolMinutiae
FROM dbo.Verification INNER JOIN dbo.Enrolment ON
dbo.Verification.EnrolmentModuleID = dbo.Enrolment.ModuleID AND
dbo.Verification.EnrolmentSeafarerID = dbo.Enrolment.SeafarerID AND
dbo.Verification.EnrolmentFinger = dbo.Enrolment.Alt_Finger
WHERE (dbo.Verification.FingerAvailable = 1)
ORDER BY dbo.Verification.SeafarerID, EnrolSeafarerID,
dbo.Verification.EnrolmentFinger
```

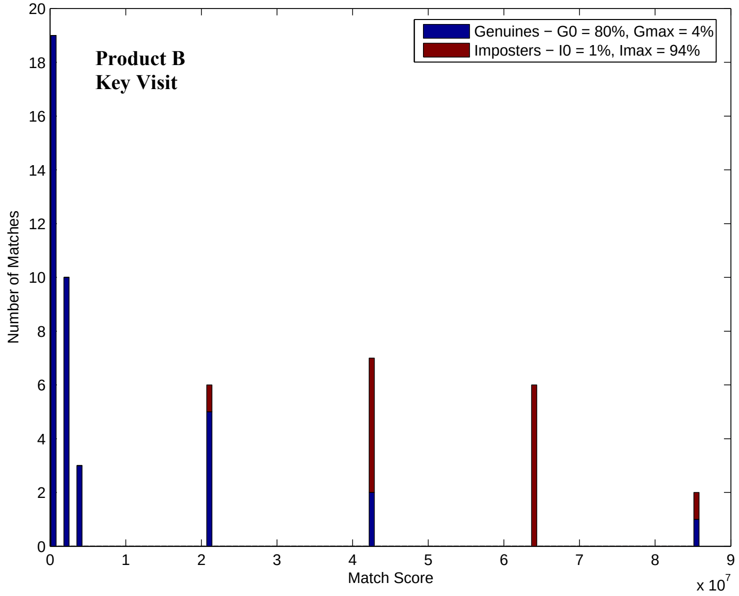
dbo.ReportVerify2Finger

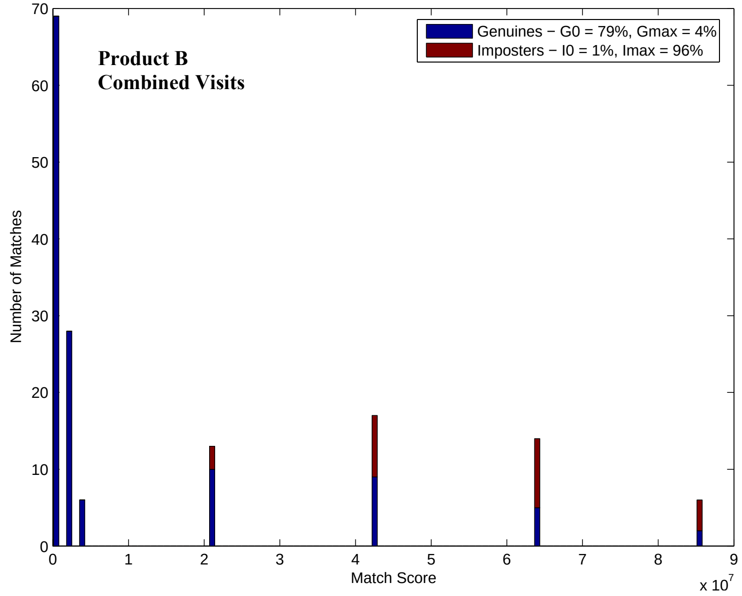
```
CREATE VIEW dbo.ReportVerify2Finger
AS
SELECT DISTINCT TOP 100 PERCENT dbo.ReportVerifyPrimary.Visit,
dbo.ReportVerifyPrimary.ModuleID, dbo.ReportVerifyPrimary.EnrolModuleID,
dbo.ReportVerifyPrimary.SeafarerID, dbo.ReportVerifyPrimary.EnrolSeafarerID,
dbo.ReportVerifyPrimary.Score AS PriScore, dbo.ReportVerifyPrimary.Attempts AS
PriAttempts, dbo.ReportVerifyAlt.Score AS AltScore, dbo.ReportVerifyAlt.Attempts AS
AltAttempts
FROM dbo.ReportVerifyPrimary INNER JOIN dbo.ReportVerifyAlt ON
dbo.ReportVerifyPrimary.Visit = dbo.ReportVerifyAlt.Visit AND
dbo.ReportVerifyPrimary.ModuleID = dbo.ReportVerifyAlt.ModuleID AND
dbo.ReportVerifyPrimary.EnrolModuleID = dbo.ReportVerifyAlt.EnrolModuleID AND
dbo.ReportVerifyPrimary.SeafarerID = dbo.ReportVerifyAlt.SeafarerID AND
dbo.ReportVerifyPrimary.EnrolSeafarerID = dbo.ReportVerifyAlt.EnrolSeafarerID
ORDER BY dbo.ReportVerifyPrimary.ModuleID,
dbo.ReportVerifyPrimary.EnrolModuleID, dbo.ReportVerifyPrimary.SeafarerID,
dbo.ReportVerifyPrimary.EnrolSeafarerID, dbo.ReportVerifyPrimary.Visit
```

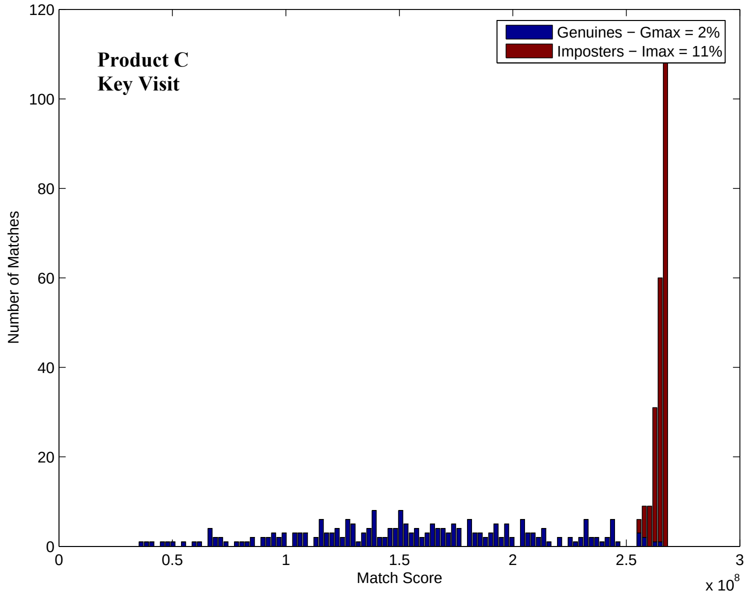
Annex G – Native-Comparison Genuine and Impostor Score Histograms

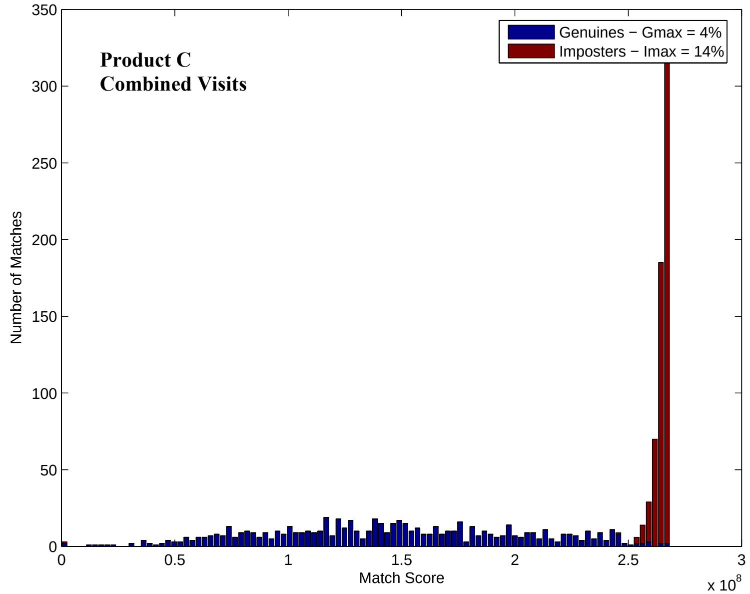


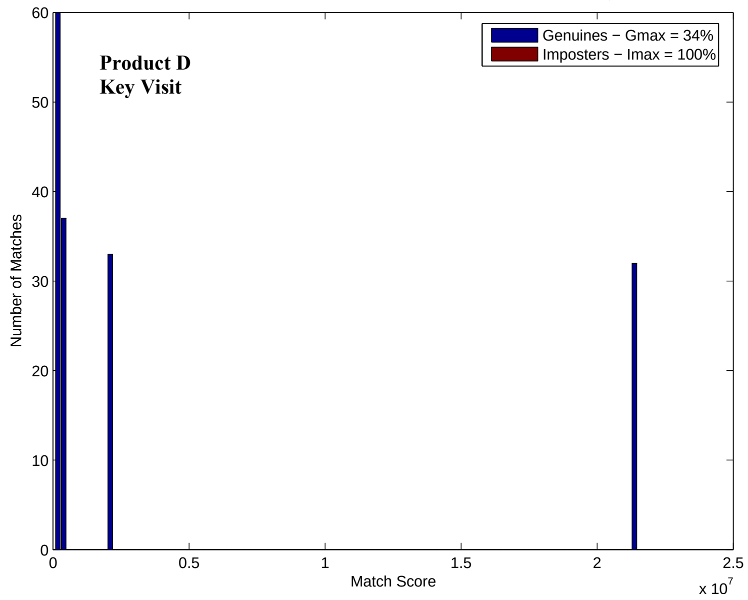


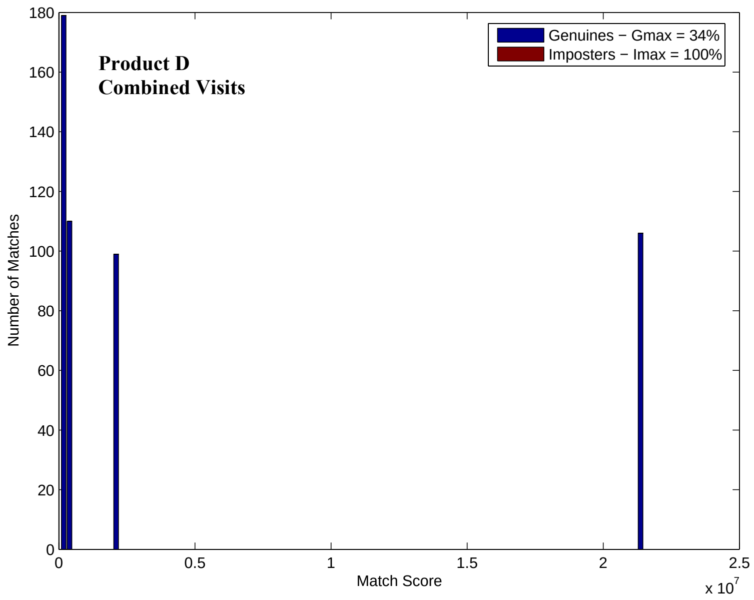

Product B
Key Visit
Genuines − G0 = 80%, Gmax = 4%
Imposters − I0 = 1%, Imax = 94%
Number of Matches
Match Score
x 10^7

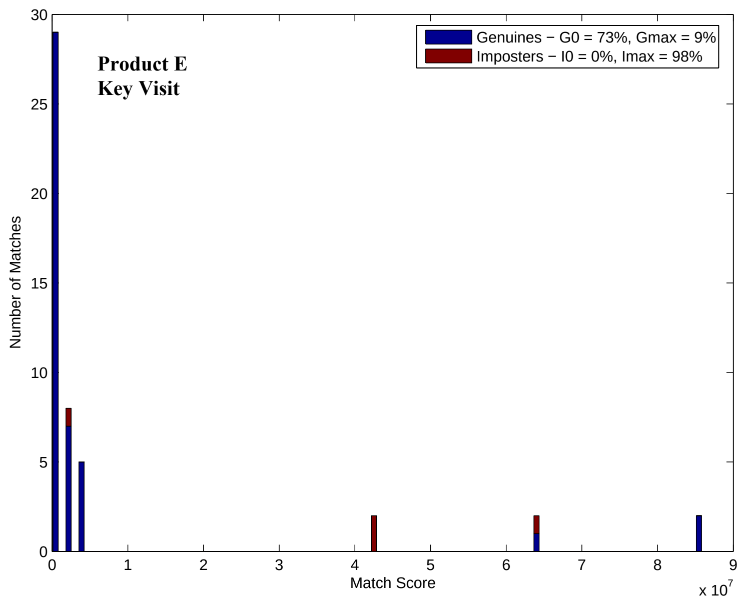

Product B
Combined Visits
Genuines − G0 = 79%, Gmax = 4%
Imposters − I0 = 1%, Imax = 96%
Number of Matches
Match Score
x 10^7

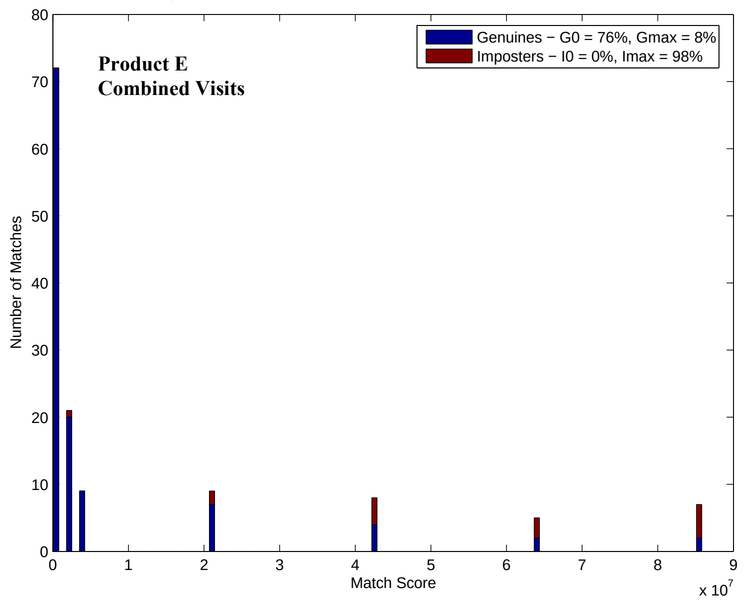

Product C
Key Visit
Genuines − Gmax = 2%
Imposters − Imax = 11%
Number of Matches
Match Score
x 10^8

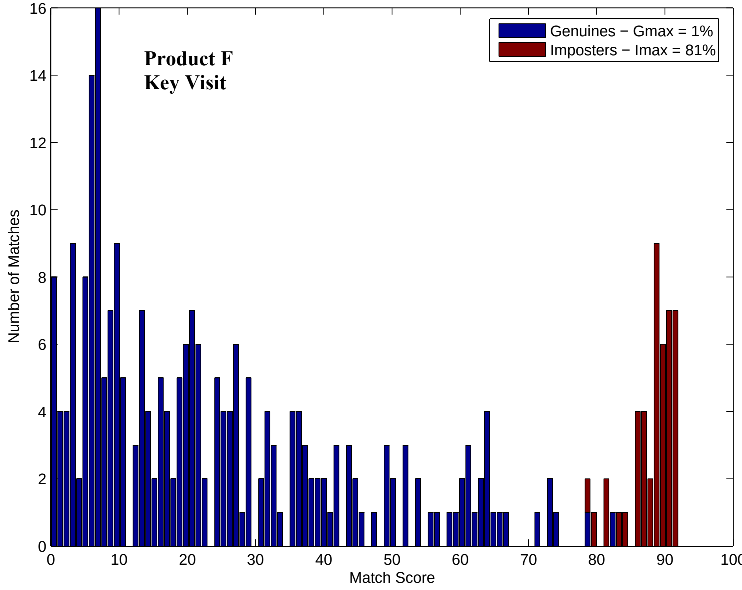

Product C
Combined Visits
