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Biometric Specifications for Personal Identity Verification

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EDITORIAL NOTES

- This document is a second draft of NIST Special Publication 800-76-2. It is open for public comment until Noon on August 15, 2012. Comments should be directed to patrick.grother@nist.gov

- This document supports the second draft version of FIPS 201-2, released June, 2012 http://csrc.nist.gov/publications/PubsFIPS.html

- This document revises NIST Special Publication 800-76-1 published January 24, 2007, http://csrc.nist.gov/publications/nistpubs/800-76-1/SP800-76-1_012407.pdf
- and updates an April 2011 draft, NIST Special Publication 800-76-2 http://csrc.nist.gov/publications/PubsDrafts.html#SP-800-76--2

- Editor's Notes appear in blue. The coloration, and these notes, will be removed from the final publication.

- The main modifications from 800-76-1 and from the 2011 draft of 800-76-2 are as follows.
- The inclusion of specifications for an optional iris biometric record, intended to afford an alternative to fingerprint based authentication and chain-of-trust maintenance. This includes
    - Standardized iris image specification for the PIV Card
    - Standardized iris image specification for off-card use of iris images
    - Specifications for the iris camera, modified
    - Specifications for the semantic properties of iris images
    - An iris image capture interface, removed pending standardization
    - An iris recognition interface, removed pending standardization
- A specification for on-card biometric comparison of fingerprint minutiae to support card activation (instead of PIN) and authentication. This includes
    - Standardized fingerprint and auxilliary data specifications
    - Profile of 7816-4 for Standardized interface, removed pending inclusion in 800-73-3 revision
    - A provisional specification for use of swipe fingerprint sensors with on-card comparison, removed see explanatory note on the next page.
- Specification of revised minimum biometric accuracy in terms of false match rates
    - For off-card authentication with fingerprint minutiae
    - For on-card authentication with fingerprint minutiae
    - For off-card authentications with iris images
    - For attended authentication of face images, per FIPS inception of such
- Requirements for inclusion of fingerprint minutia templates when fingerprints cannot be collected or authenticated
- A modified procedure for quality assessment during fingerprint capture.
- Notes on availability of sensor interfaces.

EDITOR'S NOTE ON THE EXCLUSION OF SWIPE SENSORS FROM PIV SPECIFICATIONS

In April 2011, NIST circulated the first draft of this document with the following

> **EDITOR's NOTE:** The specifications are circulated for public comment. Unlike much of the other content NIST has little empirical data on which to safely include swipe matching into PIV. Swipe is attractive on grounds of cost, and possibly on grounds of spoof resistance. NIST solicits input on swipe accuracy and viability, particularly regarding
>
> - interoperability with optically-derived templates,
> - operating with standardized minutia templates (vs. proprietary representations),
> - operational experiences,
> - liveness,
> - how minutia standards might be revised,
> - whether these provisions should be allowed only after a certain date (sunrise).
>
> **All swipe-related specifications may be withdrawn in the next version of this draft.**

Factors supporting use of swipe: The motivation was to reduce the cost of fingerprint collection equipment and to thereby more widely deploy it. Comment received on the 2011 draft of 800-76-2 noted this and other benefits:

1. Cost
2. Packaging size
3. Power consumption
4. They are self-cleaning
5. Small form factor supporting use in mobile and tablet devices
6. Use of thermal sensors in harsh environments.

Comments: The cost argument is valid, especially for large-volume logical access control in Federal agencies. The cost argument is less valid for physical access control where single access points would service multiple persons and fewer sensors would be procured.

The cleaning point is valid also, but affected plain-impression sensors have image processing techniques to alleviate last-user-impression noise and have long been used successfully in multi-user environments.

The small size affords use in personal handheld devices. Mobile devices used to collect images for transmission to central matching servers have used plain-impression sensors.

The harsh environment use-case will be a small part of Federal deployment.

Factors contra-indicating use of swipe sensors: Swipe sensors are usually used in a technical context that is not subject to the same constraints as PIV. These are compared as follows:

#	Many existing deployments of swipe sensor technologies have the following characteristics	PIV constraints imply a different use of fingerprints vs. swipe, as follows:
1	The subject enrolls and verifies using the same swipe sensor on the same host (e.g. on a laptop for logical access)	PIV cards are intended to be globally interoperable. This means enrollment and verification must be viable on separate makes, models and technologies of sensors.
2	The enrollment data is stored locally to the sensor module or the host device, not on a credential.	Fingerprint data is stored on the PIV card. The number of fingers and template size of the data is limited by capacity constraints of the card.
3	The enrolled template data is proprietary in nature. It is not limited or constrained by a standard and is not interoperable with any other data. In closed systems, there is no requirement for interoperability.	The template is standardized – INCITS 378:2004 which regulates syntax and features. There is a plural marketplace of implementations of this standard.
4	The fingerprint templates are information rich i.e. they include features beyond or even different from (standardized) fingerprint minutiae (e.g. texture, or ridge flow).	PIV fingerprint data is stored as standardized minutiae data. Standardized minutia data has been shown to offer lower accuracy than proprietary data [MINEX04].

5	Data from more than two fingers might be enrolled.	Two fingers are enrolled.

Cross-sensor accuracy: Fingerprints are collected in PIV today using plain impressions on area-sensors. Authentication against swipe-derived data has imperfect interoperability arising because:

1. the two capture modes have inherent differences in the elastic deformation of the skin, and
2. the swipe sensor must reconstruct an image from the line scans

Together these effects give a systematic distortion in the minutia fields extracted from the collected imagery. This in turn gives degraded accuracy vs. flat-flat or swipe-swipe. Available publications and 800-76-2 comments assert that false rejection rates for swipe-plain are asserted to be higher by factors of 2.5, 3, 4-8 and unstated.

Two identical comments asserted that swipe-plain sensors can be used interchangeably.

Another comment advocated interoperability testing. This would give improved estimates of the magnitude of the accuracy loss. No database of swipe-derived images is available (to NIST).

Diversity of swipe sensors: Swipe scanners themselves are different, and have different imaging widths. One commenter asserts a 1.5 times higher false rejection rate across swipe sensors.

Multiple views: Swipe enrollment typically uses several presentations to make a single image, and make use several images. This may be done for multiple fingers. Use of several presentations is viable in PIV. But if these result in multiple templates then one finger will require expanded storage size and processing time.

Multiple fingers: One comment advocated use of more than two fingers and placement of multiple templates on-card. Use of more fingers, and/or a one-to-many search of those templates (obviating user prompt), would lead to elevated false match rates.

Restriction to standardized data: The possibility to allow proprietary non-standard data in the extended-data section of standard fingerprint templates was proposed for PIV. While the standards support proprietary extended data, and INCITS 378 implementations should operate correctly, the reliance on extended data is not viable because PIV-Cards are required to be globally interoperable. Now while the standardized minutia data portion of a template would support the cross-agency aspects, there is a provider lock-in hazard presented if the standard minutia data were technically conformant but somehow undermined (e.g. only 3 minutiae were stored to reduce record size). This risk would require strong conformance testing of the standardized data *in the deployed operation*.

Template interoperability: PIV uses standard templates. In 2004, 800-76 initially specified standardized images but their size, ~7KB per finger, was considered too large for fast authentication vs. standard templates (~0.4KB). The accuracy loss in using standard templates vs. standard images was documented in [MINEX04].

A further loss is incurred when standard templates are produced by various commercial template generators (vendors A, B, C etc). [MINEX04] also documented the loss in accuracy incurred when matching templates from different minutia detection algorithms (A-B) vs. a single product (A-A). This applies for images from the same optical sensor. Cross-template interoperability issues are mitigated by the PIV mandated tests (Ongoing [MINEX]).

Conclusion: This second draft excludes swipe sensors essentially because existing deployments of swipe are technically advantaged and distinct from that needed in PIV. Accuracy losses associated with swipe-plain interoperability, swipe-swipe interoperability, the use of purely standardized data, and the restriction to one view of each finger will all undermine accuracy. These effects will inevitably be mitigated by relaxing operating thresholds (giving elevated FMR), by using of more fingers (giving elevated FMR - and use of a one-to-many mode also giving increase in FMR), and use of extended data (without interoperability).

The first draft proposed a human-in-the-loop ISO/IEC 19795 performance test to certify a swipe sensor. The testing campaign would need to include swipe-plain interoperability testing. This, population recruitment, and possible failure, would elevate costs. Further the activity would not automatically cover swipe-swipe interoperability.

Future options: Establish a swipe sensor certification that could test conformance to a spatial distortion criterion. Additionally, recognize that card IO has become faster, and allow images to be stored on cards.

REPORTS ON COMPUTER SYSTEMS TECHNOLOGY

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National Institute of Standards and Technology Special Publication 800-76-2, 57 pages

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EXECUTIVE SUMMARY

Homeland Security Presidential Directive HSPD-12 called for new standards to be adopted governing interoperable use of identity credentials to allow physical and logical access to Federal government locations and systems. The Personal Identity Verification (PIV) standard for Federal Employees and Contractors, Federal Information Processing Standard (FIPS 201), was developed to define procedures and specifications for issuance and use of an interoperable identity credential. This document, Special Publication 800-76 (SP 800-76), is a companion document to FIPS 201. It describes technical acquisition and formatting specifications for the PIV system, including the PIV Card[1] itself. It also establishes minimum accuracy specifications for deployed biometric authentication processes. The approach is to enumerate procedures and formats for collection and preparation of fingerprint, iris and facial data, and to restrict values and practices included generically in published biometric standards. The primary design objective behind these particular specifications is high performance and universal interoperability. The addition of iris and face specifications in the 2012 edition adds an alternative modality for biometric authentication and extends coverage to persons for whom fingerprinting is problematic. The addition of on-card comparison offers an alternative to PIN-mediated card activation as well as additional authentication method. For the preparation of biometric data suitable for the Federal Bureau of Investigation (FBI) background check, SP 800-76 references FBI documentation, including the ANSI/NIST Fingerprint Standard and the Electronic Fingerprint Transmission Specification. This document does not preclude use of other biometric modalities in conjunction with the PIV card.

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[1] A physical artifact (e.g., identity card, "smart" card) issued to an individual that contains stored identity credentials (e.g., photograph, cryptographic keys, biometric data) so that the claimed identity of the cardholder can be verified against the stored credentials by another person (human readable and verifiable) or an automated process (computer readable and verifiable).

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1. Introduction

1.1 Authority

This document has been developed by the National Institute of Standards and Technology (NIST) in furtherance of its statutory responsibilities under the Federal Information Security Management Act (FISMA) of 2002, Public Law 107-347.

NIST is responsible for developing standards and guidelines, including minimum requirements, for providing adequate information security for all agency operations and assets, but such standards and guidelines **shall** not apply to national security systems. This recommendation is consistent with the requirements of the Office of Management and Budget (OMB) Circular A-130, Section 8b(3), Securing Agency Information Systems, as analyzed in A-130, Appendix IV: Analysis of Key Sections. Supplemental information is provided in A-130, Appendix III.