Genuines − Gmax = 4%
Imposters − Imax = 14%
Number of Matches
Match Score
x 10^8

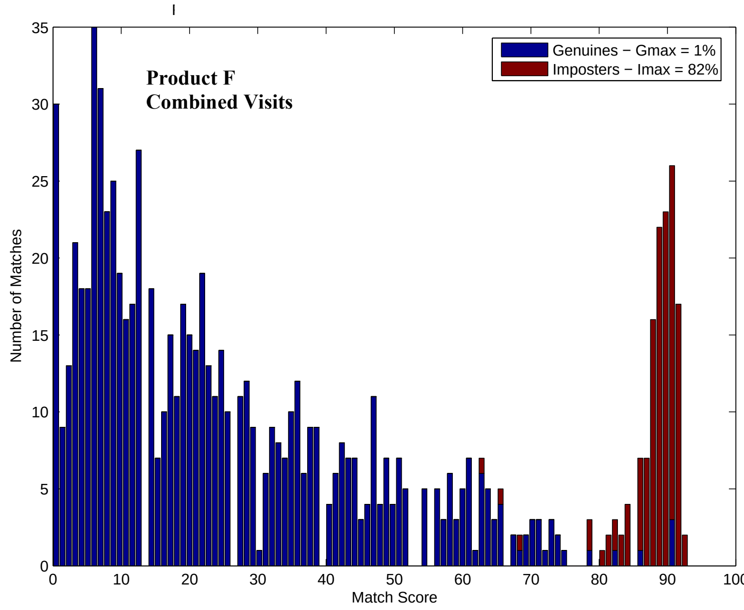

Product D
Key Visit
Genuines − Gmax = 34%
Imposters − Imax = 100%
Number of Matches
Match Score
x 10^7

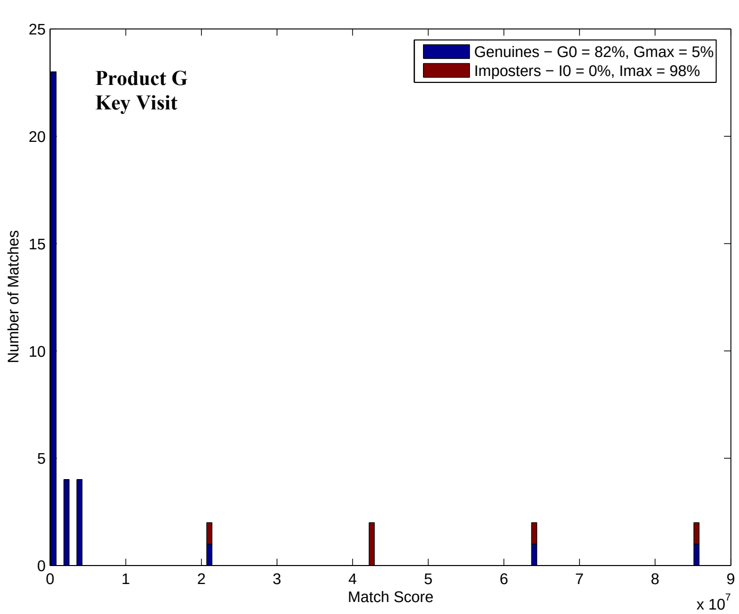

Product D
Combined Visits
Genuines − Gmax = 34%
Imposters − Imax = 100%
Number of Matches
Match Score
x 10^7

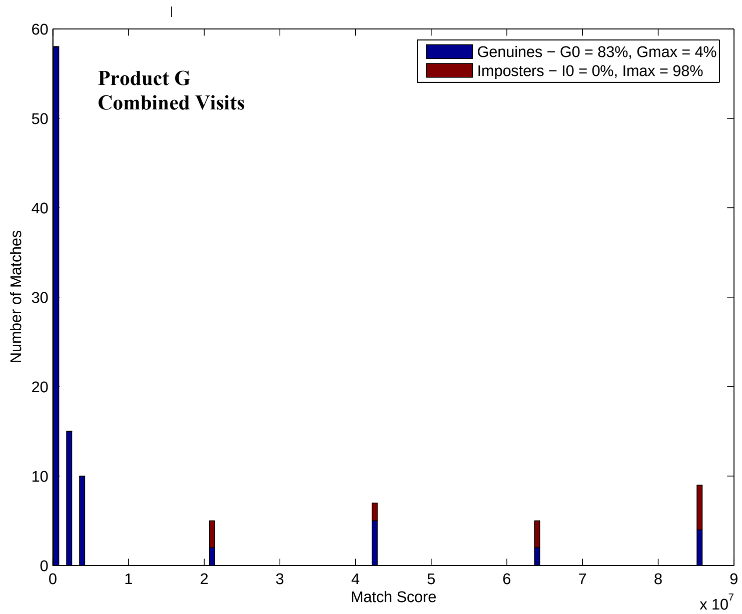

Product E
Key Visit
Genuines − G0 = 73%, Gmax = 9%
Imposters − I0 = 0%, Imax = 98%
Number of Matches
Match Score
x 10^7


Product E
Combined Visits
Genuines − G0 = 76%, Gmax = 8%
Imposters − I0 = 0%, Imax = 98%
Number of Matches
Match Score
x 10^7

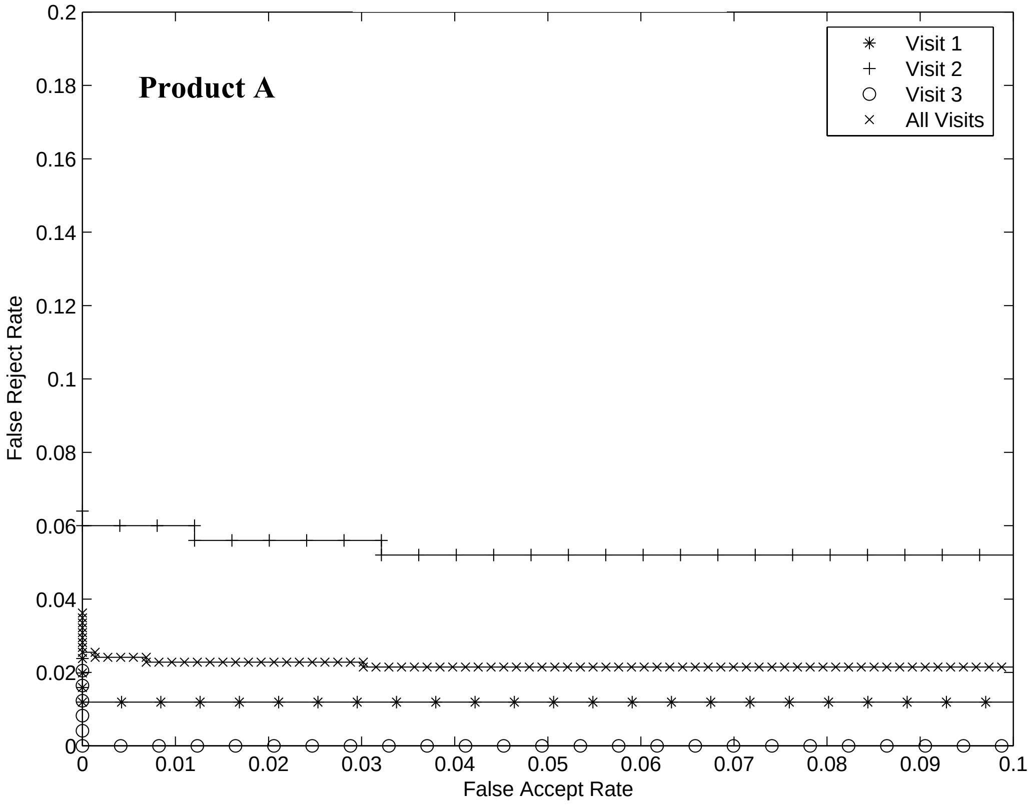

Product F
Key Visit
Genuines − Gmax = 1%
Imposters − Imax = 81%
Number of Matches
Match Score

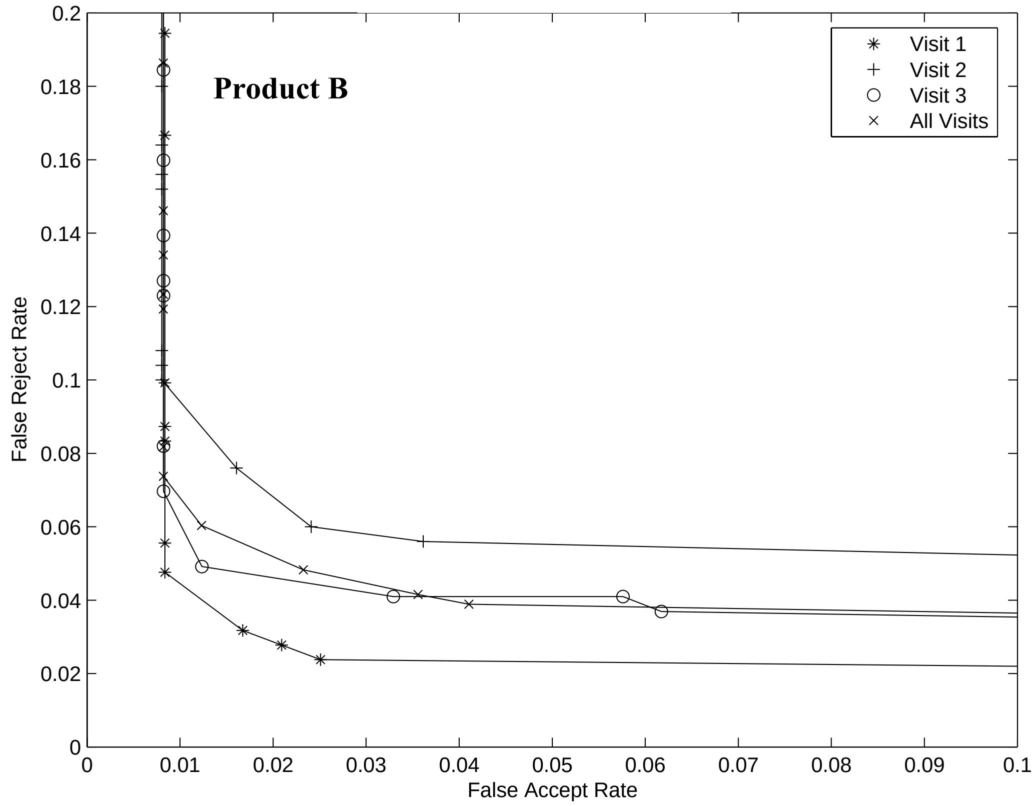

Product F
Combined Visits
Genuines − Gmax = 1%
Imposters − Imax = 82%
Number of Matches
Match Score

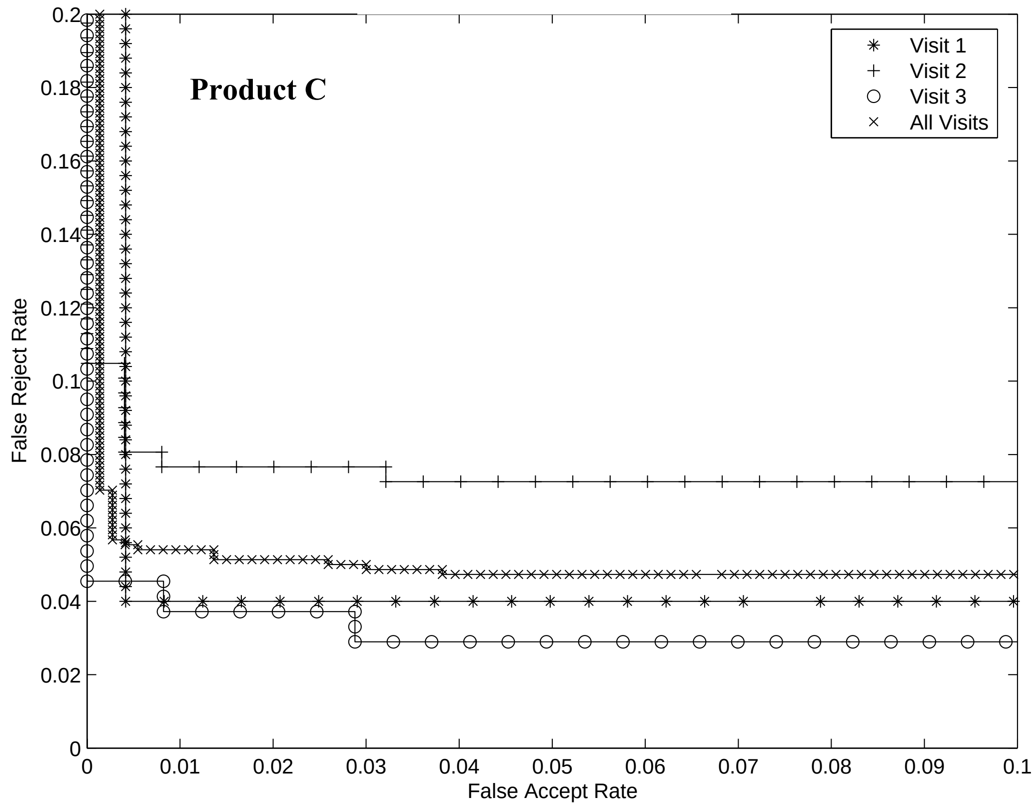

Product G
Key Visit
Genuines − G0 = 82%, Gmax = 5%
Imposters − I0 = 0%, Imax = 98%
Number of Matches
Match Score
x 10^7

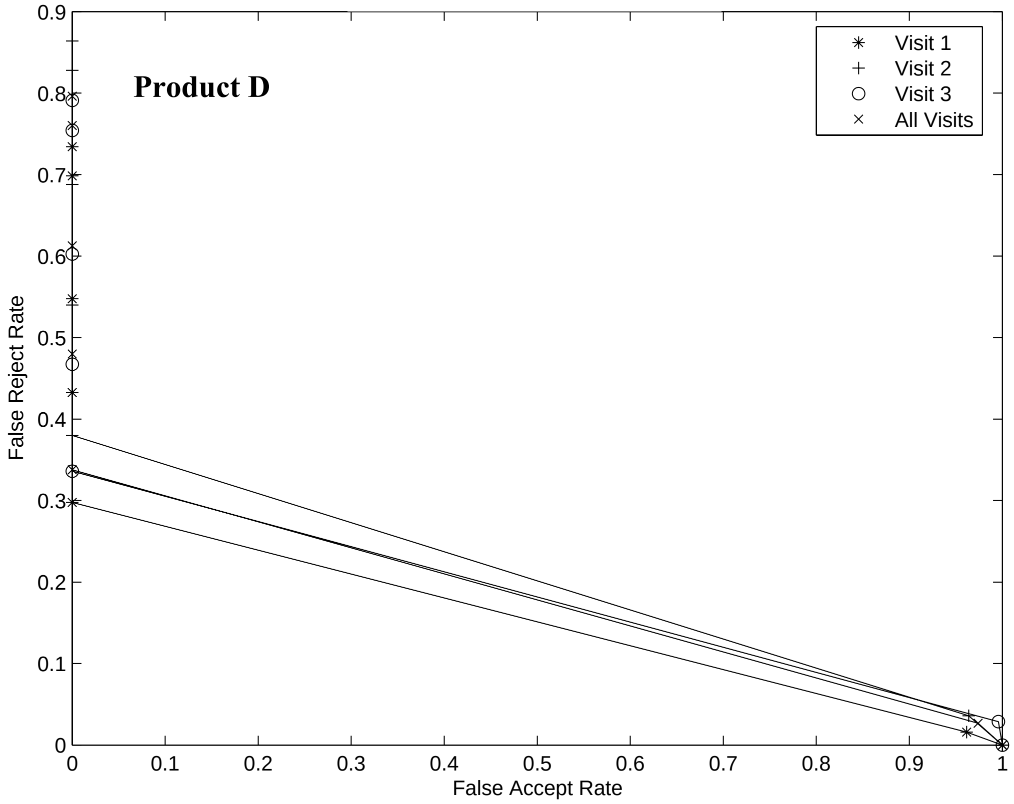

Product G
Combined Visits
Genuines − G0 = 83%, Gmax = 4%
Imposters − I0 = 0%, Imax = 98%
Number of Matches
Match Score
x 10^7

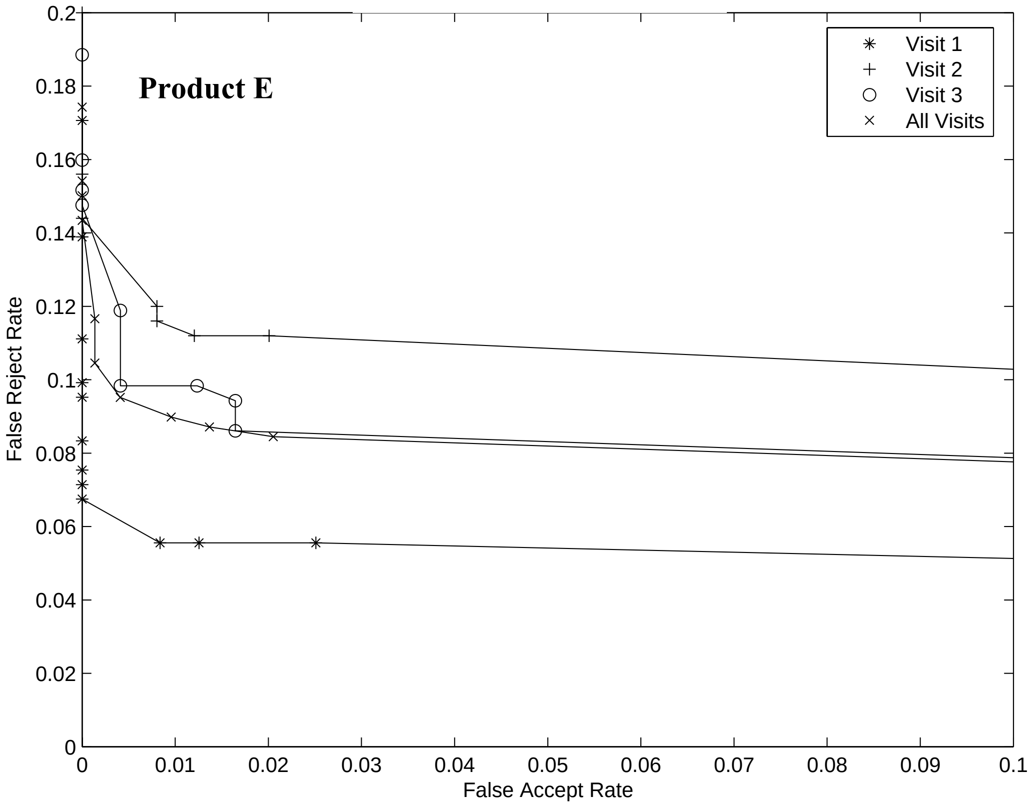
Annex H – Native-Comparison Two-Finger DET Curves

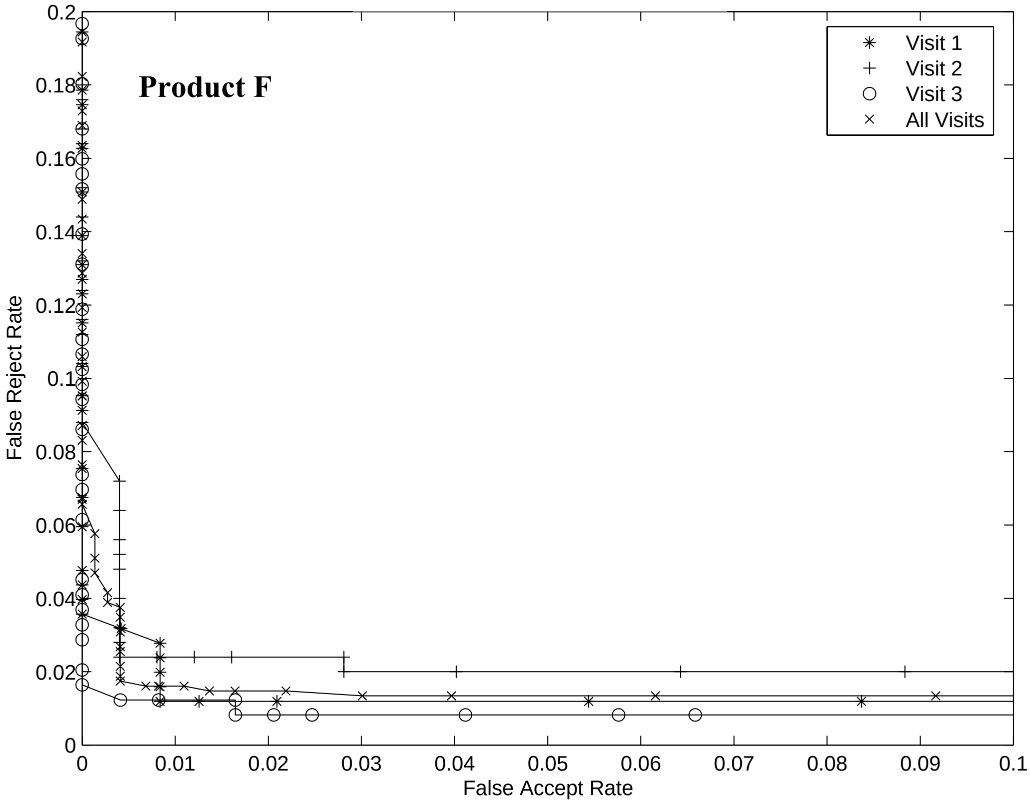


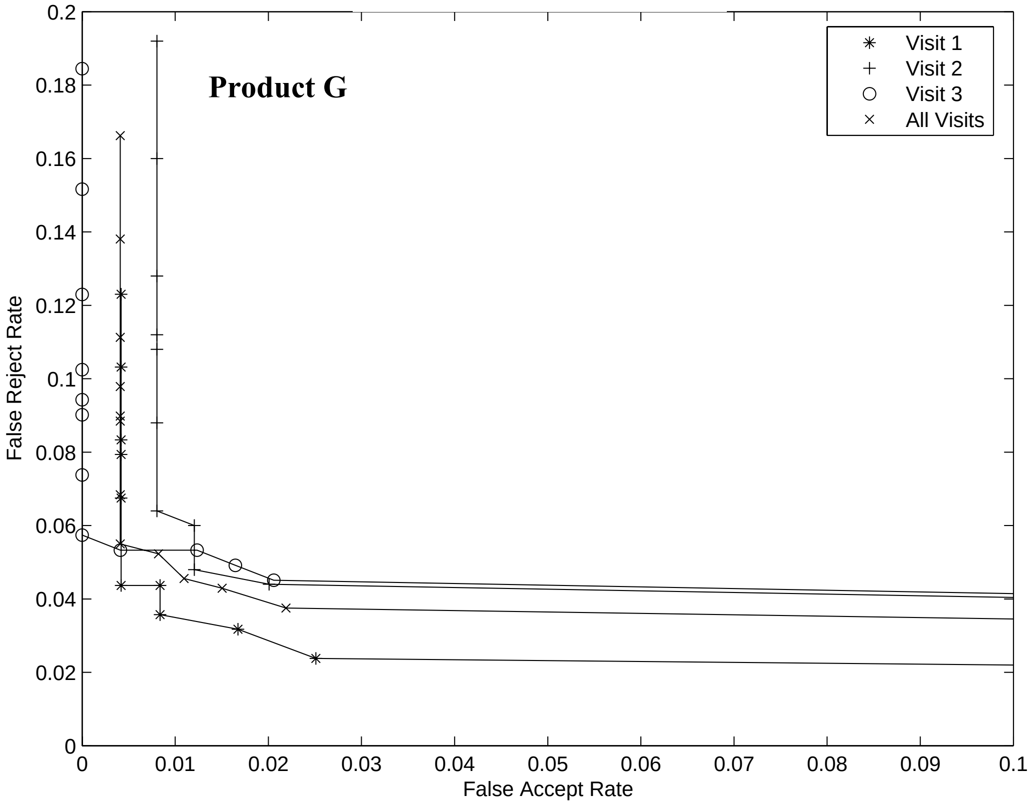

Product B
Visit 1
Visit 2
Visit 3
All Visits
False Reject Rate
False Accept Rate
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.01
0.03
0.05
0.07
0.09


Product C
Visit 1
Visit 2
Visit 3
All Visits
False Reject Rate
False Accept Rate
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.01
0.03
0.05
0.07
0.09


Product D
Visit 1
Visit 2
Visit 3
All Visits
False Reject Rate
False Accept Rate
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Product E
Visit 1
Visit 2
Visit 3
All Visits
False Reject Rate
False Accept Rate
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.01
0.03
0.05
0.07
0.09


Product F
Visit 1
Visit 2
Visit 3
All Visits
False Reject Rate
False Accept Rate
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1


Product G
Visit 1
Visit 2
Visit 3
All Visits
False Reject Rate
False Accept Rate
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1

Annex I – Interoperability Tables for Best Product Combinations

Key Visit at 1% FAR*

Best 2-Product Combination

	Product (Sensor and BSP)				Aggregate Mean	
Template		A	F	Mean		
	A	0.0%	1.6%	0.8%	A	0.4%
	F	0.0%	0.0%	0.0%	F	0.4%
	Mean	0.0%	0.8%	0.4%		

Best 3-Product Combination

	Product (Sensor and BSP)					Aggregate Mean	
Template		A	C	F	Mean		
	A	0.0%	3.6%	1.6%	1.7%	A	0.9%
	C	0.0%	1.7%	59.4%	20.3%	C	11.9%
	F	0.0%	4.9%	0.0%	1.6%	F	11.0%
	Mean	0.0%	3.4%	20.3%	7.9%		

Best 4-Product Combination

	Product (Sensor and BSP)						Aggregate Mean	
Template		A	C	E	G	Mean		
	A	0.0%	3.6%	52.0%	40.6%	24.1%	A	12.8%
	C	0.0%	1.7%	5.5%	3.0%	2.5%	C	8.5%
	E	1.9%	6.3%	4.9%	3.6%	4.2%	E	10.7%
	G	4.3%	46.6%	6.3%	1.6%	14.7%	G	13.4%
	Mean	1.5%	14.5%	17.2%	12.2%	11.4%		

Best 5-Product Combination

	Product (Sensor and BSP)							Aggregate Mean	
Template		A	C	E	F	G	Mean		
	A	0.0%	3.6%	52.0%	1.6%	40.6%	19.6%	A	10.4%
	C	0.0%	1.7%	5.5%	59.4%	3.0%	13.9%	C	13.2%
	E	1.9%	6.3%	4.9%	1.8%	3.6%	3.7%	E	12.9%
	F	0.0%	4.9%	41.9%	0.0%	27.3%	14.8%	F	15.4%
	G	4.3%	46.6%	6.3%	17.0%	1.6%	15.1%	G	15.2%
	Mean	1.2%	12.6%	22.1%	15.9%	15.2%	13.4%		

*Product B removed since unable to produce FAR of 1%

Combined Visits at 1% FAR*

Best 2-Product Combination							
	Product (Sensor and BSP)					Aggregate Mean	
Template		A	F	Mean			
	A	1.9%	1.4%	1.7%		A	2.0%
	F	3.0%	0.3%	1.6%		F	1.2%
	Mean	2.4%	0.9%	1.6%			

Best 3-Product Combination								
	Product (Sensor and BSP)						Aggregate Mean	
Template		A	C	E	Mean			
	A	1.9%	7.0%	41.7%	16.9%		A	9.4%
	C	0.0%	2.4%	2.5%	1.6%		C	3.4%
	E	4.1%	5.8%	3.2%	4.4%		E	10.1%
	Mean	2.0%	5.1%	15.8%	7.6%			

Best 4-Product Combination									
	Product (Sensor and BSP)							Aggregate Mean	
Template		A	C	E	F	Mean			
	A	1.9%	7.0%	41.7%	1.4%	13.0%		A	7.6%
	C	0.0%	2.4%	2.5%	65.0%	17.5%		C	11.3%
	E	4.1%	5.8%	3.2%	2.8%	4.0%		E	11.8%
	F	3.0%	5.6%	31.5%	0.3%	10.1%		F	13.7%
	Mean	2.2%	5.2%	19.7%	17.4%	11.1%			

Best 5-Product Combination										
	Product (Sensor and BSP)								Aggregate Mean	
Template		A	C	E	F	G	Mean			
	A	1.9%	7.0%	41.7%	1.4%	49.6%	20.3%		A	11.4%
	C	0.0%	2.4%	2.5%	65.0%	4.8%	14.9%		C	13.6%
	E	4.1%	5.8%	3.2%	2.8%	2.4%	3.7%		E	10.7%
	F	3.0%	5.6%	31.5%	0.3%	36.9%	15.5%		F	16.4%