This recommendation, prepared for use by federal agencies, may be used by non-governmental organizations on a voluntary basis and is not subject to copyright. Nothing in this document should be taken to contradict standards and guidelines made mandatory and binding on Federal agencies by the Secretary of Commerce under statutory authority. Nor should this recommendation be interpreted as altering or superseding the existing authorities of the Secretary of Commerce, Director of the Office of Management and Budget, or any other Federal official.

1.2 Purpose and scope

FIPS 201 [FIPS], Personal Identity Verification (PIV) for Federal Employees and Contractors, defines procedures for the PIV lifecycle activities including identity proofing, registration, PIV Card issuance and re-issuance, chain-of-trust operations, and PIV Card usage. [FIPS] also defines an identity credential which includes biometric data. Requirements on interfaces are described in [800-73, parts 1-4]. Those on cryptographic protection of the biometric data are described in [FIPS] and in [800-78].

This document contains technical specifications for biometric data mandated or allowed in [FIPS]. These specifications reflect the design goals of interoperability, performance and security of the PIV Card and PIV processes. This specification addresses image acquisition to support the background check, fingerprint template creation, retention, and authentication. The goals are addressed by normatively citing biometric standards and by enumerating requirements where the standards include options and branches. In such cases, a biometric profile can be used to declare what content is required and what is optional. This document goes further by constraining implementers' interpretation of the standards. Such restrictions are designed to ease implementation, assure conformity, facilitate interoperability, and ensure performance, in a manner tailored for PIV applications.

The biometric data specifications herein are mandatory for biometric data carried in the PIV Data Model (Appendix A of [800-73] Part 1). Biometric data used outside the PIV Data Model is not within the scope of this standard.

This document does however specify that any biometric data in the PIV Data Model **shall** be embedded in the Common Biometric Exchange Formats Framework (CBEFF) structure of clause 9. This document provides an overview of the strategy that can be used for testing conformance to the standard. It is not meant to be a comprehensive set of test requirements that can be used for certification or demonstration of compliance to the specifications in this document. NIST Special Publication 800-85A implements those objectives.

1.3 Audience and assumptions

This document is targeted at Federal agencies and implementers of PIV systems. In addition, it should be of interest to the biometric access control industry. Readers are assumed to have a working knowledge of biometric standards and applications.

1.4 Overview

1.4.1 Document structure

This document defines:

— In clause 2, acronyms and terms;

- in clause 3, the fingerprint acquisition process, requirements for transmission of data to FBI, and a format for agency-optional image retention;
- in clause 4, the format of the PIV Card minutiae templates, and specifications for algorithms used in the generation and matching of such;
- in clause 5, the formats, data structures and interfaces for minutiae used in on-card comparison operations, and specifications for algorithms used in the generation and matching of such;
- in clause 6, the format for iris data stored on and off PIV Cards, and specifications for cameras and algorithms used for the collection, preparations and matching of such;
- in clause 7, facial image specifications;
- in clause 8, specifications for biometric sensors;
- in clause 9, the CBEFF header and footer supporting digital signatures on all PIV biometric data;
- in clause 10, minimum accuracy specifications
- in clause 11, additional conformance information, beyond the specifications embedded in clauses 4 through 7;
- in clause 12, references.

Figure 1 gives an approximate procedure for biometric data acquisition and disposition.

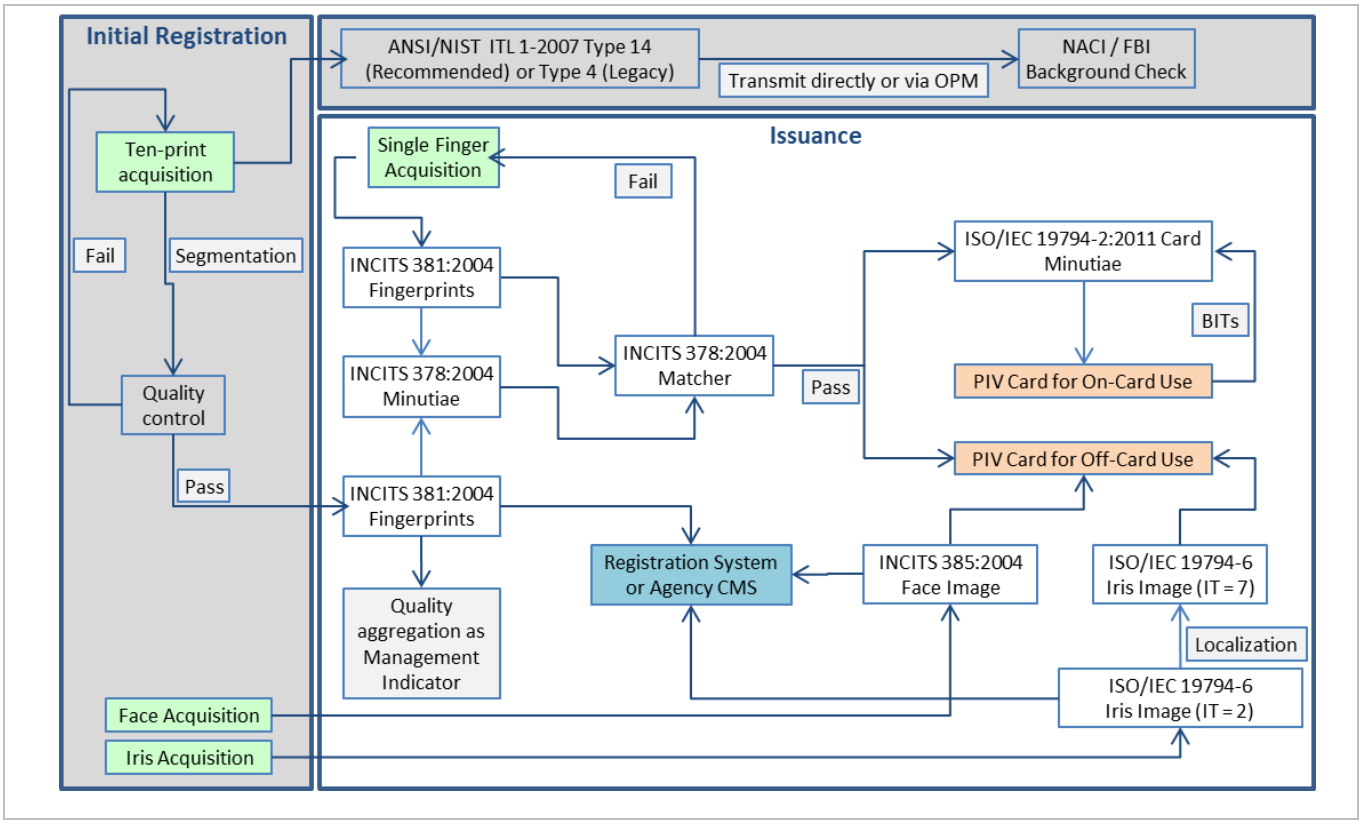


Figure 1 – PIV biometric data flow

1.4.2 Inclusion of iris recognition

Iris specifications are included, in clause 6, to support biometric authentication of individuals. [FIPS] allows use of iris for this purpose. The recommendation to agencies to install and operate iris equipment in its PIV issuance processes allows agencies to additionally populate PIV Cards with iris as an alternative authentication factor.

1.4.3 Inclusion of fingerprint on-card comparison

[FIPS] requires fingerprint templates of clause 4 as the mandatory biometric element for PIV. These templates are intended to be compared on a reader device with templates collected in an authentication attempt. [FIPS] requires the cardholder to enter a PIN number to release the templates. This constitutes multi-factor authentication.

Agencies may additionally choose to populate the card with an on-card comparison algorithm, and on-card comparison templates. The specifications for these appear in clause 5. [FIPS] does not require PIN entry ahead of a fingerprint minutiae on-card comparison transaction. Indeed, [FIPS] extends on-card comparison *as an alternative* to PIN entry in altering the state of the PIV card.

Table 1 describes the differences between the off-card and on-card specifications.

Table 1 – Summary of properties and roles of on- and off-card fingerprint comparison

#	Aspect	Off-card comparison	On-card comparison
1.	[FIPS] requirement on presence of biometric data	Mandatory	Optional
2.	Domain of use	See [FIPS]	
3.	Pre-requisites for access to the data		
4.	Interface access		
5.	Number of fingers required to be stored on card	2 But 0 or 1 allowed in exceptional cases – see [FIPS]	1 or 2
6.	Number of fingers to be used in a biometric operation	1 or 2	1 or 2
7.	Which fingers	Members of the set A, which is a subset of the ten finger set T	Members of the set B, which is a subset of the ten finger set T, and $\|A \cap B\| \geq 0$
8.	Location of data format specifications	This document, clause 4	This document, clause 5
9.	Location of card Interface specifications	SP 800-73-3	SP 800-73-3 est. 2012-2013.
10.	Underlying data format standard	INCITS 378:2004	ISO/IEC 19794-2:2011 This template **shall** be computed from the off-card INCITS 378:2004 template.
11.	How to identify specific fingers	INCITS 378:2004	ISO/IEC 7816-11:2007
12.	Fingerprint capture device for biometric operations	Plain impression as specified in 4.7	
13.	Accuracy testing	MINEX III (formerly Ongoing MINEX)	MINEX IV

1.5 Relation to other biometric applications

[FIPS] advances a PIV concept of biometric operations that is three-factor: A PIN verification is required before biometric data is read from the Card and matched during authentication. In other programs, biometrics are sometimes stored on a central server, or read from a card and cached on one. In others, the biometric is matched in a one-to-many mode without presentation of a card. There are tradeoffs with such approaches.

- PIV Card read times are replaced with network transmission times.
- PIN entry times are eliminated but the something-you-know additional factor is lost.
- The remote server is subject to physical or logical attack. Many kinds of templates stored on a server can be reversed to produce a matchable-sample [REVFING, REVIRIS, REVFACE]. Template protection schemes, which mitigate compromised databases, require further testing.
- One-to-many mode loses the something-you-have factor, and necessitates mitigation of elevated false match rates.

Such use cases are not addressed by this specification.

1.6 Second generation standards

Since the first publication of SP 800-76 in 2005, considerable effort has been dedicated to the development of second-generation biometric data interchange standards. These standards, primarily the parts of ISO/IEC 19794, have not been leveraged here as replacements for the extant PIV biometric standards - INCITS 385 (face), INCITS 381 (fingerprint image), and INCITS 378 (fingerprint minutiae) – because

- they are not binary compatible with the earlier standards,
- they confer essentially no performance advantages over the earlier standards,
- deployed infrastructure (readers) would be need to updated to support both the legacy and second generation standards.

The ISO/IEC 19794 Part 2 and Part 6 standards have been adopted for, respectively, on-card comparison and iris recognition.

2. Terms, acronyms, and notation

2.1 Terms

Term	Definition
Segmentation	For fingerprints, segmentation is the separation of an N finger image into N single finger images.