	G	3.6%	40.7%	9.4%	17.5%	1.9%	14.6%		G	16.9%
	Mean	2.5%	12.3%	17.7%	17.4%	19.1%	13.8%			

*Product B removed since unable to produce FAR of 1%

Key Visit at 2% FAR

Best 2-Product Combination						
	Product (Sensor and BSP)				Aggregate Mean	
Template		A	F	Mean		
	A	0.0%	1.6%	0.8%	A	0.4%
	F	0.0%	0.0%	0.0%	F	0.4%
	Mean	0.0%	0.8%	0.4%		

Best 3-Product Combination							
	Product (Sensor and BSP)					Aggregate Mean	
Template		B	E	G	Mean		
	B	2.1%	10.2%	3.6%	5.3%	B	4.5%
	E	4.0%	4.9%	3.6%	4.2%	E	5.4%
	G	4.7%	4.8%	1.6%	3.7%	G	3.3%
	Mean	3.6%	6.6%	2.9%	4.4%		

Best 4-Product Combination								
	Product (Sensor and BSP)						Aggregate Mean	
Template		B	C	E	G	Mean		
	B	2.1%	5.9%	10.2%	3.6%	5.4%	B	4.8%
	C	5.6%	1.7%	5.5%	2.0%	3.7%	C	8.3%
	E	4.0%	6.3%	4.9%	3.6%	4.7%	E	5.5%
	G	4.7%	37.9%	4.8%	1.6%	12.3%	G	7.5%
	Mean	4.1%	12.9%	6.3%	2.7%	6.5%		

Best 5-Product Combination									
	Product (Sensor and BSP)							Aggregate Mean	
Template		A	B	C	E	G	Mean		
	A	0.0%	54.4%	3.3%	45.5%	40.6%	28.8%	A	15.2%
	B	3.1%	2.1%	5.9%	10.2%	3.6%	5.0%	B	9.6%
	C	0.0%	5.6%	1.7%	5.5%	2.0%	2.9%	C	7.0%
	E	1.9%	4.0%	6.3%	4.9%	3.6%	4.1%	E	9.1%
	G	3.1%	4.7%	37.9%	4.8%	1.6%	10.4%	G	10.4%
	Mean	1.6%	14.2%	11.0%	14.2%	10.3%	10.2%		

Best 6-Product Combination										
	Product (Sensor and BSP)								Aggregate Mean	
Template		A	B	C	E	F	G	Mean		
	A	0.0%	54.4%	3.3%	45.5%	1.6%	40.6%	24.2%	A	12.8%
	B	3.1%	2.1%	5.9%	10.2%	4.5%	3.6%	4.9%	B	11.8%
	C	0.0%	5.6%	1.7%	5.5%	56.5%	2.0%	11.9%	C	10.9%
	E	1.9%	4.0%	6.3%	4.9%	1.8%	3.6%	3.7%	E	10.8%
	F	0.0%	41.5%	4.7%	35.9%	0.0%	23.1%	17.5%	F	15.5%
	G	3.1%	4.7%	37.9%	4.8%	16.2%	1.6%	11.4%	G	11.9%
	Mean	1.4%	18.7%	9.9%	17.8%	13.4%	12.4%	12.3%		

Combined Visits at 2% FAR

Best 2-Product Combination							
	Product (Sensor and BSP)					Aggregate Mean	
Template		A	F	Mean			
	A	1.9%	1.4%	1.7%		A	2.0%
	F	3.0%	0.3%	1.6%		F	1.2%
	Mean	2.4%	0.9%	1.6%			

Best 3-Product Combination								
	Product (Sensor and BSP)						Aggregate Mean	
Template		B	E	G	Mean			
	B	1.5%	4.2%	2.7%	2.8%		B	2.8%
	E	2.4%	3.2%	2.0%	2.5%		E	3.9%
	G	4.7%	8.1%	1.5%	4.8%		G	3.4%
	Mean	2.9%	5.2%	2.1%	3.4%			

Best 4-Product Combination									
	Product (Sensor and BSP)							Aggregate Mean	
Template		B	C	E	G	Mean			
	B	1.5%	7.8%	4.2%	2.7%	4.0%		B	3.8%
	C	5.9%	2.2%	2.4%	2.0%	3.1%		C	8.0%
	E	2.4%	5.4%	3.2%	2.0%	3.3%		E	3.9%