2.2 Acronyms

Acronym	Definition
ANSI	American National Standards Institute
CBEFF	Common Biometric Exchange Formats Framework
FAR	False Accept Rate (defined over an authentication transaction)
FIPS	Federal Information Processing Standard
FMR	False Match Rate (defined over single comparisons)
FNMR	False Non-Match Rate (defined over single comparisons)
FRR	False Reject Rate (defined over an authentication transaction)
FTE	Failure to Enroll Rate
EBTS / F	Electronic Biometric Transmission Specification (Appendix F)
INCITS	InterNational Committee for Information Technology Standards
ISO	International Organization for Standardization
IEC	International Electrotechnical Commission
ITL	Information Technology Laboratory (of NIST)
NFIQ	NIST Fingerprint Image Quality
NIST	National Institute of Standards and Technology
PIV	Personal Identity Verification
SC 37	The Biometrics standardization committee under ISO/IEC JTC 1
WSQ	Wavelet Scalar Quantization

3. Fingerprint enrollment

3.1 Scope

The specifications in this clause pertain to the production of the mandatory PIV biometric enrollment data. That is, this clause provides specifications for acquisition, formatting, and storage of fingerprint images and templates. The following is an overview of the material covered in this clause.

- Clause 3.2 gives specifications for the use of fingerprint scanners to capture fingerprint images for PIV Registration;
- Clause 3.3.1 gives the format for fingerprint templates stored on the PIV Card;
- Clause 3.4 gives specifications for fingerprint images retained by agencies;
- Clause 3.5 specifies the transformation of fingerprints into records suitable for transmission to the FBI for the background check.

Note that although FBI requirements drive the sensor specifications, the permanent electronic storage formats, specified in Clauses 3.3.1 and 3.4, are INCITS (i.e. non-FBI) standard records and are therefore specified independently.

3.2 Fingerprint data retention

[FIPS] establishes requirements and options for the retention of biometric data. If fingerprint images are retained they **shall** be stored in the format specified in clause 3.4. The format specification includes the [CBEFF] header of clause 9 to implement the requirement to protect the integrity, and to allow for encryption, of the image records.

If an agency retains fingerprint templates, in either proprietary or standardized formats, then they **shall** be embedded in the [CBEFF] header of clause 9. This requires integrity protection and allows for encryption of the records.

Retention of data supports, for example, detection of duplicate identities.

3.3 Fingerprint image acquisition

This clause specifies the capture of a full set of fingerprint images for PIV registration. A subject's fingerprints **shall** be collected according to any of the three imaging modes enumerated in Table 2.

Table 2 – Fingerprint acquisition protocols

<table>
<tr><td colspan="2">Option 1 – Required presentations for plain live scan</td></tr>
<tr><td colspan="2">Combined plain impression of the four fingers on the right hand (no thumb)</td></tr>
<tr><td colspan="2">Combined plain impression of the four fingers on the left hand (no thumb)</td></tr>
<tr><td colspan="2">Combined impression of the two thumbs</td></tr>
<tr><td colspan="2">Option 2 – Required presentations for rolled live scan</td></tr>
<tr><td colspan="2">10 separately rolled fingers</td></tr>
<tr><td colspan="2">Combined plain impression of the four fingers on the right hand (no thumb)</td></tr>
<tr><td colspan="2">Combined plain impression of the four fingers on the left hand (no thumb)</td></tr>
<tr><td>Left thumb plain impression</td><td rowspan="2">These captures may be simultaneous (two thumbs next to each other) or sequential (one thumb at a time)</td></tr>
<tr><td>Right thumb plain impression</td></tr>
<tr><td colspan="2">Option 3 - Required presentations for rolled ink on card</td></tr>
<tr><td colspan="2">10 separately rolled fingers</td></tr>
<tr><td colspan="2">Combined plain impression of the four fingers on the right hand (no thumb)</td></tr>
<tr><td colspan="2">Combined plain impression of the four fingers on the left hand (no thumb)</td></tr>
<tr><td>Left thumb plain impression</td><td rowspan="2">These captures may be simultaneous (two thumbs next to each other) or sequential (one thumb at a time)</td></tr>
<tr><td>Right thumb plain impression</td></tr>
</table>

INFORMATIVE NOTES:

1. There is no requirement that the order specified above is the order in which the images must be acquired.
2. The combined multi-finger plain-impression images are also referred to as slaps or flats. They are obtained by simultaneous placement of multiple fingers on the imaging surface without specific rolling movement.
3. Options 2 and 3 represent existing agency practice. Although Option 1 is now acceptable to the FBI agencies may need to implement Options 2 or 3 for transmission via the Office of Personnel Management.

For Options 1 and 2 the devices used for capture of the fingerprints **shall** have been certified by the FBI to conform to Appendix F of the FBI's Electronic Biometric Transmission Specification [EBTS, Appendix F]. For Option 3, a scan of the inked card **shall** be performed to effect conversion to electronic form. The scanner **shall** be certified by the FBI as being compliant with [EBTS, Appendix F]. The scanning is needed to produce fingerprints in the digital format described in Clause 3.4 and thereby Clause 3.5. The FBI specifications include width and height specifications for the imaging surface. The native scanning resolution of the device **shall** be 197 pixels per centimeter (500 pixels per inch) in both the horizontal and vertical directions. These specifications comply with the FBI submission requirements and with the Image Acquisition Setting Level 31 of the Finger Image-Based Data Interchange Format standard, INCITS 381 [FINGSTD].

For live-scan acquisition, the enrollment client software should display the images to the attending operator. The operator should repeat acquisition if the ridge structure is not clear, broken, or incomplete in the displayed images.

The procedure for the collection of fingerprints, presented in Table 3, **shall** be followed. The procedure **shall** employ the NIST Fingerprint Image Quality [NFIQ] algorithm[2] to initiate any needed reacquisition of the images. An attending official **shall** be present at the time of fingerprint capture. The agency **shall** employ measures to ensure the quality of acquisition and guard against faulty presentation, whether malicious or unintentional. Such activity might be an integral function of the acquisition device or might be implemented by the attending official. In any case, the agency **shall** ensure that the applicant does not swap finger positions or hands, occlude fingers, or misalign or misplace the fingers. Particularly, because it is common during collection of multi-finger plain impressions for fingers 05 and 10 to not be long enough to reach the imaging platen, it is accepted practice for the hand be placed at an angle to the horizontal to ensure imaging of all four fingers. Although this is not needed with newer, large-platen, devices the official **shall** in all cases take care to image all fingers completely. The procedure requires segmentation of the multi-finger plain impressions; this operation may be assisted by the attending official.

Table 3 – Quality control procedure for acquisition of a full set of fingerprint images

Step	Action
1.	Attending official should inspect fingers and require absence of dirt, coatings, gels, and other foreign material.
2.	Official should ensure imaging surface of the sensor, or the card, is clean.
3.	Acquire fingerprints according to Option 1, 2, or 3 in Table 2. For Option 3, scan the inked card using [EBTS, Appendix F] certified scanner.
4.	Segment the multi-finger plain impression images into single-finger images. Automated segmentation is recommended. Attending official should inspect the boundaries of the automatic segmentation and correct any failures, perhaps via an interactive graphical user interface.
5.	Compute NFIQ value for thumbs and index fingers. If all have NFIQ values of 1, 2, or 3 (i.e., good quality) then go to step 8.
6.	Repeat steps 2-5 up to three more times.
7.	If after four acquisitions the index fingers and thumbs do not all have NFIQ values of 1, 2 or 3 then select that set, acquired in step 3 and segmented in step 4, for which the mean of the NFIQ values of the left index, right index, left thumb, and right thumb is minimum (i.e. of best quality). If all of the index finger and thumb quality values are unavailable (perhaps because of injury to one or more of those fingers) then use the last set from step 3 of those fingers that are available, without any application of NFIQ.
8.	Prepare and store the final records per Clauses 3.3.1, 3.4, and 3.5

[2] A major revision of the NFIQ algorithm is underway. This is expected to a) produce quality values that offer better predictive accuracy, a) offer finer control of quality thresholds and c) offer additional capabilities. http://www.nist.gov/itl/iad/ig/development_nfiq_2.cfm

Ordinarily, all ten fingerprints **shall** be imaged in this process; however, if one or more fingers are not available (for instance, because of amputation) then as many fingers as are available **shall** be imaged. When fewer than ten fingers are collected, the FBI background transaction of Clause 3.4 requires (in field AMP 2.084 of an accompanying Type 2 record) the labeling of those fingers that are amputated or otherwise not imaged; see [EBTS, Appendix C].

3.3.1 Training of PIV fingerprint collection staff

Quality of the biometric data is critical to the success of a biometric application. This is particularly true for enrollment data that typically persists for years. As enrollment is an attended operation, the operator is key in support collection of high quality data. Attending staff should therefore be trained to maintain, clean and collect in accordance with manufacturer's guidance and this document. Specifically Agencies **shall** apprise staff that:

- That low humidity - typical in winter – causes dry fingers from which good images are more difficult to collect. This risk can be mitigated by measurement and appropriate use of supplemental humidification. Fingers may be lightly moisturized.
- Exposure of biometric equipment to bright light sources, such as direct sunlight, is generally adverse for collection of faces, fingerprints and irises.
- The background check can be defeated by mutilation of the fingerprints e.g. either temporarily (e.g. by burns or abrasives) or permanently (e.g. by surgical means). In addition certain medications can cause loss of fingerprint ridge structure. It is recommended that collection of fingerprints from applicants with finger injuries is deferred.

3.3.2 Monitoring overall enrollment quality

In order to track enrollment quality over time, a numerical summary of operational quality may be computed as a management indicator. If computed, this summary **shall** be computed from the NFIQ values of primary fingers of all PIV card applicants processed in each calendar month. If computed, the summary **shall** be computed using the method of NIST Interagency Report 7422 [NFIQ SUMMARY] which uses a simple formula to aggregate NFIQ values.

Managers can track this over time, collection sites or stations, over different populations (e.g. contractors vs. employees), across functions (PIV issuance vs. re-issuance), or even across fingers. Managers can use aggregated quality indicators to identify fingerprint collection problems. These may be due to changes in the physical environment or unintended changes in operating procedures.

3.4 Fingerprint image format for images retained by agencies

This clause specifies a common data format record for the retention of the fingerprint images collected in Clause 3.2. Specifically fingerprint images enrolled or otherwise retained by agencies **shall** be formatted according to the INCITS 381-2004 finger image based interchange format standard [FINGSTD]. This set **shall** include ten single-finger images. These **shall** be obtained by segmentation of the plain multi-finger images gathered in accordance with Options 1, 2 or 3 of Table 2, and the single plain thumb impressions from presentations 4 & 5 of Options 2 and 3. These images **shall** be placed into a single [FINGSTD] record. The record may also include the associated multi-finger plain impressions and the rolled images. This document ([800-76]) does not specify uses for any single-finger rolled images gathered according to Options 2 or 3 of Table 2. The record **shall** be wrapped in the CBEFF structure described in Clause 8. Agencies may encrypt this data per the provisions of Clause 8, Table 15, Note 2.

Table 4 gives a clause-by-clause profile of [FINGSTD]. The primary purpose of the Table is to give PIV specifications for those fields of [FINGSTD] that have optional content. Rows 1-10 give normative content. Row 11 requires the CBEFF structure of Clause 6. However, its FASC-N value (Table 15, Line 13) may be replaced by a field of all zeroes in this one exceptional case: Storage of PIV registration images before a FASC-N has been assigned. Such instances (including the digital signature) **shall** be regenerated once the FASC-N is known. Rows 12-27 give PIV specifications for the fields of the General Record Header of [FINGSTD, Table 2]. These are common to all images in the record. Similarly, Rows 28-36 provide specifications for the Finger Image Header Record in Table 4 of [FINGSTD]. The "PIV Conformance" column provides PIV specific practice and parameter defaults of the standard.

While INCITS 381 has been revised by the INCITS M1 committee, the 2004 edition is sufficient for PIV so the 2009 revision is irrelevant to PIV; however implementations should respect the version number on Line 14 of Table 4.

515 To assist implementers, NIST has made [FINGSTD] sample data available[3].

516 **Table 4 – INCITS 381 profile for agency retention of fingerprint Images**

			Clause title and/or field name (Numbers in parentheses are [FINGSTD] clause numbers)	INCITS 381-2004 Field or content	INCITS 381-2004 Value required	PIV Conformance Values allowed	Informative Remarks
1.			Byte and bit ordering (5.1)	NC		A	Big Endian MSB then LSB
2.			Scan sequence (5.2)	NC		A	
3.			Image acquisition reqs. (6)	NC		Level 31	Table 1
4.			Pixel Aspect Ratio (6.1)	NC		A	1:1
5.			Pixel Depth (6.2)	NC		A	Level 31 →8
6.			Grayscale data (6.3)	NC		A	Level 31 →1 byte per pixel
7.			Dynamic Range (6.4)	NC		A	Level 31 →200 gray levels
8.			Scan resolution (6.5)	NC		A	Level 31 →500 ppi
9.			Image resolution (6.6)	NC		197	Pixels per centimeter - no interpolation
10.			Fingerprint image location (6.7)	NC		A	Slap placement info, centering
11.			CBEFF Header (7)	MF	MV	Patron Format PIV	Multi-field CBEFF Header, Sec. 7.3
12.			General Record Header (7.1)	NC		A	
13.	Finger image record format		Format Identifier (7.1.1)	MF	MV	0x46495200	i.e. ASCII "FIR\0"
14.			Version Number (7.1.2)	MF	MV	0x30313000	i.e. ASCII "010\0"
15.			Record Length (7.1.3)	MF	MV	MIT	Size excluding CBEFF structure
16.			CBEFF Product Owner (7.1.4)	MF	MV	> 0	CBEFF PID.
17.			CBEFF Product Identifier Type (7.1.4)	MF	MV	> 0	
18.			Capture Device ID (7.1.5)	MF	MV	MIT	Vendor specified. See Note 1
19.			Image Acquisition Level (7.1.6)	MF	MV	31	Settings Level 31
20.			Number of Images (7.1.7)	MF	MV	MIT	Denote by K, see lines 28-37, see Notes 2-4
21.			Scale units (7.1.8)	MF	MV	0x02	Centimeters
22.			Scan resolution (horz) (7.1.9)	MF	MV	197	Pixels per centimeter
23.			Scan resolution (vert) (7.1.10)	MF	MV	197	
24.			Image resolution (horz) (7.1.11)	MF	MV	197	
25.			Image resolution (vert) (7.1.12)	MF	MV	197	
26.			Pixel Depth (7.1.13)	MF	MV	8	Grayscale with 256 levels
27.			Image compression algorithm (7.1.14)	MF	MV	0 or 2	Uncompressed or WSQ 3.1 See Notes 5 and 6.
28.			Reserved (7.1.15)	MF	MV	0	Two bytes, see Note 12
29.	K fingerprints, or multi-finger prints		Finger data block length (7.2.1)	MF	MV	MIT	
30.			Finger position (7.2.2)	MF	MV	MIT	
31.			Count of views (7.2.3)	MF	MV	≥ 1	M views of this finger, see Note 7
32.		M finger views	View number (7.2.4)	MF	MV	MIT	
33.			Finger image quality (7.2.5)	MF	MV	20,40,60,80,100	Transformed NFIQ. See Notes 8 and 9
34.			Impression type (7.2.6)	MF	MV	0 or 2	See ANSI NIST ITL 1-2000
35.			Horizontal line length (7.2.7)	MF	MV	MIT	See Note 10
36.			Vertical line length (7.2.8)	MF	MV	MIT	
37.			Reserved (no clause)	MF	MV	0	See Note 11
38.			Finger image data (7.2.9)	MF	MV	MIT	Uncompressed or compressed WSQ Data
END OF TABLE							

517

Acronym		Meaning
MF	mandatory field	[FINGSTD] mandates a field **shall** be present in the record
MV	mandatory value	[FINGSTD] mandates a meaningful value for this field
NC	normative content	[FINGSTD] gives normative practice for PIV. Such clauses do not define a field in the FIR.
A	as required by standard	For PIV, value or practice is as specified in [FINGSTD]
MIT	mandatory at time of instantiation	For PIV, mandatory value that **shall** be determined at the time the record is instantiated and **shall** follow the practice specified in [FINGSTD]

518

519 NORMATIVE NOTES:

[3] Fingerprint images conformant to the PIV specification are here http://www.itl.nist.gov/iad/894.03/nigos/piv_sample_data.html and these were prepared using NIST software available from http://www.itl.nist.gov/iad/894.03/nigos/incits.html

1. The Capture Device ID should indicate the hardware model. The CBEFF PID [FINGSTD, 7.1.4] should indicate the firmware or software version.
2. If certain fingers cannot be imaged, the value of this field **shall** be decremented accordingly.
3. The left and right four-finger images, and two-thumb, images may also be included. The value of this field **shall** be incremented accordingly.
4. For PIV enrollment sets, the number of images will ordinarily be thirteen (that is, the ten segmented images from the multi-finger plain impressions, and the three plain impressions themselves) or fourteen (if the plain thumb impressions were imaged separately).
5. Images **shall** either be uncompressed or compressed using an implementation of the Wavelet Scalar Quantization (WSQ) algorithm that has been certified by the FBI. As of February 2011, Version 3.1 of the WSQ algorithm **shall** be used [WSQ31]. The FBI's requirement for a 15:1 nominal compression ratio **shall** apply.
6. Compression should only be applied after the records required by clauses 3.3.1 and 3.5 have been prepared and transformed NFIQ values have been assigned.
7. The term view refers to the number of images of that particular finger. This value would exceed one if imaging has been repeated. Inclusion of more than one image of a finger can afford some benefit in a matching process. This document recommends that any additionally available images (say, from a PIV Card re-issuance procedure) with quality value 1 to 3 should be included in the record. In all cases the images **shall** be stored in order of capture date, with newest first.
8. Quality values **shall** be present. These **shall** be calculated from the NIST Fingerprint Image Quality (NFIQ) method described in [NFIQ] using the formula Q = 20*(6 - NFIQ). This scale reversal ensures that high quality values connote high predicted performance and consistency with the dictionary definition. The values are intended to be predictive of the relative accuracy of a minutia based fingerprint matching system. It is recommended that a user should be prompted to first attempt authentication using the finger with the highest quality, regardless of whether this is the primary or secondary finger.
9. The quality value **shall** be set to 254 (the [FINGSTD] code for undefined) if this record is not a single finger print (i.e., it is a multi-finger image, or a palm print) or if the NFIQ implementation fails.
10. There is no restriction on the image size. However non-background pixels of the target finger **shall** be retained (i.e. cropping of the image data is prohibited).
11. [FINGSTD, Table 4] refers to a single-byte field labeled "reserved", but there is no corresponding clause to formally define it. The M1 committee has undertaken to resolve this by inserting a new subclause to require inclusion of the "Reserved" field. This will appear in a revision of [FINGSTD]. In any case, PIV implementations **shall** include the single byte field, setting the value to 0.
12. Line 27 indicates that the "Reserved" field **shall** have length 2 bytes. [FINGSTD, 7.1.15] indicates a length of 4 bytes which disagrees with the value in [FINGSTD, Table 2]. The INCITS M1 committee has indicated 2 bytes is the correct value. PIV implementations **shall** include the 2 byte field, setting the value to 0.

3.5 Fingerprint image specifications for background checks

PIV fingerprint images transmitted to the FBI as part of the background checking process **shall** be formatted according to the ANSI/NIST-ITL 1-2011 standard [FFSMT] and the CJIS-RS-0010 [EBTS] specification. Such records **shall** be prepared from, and contain, only those images collected as per specifications in Clause 3.1.

Table 5 enumerates the appropriate transaction formats for the three acquisition options of Clause 3.2. The FBI documentation [EBTS] should be consulted for definitive requirements.

Table 5 – Record types for background checks

Option	Transaction Data Format in [FFSMT]	Reference
1	Three Type 14 records (and see Note 1)	[EBTS, Appendix N].
2 or 3	Fourteen Type 4 records (and see Note 1)	Clause 3.1.1.4 "Federal Applicant User Fee" of [EBTS]

NORMATIVE NOTES:

1. All types of transactions with the FBI require both a Type 1 and Type 2 record to accompany the data; see [FFSMT, Table 2]. The Type 2 supports labeling of missing fingers.

4. Fingerprint off-card authentication specifications

4.1 Scope

This clause specifies how the PIV mandatory biometric elements specified in [FIPS] are to be generated and stored. This specification applies to templates stored within the PIV Card, and to [MINUSTD] templates otherwise retained by agencies. The templates constitute the enrollment biometrics for PIV authentication and as such are supported by a high quality image acquisition specification, and a FBI-certified compression format. The specification of a standardized template in this clause enables use of the PIV Card in a multi-vendor product environment.

4.2 Source images

Two [MINUSTD] fingerprint templates **shall** be stored on the PIV Card; these are hereafter referred to as PIV Card templates. These **shall** be prepared from images of the primary and secondary fingers. These fingers should be selected on the basis of:

- **Availability:** Ability of individuals to mechanically place the finger on a generic sensor – this deprecates ring fingers, and sometimes thumbs
- **Control:** Ability to use fine motor control in placing the finger on a sensor – this promotes use of index fingers
- **Handedness:** Individuals should favor their preferred hand, for most people this is the right hand
- **Injury:** Presence of permanent or temporary injury to the friction ridge structure, or the finger itself – this contraindicates use of afflicted fingers
- **Area:** Area of the finger's volar pad – this promotes use of thumbs, and deprecates little fingers
- **Two-finger sensors:** If two-finger sensors are deployed and used, adjacent fingers can be placed simultaneously
- **Sensor placement:** If the fingerprint sensor is to the side of a user vs. in front (as for the driver of a vehicle), the fingers from the same hand might be used.

Thus a PIV Card applicant, in consultation with an attending operator, should select primary and secondary fingers given the following default order:

1. Preferred index	3. Preferred middle	5. Preferred thumb	7. Preferred ring	9. Preferred little
2. Other index	4. Other middle	6. Other thumb	8. Other ring	10. Other little

These images **shall** be either:

- those obtained by segmenting the initial plain impressions of the full set of fingerprints captured during PIV Registration and stored in row 8 of Table 3, or
- new images collected and matched against the initial plain impressions (see [FIPS]).