	G	4.7%	36.1%	8.1%	1.5%	12.6%		G	7.3%
	Mean	3.6%	12.9%	4.5%	2.1%	5.8%			

Best 5-Product Combination										
	Product (Sensor and BSP)								Aggregate Mean	
Template		A	B	C	E	G	Mean			
	A	1.9%	49.1%	7.0%	38.3%	40.7%	27.4%		A	14.7%
	B	2.7%	1.5%	7.8%	4.2%	2.7%	3.8%		B	8.2%
	C	0.0%	5.9%	2.2%	2.4%	2.0%	2.5%		C	7.1%
	E	2.7%	2.4%	5.4%	3.2%	2.0%	3.2%		E	7.2%
	G	2.7%	4.7%	36.1%	8.1%	1.5%	10.6%		G	10.2%
	Mean	2.0%	12.7%	11.7%	11.3%	9.8%	9.5%			

Best 6-Product Combination											
	Product (Sensor and BSP)									Aggregate Mean	
Template		A	B	C	E	F	G	Mean			
	A	1.9%	49.1%	7.0%	38.3%	1.4%	40.7%	23.1%		A	12.6%
	B	2.7%	1.5%	7.8%	4.2%	4.5%	2.7%	3.9%		B	10.4%
	C	0.0%	5.9%	2.2%	2.4%	53.0%	2.0%	10.9%		C	10.8%
	E	2.7%	2.4%	5.4%	3.2%	2.4%	2.0%	3.0%		E	8.6%
	F	3.0%	38.3%	5.4%	29.1%	0.3%	25.9%	17.0%		F	14.9%
	G	2.7%	4.7%	36.1%	8.1%	14.6%	1.5%	11.3%		G	11.9%
	Mean	2.2%	17.0%	10.7%	14.2%	12.7%	12.5%	11.5%			

Key Visit for Observed Binary Decisions

Best 2-Product Combination							
	Product (Sensor and BSP)					Aggregate Mean	
Template		A	F	Mean			
	A	0.0%	1.6%	0.8%		A	0.4%
	F	0.0%	0.0%	0.8%		F	0.4%
	Mean	0.0%	0.0%	0.4%			

Best 3-Product Combination								
	Product (Sensor and BSP)						Aggregate Mean	
Template		B	E	G	Mean			
	B	2.5%	12.5%	6.3%	7.1%		B	5.5%
	E	4.7%	4.9%	3.6%	4.4%		E	6.1%
	G	4.7%	6.3%	1.6%	4.2%		G	4.0%
	Mean	3.9%	7.9%	3.8%	5.2%			

Best 4-Product Combination									
	Product (Sensor and BSP)							Aggregate Mean	
Template		B	C	E	G	Mean			
	B	2.5%	7.8%	12.5%	6.3%	7.3%		B	5.9%
	C	6.3%	2.5%	5.5%	6.3%	5.1%		C	15.5%
	E	4.7%	14.1%	4.9%	3.6%	6.8%		E	7.0%
	G	4.7%	79.3%	6.3%	1.6%	23.0%		G	13.7%
	Mean	4.5%	25.9%	7.3%	4.4%	10.5%			

Best 5-Product Combination										
	Product (Sensor and BSP)								Aggregate Mean	
Template		A	B	C	E	G	Mean			
	A	0.0%	56.5%	4.0%	53.1%	45.3%	31.8%		A	16.2%
	B	1.6%	2.5%	7.8%	12.5%	6.3%	6.1%		B	10.5%
	C	0.0%	6.3%	2.5%	5.5%	6.3%	4.1%		C	12.8%
	E	0.0%	4.7%	14.1%	4.9%	3.6%	5.4%		E	10.9%
	G	1.6%	4.7%	79.3%	6.3%	1.6%	18.7%		G	15.6%
	Mean	0.6%	14.9%	21.5%	16.4%	12.6%	13.2%			

Best 6-Product Combination											
	Product (Sensor and BSP)									Aggregate Mean	
Template		A	B	C	E	F	G	Mean			
	A	0.0%	56.5%	4.0%	53.1%	1.6%	45.3%	26.7%		A	13.6%
	B	1.6%	2.5%	7.8%	12.5%	1.6%	6.3%	5.4%		B	12.7%
	C	0.0%	6.3%	2.5%	5.5%	68.5%	6.3%	14.8%		C	17.0%