Significant rotation, exceeding 30 degrees, of the multi-finger plain impressions (for example, that which can occur when four fingers are imaged using a narrow platen) **shall** be removed prior to, or as part of, the generation of the mandatory minutiae templates. The rotation angle **shall** be that which makes the inter-phalangeal creases approximately horizontal or, equivalently, the inter-finger spaces approximately vertical. This requirement supports interoperable fingerprint matching.

4.3 Card issuance

[FIPS] establishes requirements on authentication of card applicants for example to bind the PIV cardholder to the individual whose background was checked. This authentication **shall** use images collected using either a [EBTS/F] multi-finger fingerprint imaging device of clause 3.2, or a [SINGFING] device of clause 8.

4.4 Minutia record

4.4.1 Use of a standard

PIV Card templates **shall** be a conformant instance of the INCITS 378-2004 [MINUSTD] minutiae template standard. A standard record is used to satisfy global interoperability objectives. Other standards have been published since the first PIV specification appeared in 2005. These other standards include ISO/IEC 19794-2 and a second edition of the INCITS 378 standard published in 2009. SP 800-76-2 does not use the new standards because there are many deployed PIV Cards and Readers that would require replacement or modification. The original 2004 edition of the INCITS 378 standard is sufficient. Implementations should respect the version number on Line 14 of Table 6.

4.4.2 General case

That is, the minutiae from both the primary and secondary fingers **shall** reside within a single INCITS 378 record. This means that there will be one instance of the "General Record Header" [MINUSTD, 6.4], and two instances of the "Finger View Record" [MINUSTD, 6.5]. This record **shall** be wrapped in a single instance of the CBEFF structure specified in Clause 8 prior to storage on the PIV Card. The PIV Card templates **shall** not be encrypted.

Table 6 is a profile of the generic [MINUSTD] standard. Its specifications **shall** apply to all minutiae templates placed on PIV Cards. These constraints are included to promote highly accurate and interoperable personal identity verification. This document recommends that the minutiae records should be prepared soon after the images are captured and before they are compressed for storage.

To assist implementers, NIST has made [MINUSTD] sample data available[4].

Table 6 – INCITS 378 profile for PIV Card templates

			Clause title and/or field name (Numbers in parentheses are [MINUSTD] clause numbers)	INCITS 378-2004 Field or content	INCITS 378-2004 Value Required	PIV Conformance Values Allowed	Informative Remarks
1.			Principle (5.1)	NC		A	Defines fingerprint minutiae
2.			Minutia Type (5.2)			See Note 1	[MINUSTD, 5.2] defines minutiae type but contains no normative content
3.			Minutia Location : Coordinate System (5.3.1)	NC		A	Minutia placement and angle are influential on accuracy and interoperability. Developers should ensure the listed requirements are actually achieved by their minutia detection algorithms. In addition, correct detection of true minutiae, and correct suppression of false minutiae have been shown to influence interoperability [BAZIN, MANSFIELD].
4.			Minutia Location : Minutia Placement on a Ridge Ending (5.3.2)	NC		A	
5.			Minutia Location : Minutia Placement on a Ridge Bifurcation (5.3.3)	NC		A	
6.			Minutia Location : Minutia Placement on Other Minutia Types (5.3.4)	NC		See Note 1	
7.			Minutia Direction : Angle Conventions (5.4.1)	NC		A	
8.			Minutia Direction : Angle of a Ridge Ending (5.4.2)	NC		A	
9.			Minutia Direction : Angle of a Ridge Bifurcation (5.4.3)	NC		A	
10.	General Record Header		Byte Ordering (6.2)	NC		A	Big Endian, unsigned integers
11.			Minutia Record Organization (6.3)	NC		A	
12.			CBEFF Record Header (6.4)	MF	MV	Patron format PIV	Multi-field CBEFF Header, Sec. 7.3.
13.			Format Identifier (6.4.1)	MF	MV	0x464D5200	i.e. ASCII "FMR\0"
14.			Version Number (6.4.2)	MF	MV	0x20323000	i.e. ASCII " 20\0" which is INCITS 378-2004. See Note 2
15.			Record Length (6.4.3)	MF	MV	$26 \leq L \leq 1574$	This connotes a 2 byte field. See Note 3
16.			CBEFF Product Identifier Owner (6.4.4)	MF	MV	> 0	See Note 4
17.			CBEFF Product Identifier Type (6.4.4)	MF	MV	> 0	See Note 4
18.			Capture Equipment Compliance (6.4.5)	MF	MV	1000b	Sensor complies with EBTS, Appendix F per PIV Registration requirement
19.			Capture Equipment ID (6.4.6)	MF	MV	> 0	See Note 5
20.			Size of Scanned Image in x direction (6.4.7)	MF	MV	MIT	See Note 11
21.			Size of Scanned Image in y direction (6.4.8)	MF	MV	MIT	
22.			X (horizontal) resolution (6.4.9)	MF	MV	197	Parent images conform to clause 4.2

[4] Minutiae records conformant to the PIV specification are here http://www.itl.nist.gov/iad/894.03/nigos/piv_sample_data.html and these were prepared using NIST software available from http://www.itl.nist.gov/iad/894.03/nigos/incits.html

			Clause title and/or field name (Numbers in parentheses are [MINUSTD] clause numbers)	INCITS 378-2004 Field or content	Value Required	PIV Conformance Values Allowed	Informative Remarks
23.			Y (vertical) resolution (6.4.10)	MF	MV	197	
24.			Number of Finger Views (6.4.11)	MF	MV	2	Once each for primary and secondary
25.			Reserved Byte (6.4.12)	MF	MV	0	
26.	K finger views	View header	Finger View Header (6.5.1)	NC		A	
27.			Finger Position (6.5.1.1)	MF	MV	MIT	
28.			View Number (6.5.1.2)	MF	MV	0	See Note 10
29.			Impression Type (6.5.1.3)	MF	MV	0 or 2	Plain live or non-live scan images.
30.			Finger Quality (6.5.1.4)	MF	MV	20,40,60,80,100	See Note 6
31.			Number of Minutiae (6.5.1.5)	MF	MV	$0 \le M \le 128$	M minutiae data records follow
32.		M minutiae	Minutiae Type (6.5.2.1)	MF	MV	01b, 10b, or 00b	See Note 1
33.			Minutiae Position (6.5.2.2)	MF	MV	MIT	See Note 7
34.			Minutiae Angle (6.5.2.3)	MF	MV	MIT	See Note 8
35.			Minutiae Quality (6.5.2.4)	MF	MV	MIT	This may be populated.
36.			Extended Data Block Length (6.6.1.1)	MF	MV	0	See Note 0
END OF TABLE							

Acronym		Meaning
MF	mandatory field	[MINUSTD] requires a field **shall** be present in the FMR
MV	mandatory value	[MINUSTD] requires a meaningful value for a field
NC	normative content	[MINUSTD] gives normative practice for PIV. Such clauses do not define a field in the FMR.
A	as required	For PIV, value or practice is as normatively specified in [MINUSTD].
MIT	mandatory at time of instantiation	For PIV, mandatory value that **shall** be determined at the time the record is instantiated and **shall** follow the practice specified in [MINUSTD]

NORMATIVE NOTES:

1. [MINUSTD] requires that each stored minutia have a type associated with it. For PIV, the mandatory card templates **shall** contain minutiae of type ridge ending or ridge bifurcation. These types are defined in [MINUSTD, 5.3.{2,3}]. Other types of minutiae, such as trifurcations and crossovers, **shall** not be included in PIV Card templates. However, for those minutiae where it is not possible to reliably distinguish between a ridge ending and a bifurcation, the category of "other" **shall** be assigned and encoded using bit values 00b. The angle and location for a minutia of type "other" should be the angle and location that would have applied to the corresponding ridge ending or bifurcation depending on which one the encoding algorithm determines to be the most likely for that particular minutiae. This is a common characteristic of "inked" impressions that exhibit ridge endings being converted to bifurcations and vice-versa due to over- or under-inking in the image.
2. The second paragraph of [MINUSTD, 6.4.2] refers both to an ASCII space and "three ASCII numerals" mentioned in the first paragraph. The practice of using an ASCII space character as the first character of the version number **shall** be followed: " 20\0" i.e. 0x20323000.
3. The length of the entire record **shall** fit within the container size limits specified in [800-73]. These limits apply to the entire CBEFF wrapped and signed entity, not just the [FINGSTD] record.
4. Both fields ("Owner" and "Type") of the CBEFF Product Identifier of [MINUSTD, Clause 6.4.4] **shall** be non-zero. The two most significant bytes **shall** identify the vendor, and the two least significant bytes **shall** identify the version number of that supplier's minutiae detection algorithm.
5. The Capture Equipment ID **shall** be reported. Its use may improve interoperability.
6. The quality value **shall** be that computed for the parent image using [NFIQ] and reported here as Q = 20*(6 - NFIQ). A value of "255" **shall** be assigned when fingerprints are temporarily unusable for matching. A value of "254" **shall** be assigned when the fingerprints are permanently unusable.
7. All coordinates and angles for minutiae **shall** be recorded with respect to the original finger image. They **shall** not be recorded with respect to any sub-image(s) created during the template creation process.
8. Determination of the minutia direction can be extracted from each skeleton bifurcation. The three legs of every skeleton bifurcation must be examined and the endpoint of each leg determined. Figures 2A through

2C illustrate the three methods used for determining the end of a leg. The ending is established according to the event that occurs first:

- The 32nd pixel – see Figures 2A and 2B – or
- The end of skeleton leg if greater than 10 pixels (legs shorter are not used) – see Figure 2B – or
- A second bifurcation is encountered before the 32nd pixel – see Figure 2C.

The angle of the minutiae is determined by constructing three virtual rays originating at the bifurcation point and extending to the end of each leg. The smallest of the three angles formed by the rays is bisected to indicate the minutiae direction.

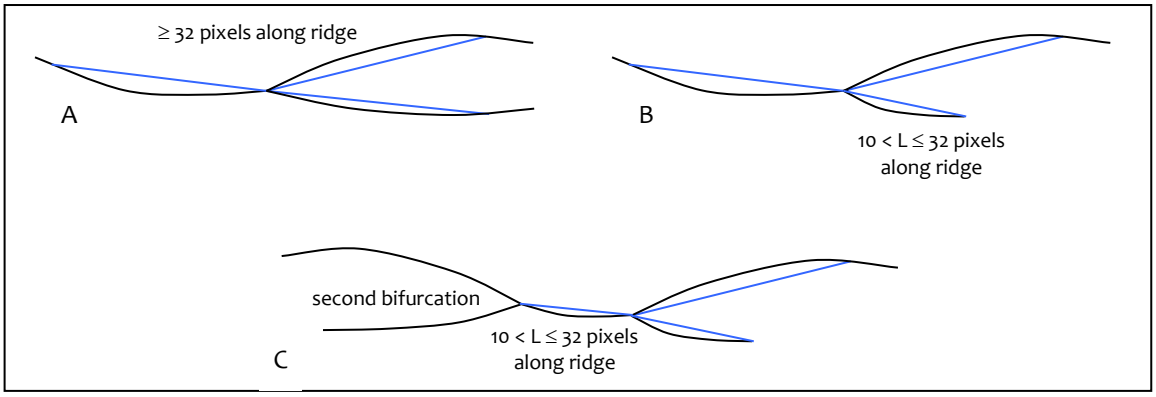


Figure 2 – Minutiae angle determination

Extensive, refined and complete guidance on minutia detection and estimation appears in INCITS 378:2009 clause 6. That standard is the revision of INCITS 378-2004 [MINUSTD]. While PIV still requires [MINUSTD] for PIV template formatting, the newer standard improves the semantic aspects associated with this note.