	E	0.0%	4.7%	14.1%	4.9%	3.5%	3.6%	5.1%		E	13.1%
	F	0.0%	45.8%	7.8%	43.8%	0.0%	38.6%	22.7%		F	19.3%
	G	1.6%	4.7%	79.3%	6.3%	20.3%	1.6%	19.0%		G	17.9%
	Mean	0.5%	20.1%	19.2%	21.0%	15.9%	16.9%	15.6%			

Combined Visits for Observed Binary Decisions

Best 2-Product Combination							
	Product (Sensor and BSP)					Aggregate Mean	
Template		A	F	Mean			
	A	0.0%	2.9%	1.4%		A	0.7%
	F	0.0%	0.3%	0.1%		F	0.9%
	Mean	0.0%	1.6%	0.8%			

Best 3-Product Combination								
	Product (Sensor and BSP)						Aggregate Mean	
Template		B	E	G	Mean			
	B	3.5%	9.0%	6.8%	6.5%		B	5.5%
	E	3.1%	3.5%	5.5%	4.0%		E	6.2%
	G	6.8%	12.7%	2.7%	7.4%		G	6.2%
	Mean	4.5%	8.4%	5.0%	6.0%			

Best 4-Product Combination									
	Product (Sensor and BSP)							Aggregate Mean	
Template		A	B	C	E	Mean			
	A	0.0%	51.9%	8.5%	51.0%	27.8%		A	14.3%
	B	2.3%	3.5%	11.9%	9.0%	6.7%		B	11.8%
	C	0.0%	9.3%	1.1%	7.5%	4.5%		C	6.8%
	E	0.7%	3.1%	14.9%	3.5%	5.5%		E	11.6%
	Mean	0.7%	16.9%	9.1%	17.7%	11.1%			

Best 5-Product Combination										
	Product (Sensor and BSP)								Aggregate Mean	
Template		A	B	C	E	G	Mean			
	A	0.0%	51.9%	8.5%	51.0%	54.2%	33.1%		A	17.0%
	B	2.3%	3.5%	11.9%	9.0%	6.8%	6.7%		B	10.8%
	C	0.0%	9.3%	1.1%	7.5%	8.8%	5.3%		C	13.7%
	E	0.7%	3.1%	14.9%	3.5%	5.5%	5.5%		E	11.1%
	G	1.8%	6.8%	74.3%	12.7%	2.7%	19.7%		G	17.6%
	Mean	0.9%	14.9%	22.1%	16.7%	15.6%	14.1%			

Best 6-Product Combination											
	Product (Sensor and BSP)									Aggregate Mean	
Template		A	B	C	E	F	G	Mean			
	A	0.0%	51.9%	8.5%	51.0%	2.9%	54.2%	28.1%		A	14.4%
	B	2.3%	3.5%	11.9%	9.0%	8.2%	6.8%	6.9%		B	13.1%
	C	0.0%	9.3%	1.1%	7.5%	73.1%	8.8%	16.6%		C	18.4%
	E	0.7%	3.1%	14.9%	3.5%	7.3%	5.5%	5.8%		E	13.6%
	F	0.0%	41.4%	10.1%	45.1%	0.3%	42.8%	23.3%		F	21.0%
	G	1.8%	6.8%	74.3%	12.7%	21.3%	2.7%	19.9%		G	20.0%
	Mean	0.8%	19.3%	20.1%	21.5%	18.8%	20.1%	16.8%			

Annex J – Interoperability Tables for Best Combinations of Two Products

Key Visit at 1% FAR*

Rank 1

	Product (Sensor and BSP)				Aggregate Mean	
Template		A	F	Mean		
	A	0.0%	1.6%	0.8%	A	0.4%
	F	0.0%	0.0%	0.0%	F	0.4%
	Mean	0.0%	0.8%	0.4%		

Rank 2

	Product (Sensor and BSP)				Aggregate Mean	
Template		A	C	Mean		
	A	0.0%	3.6%	1.8%	A	0.9%
	C	0.0%	1.7%	0.8%	C	1.7%
	Mean	0.0%	2.6%	1.3%		

Rank 3

	Product (Sensor and BSP)				Aggregate Mean	
Template		E	G	Mean		