9. The mandatory value of zero codifies the PIV specification that templates **shall** not include extended data.
10. Per [MINUSTD, 6.5.1.2] this view number field **shall** have value 0 for the primary finger and 0 for the secondary finger. The combination of view number and finger position uniquely identifies each template.
11. [MINUSTD] does not specify how to report the image sizes in the header when two or more views are included in the record and these were derived from images of different sizes. For PIV, the width on Line 20 **shall** be the larger of the widths of the two input images. Similarly the height on Line 21 **shall** be the larger of the heights of the two input images.

4.4.3 Special case for individuals who cannot be fingerprinted

If two fingerprints have never been collected (e.g. because of injury, amputation, or persistent poor quality), or all fingerprint authentication attempts fail during section 4.3 card issuance, then the PIV Card **shall** be populated with the standardized minutia record of clause 4.4 which

- has two empty views (i.e. there are zero minutiae, such that Table 6, Line 31 **shall** be zero),
- is digitally signed as usual using the properly populated CBEFF structure of clause 8,
- has fingerprint qualities (Table 6, Line 30) assigned 255 for temporarily unusable, or 254 for permanently unusable, fingerprints, and
- overrides the CBEFF quality values (Table 15, Line 11) with -1 indicating temporarily, and -2 permanently unusable fingerprints.

[FIPS] recommends iris biometrics (see clause 6) for PIV applicants for whom fingerprints are unavailable or unusable.

If only one finger is available, the first view **shall** be populated and the second view **shall** be empty, as above. Authentication systems encountering cards populated with empty minutia templates might use iris authentication.

NOTE Minutia detection and matching algorithms continue to improve. Their accuracies have been measured on reference data sets [MINEX]. Some certified implementations are significantly more accurate than others, affording lower false match rates for equal false rejection rates.

4.5 Performance specifications for PIV compliance

4.5.1 Background and scope

The intent of the [FIPS] specification of a globally interoperable biometric is to support cross-vendor and cross-agency authentication of PIV Cards. These multi-party aspects cause fingerprint recognition accuracy to vary, as documented in [MINEX]. To mitigate against poor authentication performance this clause requires template generators (minutia detection algorithms) and template matchers to produce low verification error rates in interoperability tests [MINEX III]. These specifications apply to off-card comparison of templates - separate specifications are advanced for on-card comparison in clause 5.6. For off-card comparison, these components **shall** perform according to

- interoperability specifications of clauses 4.5.2, and
- the accuracy specifications of clause 4.5.3.

The criteria implement the core global interoperability objectives of HSPD-12 by populating PIV Cards with interoperable enrollment templates. These is necessary to exclude systematically incorrect implementations of the underlying [MINUSTD] from PIV. The effect of this is to give increased assurance of low operational error rates.

4.5.2 Minimum interoperability specification

The core cross-vendor interoperability specification is met by establishing requirements on template generators and template matchers as described in the following two sub-clauses.

4.5.2.1 Conformance of template generators

A template generator is certified on the basis of the conformance of its output, its speed of computation, and on the error rates observed when its templates are matched. A template generator **shall** be certified only if:

1. it converts all input PIV representative enrollment images to Table 19 [MINUSTD] templates, and
2. all templates are syntactically conformant to the Table 19 profile of [MINUSTD], and
3. it converts 90% of PIV representative enrollment images to templates in fewer than 1.3 seconds[5] each, and
4. all certified matchers verify its output templates with FNMR less than or equal to 0.01 at a FMR of 0.01, and
5. the minutiae it reports have unique (x, y) values i.e. no two minutiae may share the same location. This requirement is additional to the minutia detection requirements of the [MINUSTD] and is instituted because non-uniqueness impedes some matching algorithms.

4.5.2.2 Conformance of template matchers

A template matcher is certified on the basis of its speed of computation, and on the error rates observed when it matches templates in interoperability tests. A template matcher **shall** be certified only if:

1. it compares all pairs of Table 19 [MINUSTD] templates to scalar scores, and
2. it executes 90% of the clause A.4 template matches in fewer than 0.1 seconds5 each, and
3. it matches templates from all certified template generators, and the template generator accompanying the matcher, with FNMR less than or equal to 0.01 at a FMR of 0.01.

4.5.3 Minimum accuracy specification

The (FMR ≤ 0.01, FNMR ≤ 0.01) interoperability criterion of clause 4.5.2.2 is designed to support low false rejection when templates can come from many sources (i.e. conformant [MINUSTD] template generators). This FMR value, however, is too high for operational application i.e. it is higher than the minimum accuracy requirements of clause 10. To support actual authentication of PIV Card templates, a template generator and matcher-pair **shall** be certified if

1. it meets all the interoperability criteria of clauses 4.5.2.1 and 4.5.2.2, and

[5] This specification applies to a commercial-off-the-shelf PC procured in 2005 and equipped with a 2GHz processor and 512 MB of main memory. This specification shall be adjusted by the testing organization to reflect significant changes of the computational platform.

2. it matches single-finger templates with FNMR less than or equal to 0.02 when the FMR is at or below 0.0001.

4.5.4 Test method

The performance specifications **shall** be tested according to the test defined by Annex B.

4.6 Performance specifications for PIV operations

Off-card fingerprint authentication implementations **shall** be configured according to the specifications of clause 10.

4.7 Fingerprint capture

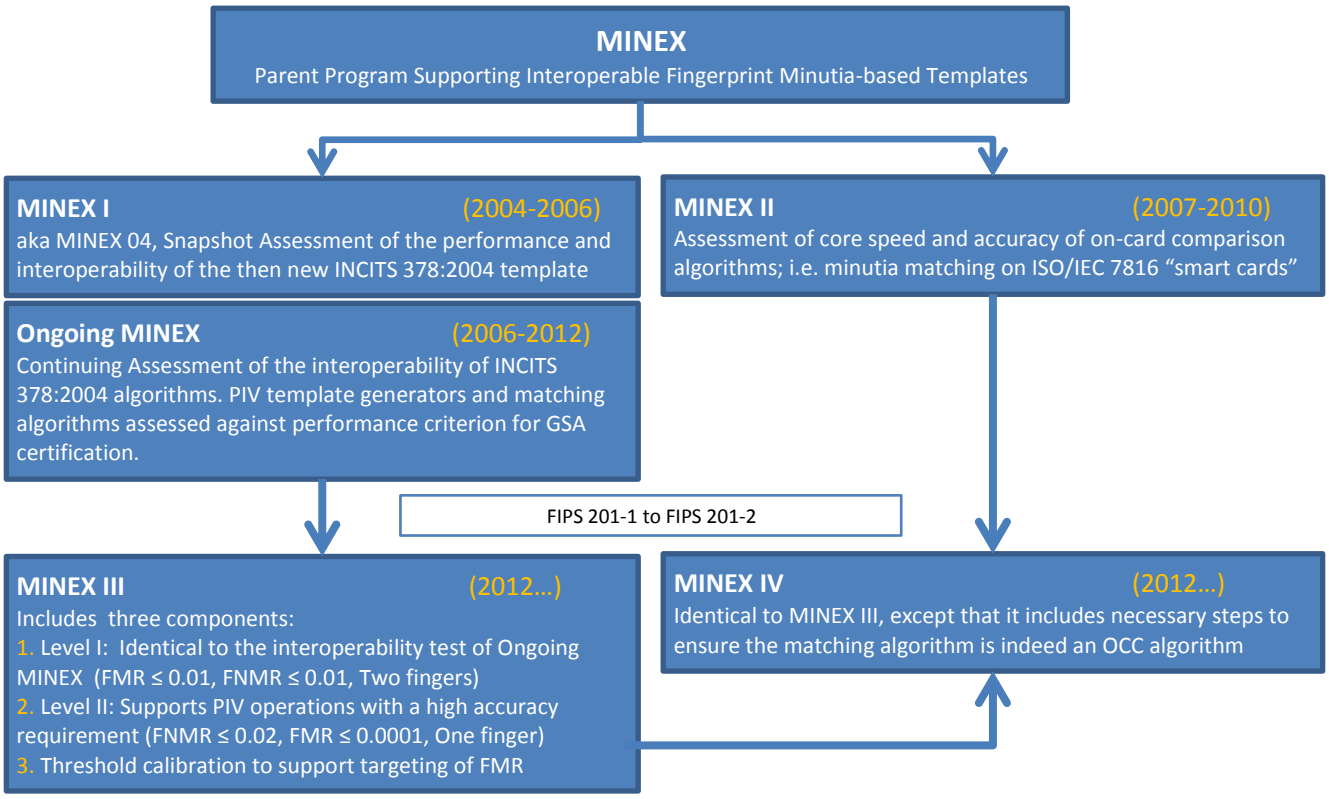
4.7.1 Scope

This clause gives specifications for fingerprint sensors used for capture of single finger images. These sensors **shall** not be used for collection of images for use in the background check i.e. the specifications are unrelated to those of clause 3 which govern ten-print enrollment.

4.7.2 Fingerprint acquisition specifications for flat capture sensors

Fingerprint sensors used for PIV authentication **shall** conform to the FBI's Image Quality Specifications For Single Finger Capture Devices [SINGFING]. The [SINGFING] specification establishes minimum sizes for the imaging platen and for the scanning resolution.

EDITOR's NOTE: The MINEX program supports fingerprint minutia-based template interoperability. The MINEX III and MINEX IV activities, which derive from prior MINEX work, will support PIV off-card and on-card comparison as follows:



5. Fingerprint on-card comparison specifications

5.1 Scope

[FIPS] allows agencies to use on-card comparison (OCC) of fingerprint minutiae. This clause gives specifications for OCC for PIV. This specification includes enrollment data to be placed on the card, authentication data to be sent to the card, and OCC certification information. This clause also specifies the data structure for the storage of card parameters, and the procedure for preparation of on-card fingerprint minutiae templates from off-card ones.

[800-73] indicates where OCC data is stored and that this data is separate and different from the mandatory off-card fingerprint templates. A revision of [800-73, Part 3] will specify the secure channel mechanisms to realize on-card comparison over the [FIPS]-specified interfaces.

5.2 Background

NIST conducted two studies to support the use of on-card comparison in identity management applications.

- The Secure Biometric Match on Card[6] activity engaged commercial providers to execute fingerprint authentication over a contactless interface within a specific time limit. The study required privacy protection via secured communication protocols and integrity protection using cryptographic signatures computed from the biometric data. In addition, the card was authenticated to the reader. The activity has been published as NIST Interagency Report 7452 [SBMOC].
- The MINEX II evaluation was initiated to measure the core algorithmic speed and accuracy of fingerprint minutia matchers running on ISO/IEC 7816 smartcards. Conducted in phases, the test required card- and fingerprint matcher-provider teams to submit on-card comparison enabled cards. The latest results were reported in NIST Interagency Report 7477 [MINEX II].

5.3 Approach to the use of standards

The PIV specification for on-card matching leverages international standards. Specifically, PIV cards **shall**

- be prepared and used by executing the commands of ISO/IEC 7816-4:2005 [CARD-CMD] per [800-73]
- embed the biometric data in the data structures defined in ISO/IEC 7816-11:2004 [CARD-BIO],
- use the core three-byte-per-minutia format defined in the ISO/IEC 19794-2:2011 standard[7], prepared from INCITS 378:2004 templates, as shown in Figure 3.
- adopt certain defined constants from ISO/IEC 19785-3:2007.
-

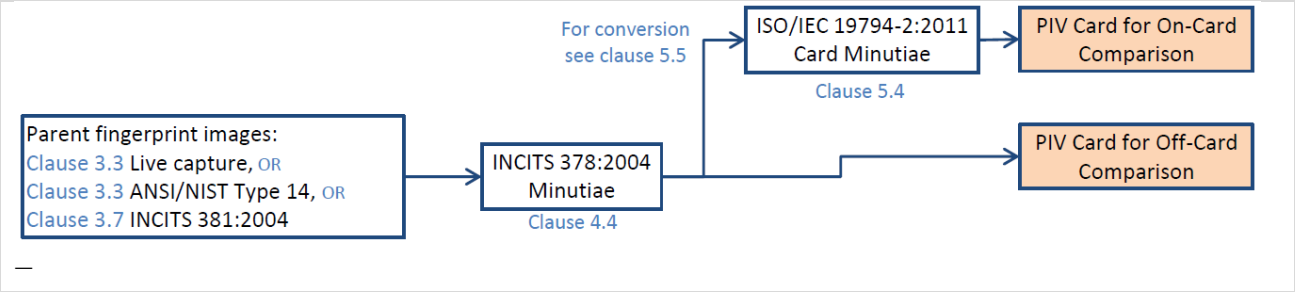


Figure 3 – Preparation of PIV Fingerprint Minutia Templates

[6] The term "on-card comparison" is used by FIPS 201-2. It is standardized and preferred over the term "match-on-card".

[7] This second edition of the minutia standard was completed in 2011-12-14.

5.4 Data objects

5.4.1 Biometric Information Template

Each submitted card **shall** be populated with Biometric Information Templates grouped under the BIT Group Template of Table 7 according to the requirements of [CARD-CMD, Tables 1 and 2]. The number of BITs **shall** be equal to 1. After card issuance, the BIT **shall** be treated as read-only data.

Table 7 – BIT group template and profile

Tag	Len.	Value									Allowed values
7F61	Var.	BIT group template									
		Tag	Len.	Value							
		02	1	1…4 (Number of BITs in the group, corresponding to number of fingers that follow)							1
		7F60	Var.	Biometric Information Template (BIT) for the first finger							
				Tag	Len.	Value					
				83	1	Reference data qualifier used by VERIFY					0, 1, 2, 3
				A1	Var.	Biometric Header Template (BHT) conforming to ISO/IEC 19785-3:2005					
						Tag	Len.	Value			
						81	1	Biometric type (i.e modality, 08 = fingerprint)			08
						82	1	Biometric subtype (e.g. finger position) - These values **shall** be from ISO/IEC 19785-3:2007, NOT from ISO/IEC 19794-2.			See NOTE 2 below
						82	1	Second instance as above for secondary finger.			
						87	2	CBEFF BDB format owner			0101 i.e. JTC1/SC37
						88	2	0x0005 (CBEFF BDB format type)			'00 05' See NOTE 1
						B1	Var.	Biometric matching algorithm parameters. ISO/IEC 19794-2 Table 14			
								Tag	Len.	Value	
								81	2	Min. and max. numbers of minutiae, see ISO/IEC 19794-2 (subclause 8.3.3, Table 10)	
								82	1	Minutiae order, see ISO/IEC 19794-2"2005 (subclause 8.3.4 and Tables 11 and 12)	
								83		This tag **shall** not be present Feature handling indicator, see ISO/IEC 19794-2:2011 (Table 15)	

NOTE 1 The 0x0005 value indicated one of two encodings of minutiae defined in the ISO standard. This one requires that the endings of ridges are reported at the point of the valley bifurcation (versus at the ridge tip itself). These are the semantics required by INCITS 378:2004. The on-card comparison templates **shall** be produced from the parent INCITS 378 templates.

NOTE 2 Which fingers are present is encoded using integers from Table 8. The finger position codes differ in the fingerprint vs. smart-card standards. For on-card comparison data, ISO/IEC 19785-3:2007 finger position codes **shall** be used (column B). For the PIV mandatory off-card templates, [MINUSTD] finger positions **shall** be used (column A). Card issuance processes **shall** transcode using the mapping of Table 8.

Table 8 – ISO/IEC 19794-2 and ISO/IEC 19785-3 finger position codes

Finger ID Biometric subtype	ISO/IEC 19794-2:2011 + INCITS 378:2004		ISO/IEC 19785-3:2007	
	Binary value	Hex Value	Binary value	Hex Value
	A		B	
No information given	00000b	00	00000000b	00
right thumb	00001b	01	00000101b	05
right index	00010b	02	00001001b	09
right middle	00011b	03	00001101b	0D
right ring	00100b	04	00010001b	11
right little	00101b	05	00010101b	15
left thumb	00110b	06	00000110b	06
left index	00111b	07	00001010b	0A
left middle	01000b	08	00001110b	0E
left ring	01001b	09	00010010b	12

left little	01010b	0A	00010110b	16

NOTE 1 PIV readers involved in on-card and off-card authentication attempts will need to heed Table 8 to correctly prompt users for which finger to present.

NOTE 2 Note that the FDIS draft of ISO/IEC 19785-3:2007 erroneously set the six bit to 1. The final standard and the PIV specification require that bits 6, 7 and 8 **shall** be 0.

5.4.2 Minutiae data for on-card comparison

This clause defines the data to be sent to be stored on card-based comparison implementations. It is included here because ISO/IEC 19794-2:2011 and its antecedents defined multiple variants[8].

All PIV on-card comparison data in PIV **shall** conform to the ISO/IEC 19794-2:2011, clause 9 compact on-card comparison format. This format encodes each minutia point in 3 bytes. The [MINUSTD] record instances of Table 6 **shall** be converted to the ISO/IEC 19794-2:2011 compact-card templates of Table 9. The conversion is non-trivial and **shall** proceed according to the steps of Figure 4.

PIV Cards' on-card comparison data **shall** not include a header[9]. In addition, standardized extended data (e.g. cores) **shall** be absent. Proprietary extended data **shall** be absent. Thus, N minutiae are encoded in exactly 3N bytes.

Table 9 – ISO/IEC 19794-2 profile for on-card comparison

#	Field name	Size (bits)	Values allowed	Units	Remark
1.	X coordinate	8	[0,255]	Expressed in units of 0.1 mm	View data. The number of instances of this data varies by person, by finger, and by capture, and by minutia detection algorithm. A median of 38 has been recorded [MINEX].
2.	Y coordinate	8	[0,255]	Expressed in units of 0.1 mm	
3.	Minutiae type	2			
4.	Minutiae angle	6	[0,63]	Resolution is 5.625 degrees	

These would be sent to the on-card biometric comparison implementations in the TLV format of Table 10. The cards would accept templates in that format.

Table 10 – Data object encapsulating ISO/IEC 19794-2 minutiae for on-card comparison

Tag	L	Value					Comment	Status
7F2E	L1	Biometric data template						Mandatory
		Tag	L	Value				
		82		This tag **shall** not be present			No proprietary data	Absent – None of these tags **shall** be present
		90		This tag **shall** not be present			No need for constructed data	
		91		This tag **shall** not be present			No ridge count data	
		92		This tag **shall** not be present			No cores	
		93		This tag **shall** not be present			No deltas	
		94		This tag **shall** not be present			No zonal quality	
		96		This tag **shall** not be present				
		81	L2	Finger minutiae data from primary finger			This data corresponds to a particular finger. The integer code identifying the finger is indicated in the second BIT	Mandatory if on-card comparison is enabled.
				X coordinate	8	[0,255]	As in Table 9. The number of minutiae is L2/3	
				Y coordinate	8	[0,255]		
				Minutiae type	2			
				Minutiae angle	6	[0,63]		
		95	1	Impression type	1	0	From plain impression sensor	
		81	L2	Finger minutiae data from secondary finger			This data corresponds to a particular finger. The integer code identifying the finger is indicated in the second BIT	Mandatory if on-card comparison is
				X coordinate	8	[0,255]	As in Table 9.	

[8] Particularly the ISO/IEC 19794-2:2005 standard includes three encodings (record, card-normal, card-compact), has versions with and without headers, has variants differing in their minutia placement semantics, has presence of standardized extended data (zonal quality etc) and of non-standard, proprietary, extended data.

[9] There was confusion in the industry, during early adoption of the compact formats, over whether the card formats should include record or view headers. The ILO Seafarer's program specified the presence of headers – Other programs used the ISO/IEC 7816-11 fields for such information.

				Y coordinate	8	[0,255]	The number of minutiae is L2/3	enabled.
				Minutiae type	2			
				Minutiae angle	6	[0,63]		
		95	1	Impression type	1	0	From plain impression sensor	

5.5 Preparation of the minutia templates

5.5.1 Conversion of INCITS 378 to ISO/IEC 19794-2 on-card comparison templates

All templates used in on-card comparison **shall** be prepared from instances of the [MINUSTD] templates required by clause 4. This **shall** be done using the algorithm specified in this sub-clause.

The BITs of clause 5.4.1 **shall** be used to parameterize the production of templates that a reader, or other system, sends to the PIV card. This applies to both the reference templates stored on the card, and those produced during, for example, an authentication transaction.

The BITs read from the card **shall** parameterize the conversion of templates sent to the card. As depicted in Figure 4, the conversion operation proceeds with a pruning operation (sec. 5.5.2.2), a re-encoding (conversion of 8 bit to 6 bit minutia angle, conversion from 14 bit to 8 bit position coordinates), and a sorting operation (sec. 5.5.2.3).