	E	4.9%	3.6%	4.2%	E	4.9%
	G	6.3%	1.6%	3.9%	G	3.3%
	Mean	5.6%	2.6%	4.1%		

Rank 4

	Product (Sensor and BSP)				Aggregate Mean	
Template		C	E	Mean		
	C	1.7%	5.5%	3.6%	C	3.8%
	E	6.3%	4.9%	5.6%	E	5.4%
	Mean	4.0%	5.2%	4.6%		

Rank 5

	Product (Sensor and BSP)				Aggregate Mean	
Template		F	G	Mean		
	F	0.0%	27.3%	13.7%	F	11.1%
	G	17.0%	1.6%	9.3%	G	11.9%
	Mean	8.5%	14.5%	11.5%		

*Product B removed since unable to produce FAR of 1%

Combined Visits at 1% FAR*

Rank 1						
	Product (Sensor and BSP)				Aggregate Mean	
Template		A	F	Mean		
	A	1.9%	1.4%	1.7%	A	2.0%
	F	3.0%	0.3%	1.6%	F	1.2%
	Mean	2.4%	0.9%	1.6%		

Rank 2						
	Product (Sensor and BSP)				Aggregate Mean	
Template		A	C	Mean		
	A	1.9%	7.0%	4.5%	A	2.7%
	C	0.0%	2.4%	1.2%	C	3.0%
	Mean	0.9%	4.7%	2.8%		

Rank 3						
	Product (Sensor and BSP)				Aggregate Mean	
Template		C	E	Mean		
	C	2.4%	2.5%	2.5%	C	3.3%
	E	5.8%	3.2%	4.5%	E	3.7%
	Mean	4.1%	2.8%	3.5%		

Rank 4						
	Product (Sensor and BSP)				Aggregate Mean	
Template		E	G	Mean		
	E	3.2%	2.4%	2.8%	E	4.6%
	G	9.4%	1.9%	5.7%	G	3.9%
	Mean	6.3%	2.1%	4.2%		

Rank 5						
	Product (Sensor and BSP)				Aggregate Mean	
Template		E	F	Mean		
	E	3.2%	2.8%	3.0%	E	10.2%
	F	31.5%	0.3%	15.9%	F	8.7%
	Mean	17.4%	1.5%	9.4%		

*Product B removed since unable to produce FAR of 1%

Key Visit at 2% FAR

Rank 1							
	Product (Sensor and BSP)					Aggregate Mean	
Template		A	F	Mean			
	A	0.0%	1.6%	0.8%		A	0.4%
	F	0.0%	0.0%	0.0%		F	0.4%
	Mean	0.0%	0.8%	0.4%			

Rank 2							
	Product (Sensor and BSP)					Aggregate Mean	
Template		A	C	Mean			
	A	0.0%	3.3%	1.7%		A	0.8%
	C	0.0%	1.7%	0.8%		C	1.7%
	Mean	0.0%	2.5%	1.2%			

Rank 3							
	Product (Sensor and BSP)					Aggregate Mean	
Template		B	G	Mean			
	B	2.1%	3.6%	2.8%		B	3.1%
	G	4.7%	1.6%	3.2%		G	2.9%
	Mean	3.4%	2.6%	3.0%			

Rank 4							
	Product (Sensor and BSP)					Aggregate Mean	
Template		E	G	Mean			
	E	4.9%	3.6%	4.2%		E	4.5%
	G	4.8%	1.6%	3.2%		G	2.9%
	Mean	4.8%	2.6%	3.7%			

Rank 5							
	Product (Sensor and BSP)					Aggregate Mean	
Template		C	E	Mean			
	C	1.7%	5.5%	3.6%		C	3.8%
	E	6.3%	4.9%	5.6%		E	5.4%
	Mean	4.0%	5.2%	4.6%			

Combined Visits at 2% FAR

Rank 1							
	Product (Sensor and BSP)					Aggregate Mean	
Template		A	F	Mean			
	A	1.9%	1.4%	1.7%		A	2.0%
	F	3.0%	0.3%	1.6%		F	1.2%
	Mean	2.4%	0.9%	1.6%			

Rank 2							
	Product (Sensor and BSP)					Aggregate Mean	
Template		B	G	Mean			
	B	1.5%	2.7%	2.1%		B	2.6%
	G	4.7%	1.5%	3.1%		G	2.6%
	Mean	3.1%	2.1%	2.6%			

Rank 3							
	Product (Sensor and BSP)					Aggregate Mean	
Template		A	C	Mean			
	A	1.9%	7.0%	4.5%		A	2.7%
	C	0.0%	2.2%	1.1%		C	2.8%
	Mean	0.9%	4.6%	2.8%			

Rank 4							
	Product (Sensor and BSP)					Aggregate Mean	
Template		B	E	Mean			
	B	1.5%	4.2%	2.8%		B	2.4%
	E	2.4%	3.2%	2.8%		E	3.3%
	Mean	1.9%	3.7%	2.8%			

Rank 5							
	Product (Sensor and BSP)					Aggregate Mean	
Template		C	E	Mean			
	C	2.2%	2.4%	2.3%		C	3.0%
	E	5.4%	3.2%	4.3%		E	3.6%
	Mean	3.8%	2.8%	3.3%			

Key Visit for Observed Binary Decisions

Rank 1						
	Product (Sensor and BSP)				Aggregate Mean	
Template		A	F	Mean		
	A	0.0%	0.0%	0.0%	A	0.4%
	F	1.6%	0.0%	0.8%	F	0.4%
	Mean	0.8%	0.0%	0.4%		

Rank 2						
	Product (Sensor and BSP)				Aggregate Mean	
Template		A	C	Mean		
	A	0.0%	0.0%	0.0%	A	1.0%
	C	4.0%	2.5%	3.2%	C	2.2%
	Mean	2.0%	1.2%	1.6%		

Rank 3						
	Product (Sensor and BSP)				Aggregate Mean	
Template		B	G	Mean		
	B	2.5%	4.7%	3.6%	B	4.0%
	G	6.3%	1.6%	3.9%	G	3.6%
	Mean	4.4%	3.2%	3.8%		

Rank 4						
	Product (Sensor and BSP)				Aggregate Mean	
Template		E	G	Mean		
	E	4.9%	6.3%	5.6%	E	4.9%
	G	3.6%	1.6%	2.6%	G	3.3%
	Mean	4.2%	3.9%	4.1%		

Rank 5						
	Product (Sensor and BSP)				Aggregate Mean	
Template		B	C	Mean		
	B	2.5%	6.3%	4.4%	B	4.7%
	C	7.8%	2.5%	5.1%	C	4.8%
	Mean	5.1%	4.4%	4.8%		

Combined Visits for Observed Binary Decisions

Rank 1							
	Product (Sensor and BSP)					Aggregate Mean	
Template		A	F	Mean			
	A	0.0%	0.0%	0.0%		A	0.7%
	F	2.9%	0.3%	1.6%		F	0.9%
	Mean	1.4%	0.1%	0.8%			

Rank 2							
	Product (Sensor and BSP)					Aggregate Mean	
Template		A	C	Mean			
	A	0.0%	0.0%	0.0%		A	2.1%
	C	8.5%	1.1%	4.8%		C	2.7%
	Mean	4.3%	0.5%	2.4%			

Rank 3							
	Product (Sensor and BSP)					Aggregate Mean	
Template		B	E	Mean			
	B	3.5%	3.1%	3.3%		B	4.8%
	E	9.0%	3.5%	6.3%		E	4.8%
	Mean	6.3%	3.3%	4.8%			

Rank 4							
	Product (Sensor and BSP)					Aggregate Mean	
Template		B	G	Mean			
	B	3.5%	6.8%	5.2%		B	5.2%
	G	6.8%	2.7%	4.8%		G	4.8%
	Mean	5.2%	4.8%	5.0%			

Rank 5							
	Product (Sensor and BSP)					Aggregate Mean	
Template		E	G	Mean			
	E	3.5%	12.7%	8.1%		E	6.3%
	G	5.5%	2.7%	4.1%		G	5.9%
	Mean	4.5%	7.7%	6.1%			