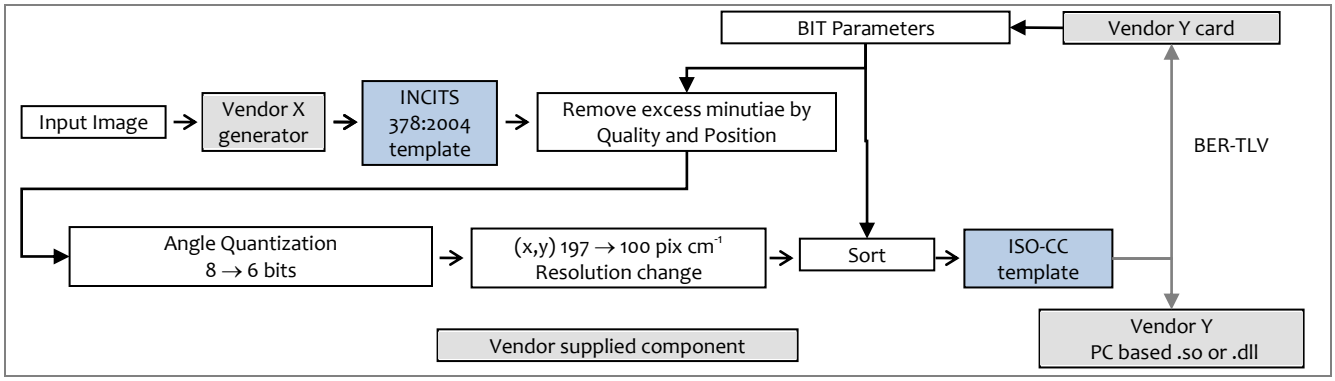


Figure 4 – Conversion of INCITS 378 to ISO/IEC 19794-2 card data

5.5.2 Effect of the BIT

5.5.2.1 Number of minutiae

The number of minutiae stored on a PIV Card for on-card comparison **shall** not exceed 83 for any one finger. The number of minutiae sent to a PIV Card for on-card comparison **shall** not exceed 83 for any one finger.

NOTE 1 Leading commercial minutia detectors produce a median of 41 minutiae from plain impression images with the 5% and 95% quantiles being 24 and 61 respectively over four large operational single index finger datasets [2].

NOTE 2 A short-length APDU command constrains the maximum number of three-byte minutiae to 83. Command chaining [CARD-CMD] would ordinarily be used for larger templates, but the PIV limit of 83 reflects NOTE 1.

Because some templates will naturally contain 0 minutiae (i.e. the algorithm does not find any), the (off-card) client **shall** respect the minimum number indicated by the card in its BIT structure. The client **shall** either terminate the minutia-based authentication attempt or prompt for (re-)presentation of one of the enrolled fingers.

All reference and verification templates **shall** be parameterized by the BIT parameters, as follows. If,

- the value indicated in the BIT for the minimum number of minutiae is $0 \le N \le 83$,
- the value indicated in the BIT for the maximum number of minutiae is $N \le M \le 83$,
- the number of minutiae present in a verification template is K, then
- the number of minutiae sent to the card, S, **shall** be

$$S = \begin{cases} M & \text{if } K \ge M \\ K & \text{if } K < M \\ K & \text{if } K < N \end{cases}$$

5.5.2.2 Minutiae removal mechanism

Minutiae **shall** be removed according to the specifications of [CARD-MIN, clause 9.3.2]. Note that because the parent [MINUSTD] template allows larger spatial extent (14 bit integers at 197 pixels cm^{-1} off card), very large fingers may yield minutiae outside the maximum possible spatial extent that can be encoded here (8 bit integers at 100 pixels cm-1 on card. The pruning mechanism **shall** remove such minutiae.

5.5.2.3 Sort order of minutiae

The BIT associated with the on-card comparison algorithm **shall** indicate how minutiae must be sorted according to the options extended in [CARD-MIN, clause 9.4]. However, because single finger PIV images have widths of fewer than 500 pixels when scanned at 19.7 pixels mm^{-1}, all possible minutiae coordinates **shall** be encoded in 8 bits, and the modulo sorting technique defined in [CARD-MIN] **shall not** be used.

NOTE Open-source INCITS 378 "C" code is maintained in http://www.itl.nist.gov/iad/894.03/nigos/biomdi.html. On-card biometric comparison client software is here: http://www.itl.nist.gov/iad/894.03/nigos/biomapp.html.

5.6 Performance specifications for PIV compliance

5.6.1 Scope

This minutia template generators and minutia matching algorithms used for on-card comparison **shall** perform according to two sets of specifications

- interoperability specifications of clauses 5.6.3, and
- the accuracy specifications of clause 5.6.4.

The interoperability criteria implement the core global interoperability objectives of HSPD-12 by populating the PIV Card with interoperable enrollment templates and an associated on-card comparison algorithm. The accuracy specifications are intended to afford low operational error rates by assuring highly accurate matching in typical authentication scenarios.

5.6.2 Background

NIST conducted tests of on-card comparison performance in its MINEX II program [MINEX-II]. Over four phases conducted between 2007 and 2010, the program showed that four implementations would have attained the PIV interoperability specifications of clause 4.5.2.

In parallel, the sBMOC [SBMOC] demonstrated cryptographic protection of the template data, and transactional durations below two seconds.

5.6.3 Minimum interoperability specification

The core cross-vendor interoperability specification is met by establishing requirements on paired template generators and on-card matchers as described in the following two sub-clauses.

5.6.3.1 Conformance of template generators used to prepare on-card comparison templates

Template generators **shall** conform to the specification of clause 4.5.3.1, for off-card authentication (because on-card comparison templates are generated off-card). No additional conformance specifications are defined here.

5.6.3.2 Conformance of on-card template matchers

A template matcher **shall** be certified if

1. it conforms to the off-card template matcher interoperability specifications of clause 4.5.2.2 but operating with Table 9 [CARD-MIN] format templates, and
2. it executes 90% of on-card genuine template pair comparisons (using the VERIFY command [CARD-CMD], for example) in fewer than 0.50 seconds, and

3. when implemented on a functional but modified PIV Card, and in a software library, it produces identical output similarity scores[10],
4. it produces at least 512 unique integer scores when comparing many templates of different persons.

5.6.3.3 Test method

The performance specifications **shall** be tested according to the test defined by Annex A modified to use [CARD-MIN] templates. This test **shall** conform to the requirements of the ISO/IEC 19795-7 testing standard. The Level 1 interoperability test embedded in NIST's MINEX IV program[11] implements this test [MINEX-IV].

5.6.4 Minimum accuracy specification

5.6.4.1 Specification

To support operational authentication of PIV Card templates against live samples a template generator and matcher-pair **shall** be certified if

1. it meets all the interoperability criteria of clauses 4.5.2.1 and 4.5.2.2, and
2. it matches single-finger templates with FNMR less than or equal to 0.02 when the FMR is at or below 0.0001.

5.6.4.2 Test method

The performance specifications **shall** be tested according to the test defined by Annex D. The Level 2 accuracy test embedded in NIST's MINEX IV program implements this test [MINEX-IV].

5.6.5 Performance specifications for PIV operations

On-card comparison authentication implementations **shall** be configured according to the specifications of clause 10.

5.7 Fingerprint capture

On-card comparison **shall** be implemented using the fingerprint sensors specified in clause 4.7.

5.8 On-card comparison interface

[FIPS] establishes requirements on interfaces to OCC implementations.

[10] This requirement implies a non-operational requirement: the Card must allow multiple comparisons without locking and must report similarity scores to a dedicated test application.

[11] The MINEX IV program replaces the original MINEX II proof-of-concept evaluation which ran 2007-2011.

6. Iris recognition specifications

6.1 Scope

This clause standardizes specifications for use of iris images as allowed by [FIPS]. The clause includes specifications

- for iris images stored on and off PIV Cards,
- for iris capture devices, and
- for components involved in automated recognition of PIV iris imagery.

The image specifications extend the format requirements of ISO/IEC 19794-6:2011 with image quality related properties. The capture device specifications concern imaging properties of the iris camera, and software interfaces around it. The recognition component is specified in terms of minimum authentication accuracy and processing speed.

This document makes no mention of an iris template. In iris recognition, templates are proprietary non-standardized mathematical encodings[12] of information extracted from the formally standardized images that are defined in this document. Templates are not interoperable. Agencies retaining only templates are subject to a supplier lock-in hazard.

6.2 Background

Digital representations of rectilinear images of the human iris have been formally standardized as ISO/IEC 19794-6:2011. This standard, which replaces earlier editions, is a necessary component in an interoperable marketplace of iris cameras and iris recognition algorithms. The standard is used because it includes specialized image formats that support compact storage[13] on ISO/IEC 7816 IC cards. The formats needed for PIV are shown in Figure 5.

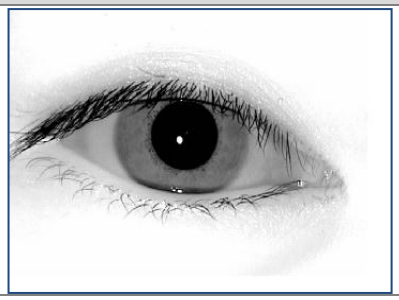
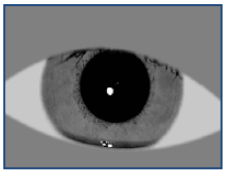
Label	A	B
Example Image		
ISO/IEC 19794-6:2011	Image Type 2	Image Type 7
Properties	Parent image, typically the output of a camera of size 640x480 pixels, not necessarily centered, but conformant to Image Type 2 of [ISOIRIS]. Images of this kind are not intended to be heavily compressed.	Cropped, masked and centered iris conformant to Image Type 7 of [ISOIRIS]. Images of this kind can be compressed to a few kilobytes.
PIV Role	Image captured from camera. This format is suitable for retention of iris images e.g. in the [FIPS] chain-of-trust.	Prepared from (A), it **shall** be used if an agency chooses to store iris on the PIV Card.

Figure 5 – Image formats of ISO/IEC 19794-6:2011

[12] Cambridge University has published at least one viable iris representation in the academic literature, and it has been implemented widely. While it is known for its power, small size, and speed, some other (commercial) template representations are actually larger than the specialized Image Type 7 PIV Card *images* specified in this document.

[13] The first generation of iris image standards included a polar-coordinate encoding of the iris. This format, intended to support compact size, was removed from second generation standards because of concerns that interoperability was sensitive to correct determination of the iris and pupil centers. An alternative, replacement format, shown in Figure 5B, has been shown to offer accurate recognition and broad industry support [IREX]. It requires localization of the boundaries and the iris center. These tasks are non-trivial and are supported by quantitative tests.

6.3 Iris image specification for PIV cards

Iris images on PIV Cards **shall** conform to the requirements expressed in the Table 11 profile of the ISO/IEC 19794-6:2011 standard. Where required values and practice are not stated, the underlying requirements of the base standard **shall** apply. The profile defines a standard record that contains one or two specialized iris images each of size around 3 kilobytes. These images **shall** follow the semantic requirements of Image Type 7 images defined in the standard. The objective of these specifications is to afford maximum possible iris accuracy, low storage requirements, and corresponding fast read times. These requirements include centering and masking of the eyelid and sclera regions (an example is shown in Figure 5, column C). The masked regions can be very efficiently compressed. This affords small record sizes and, vitally, preservation of the iris texture.

Table 11 – ISO/IEC 19794-6 profile for iris images stored on PIV Cards

		Clause or field of ISO/IEC 19794-6	ISO/IEC 19794-6		PIV Conformance	Remarks
			Field	Value	Values Allowed	
1.		CBEFF Header	MF	MV	Patron format PIV	Multi-field CBEFF Header. Sec. 7.3.
2.	Iris General Header	Format identifier	MF	MV	0x49495200	IIR\0 Four byte format identifier including null terminator.
3.		Version number	MF	MV	0x30323000	020\0 Second 19794-6 version - not the 2005 standard
4.		Length of record	MF	MV	See NOTE 1	The length (in bytes) of the entire iris image data.
5.		Number of iris representations	MF	MV	1 or 2	Number of iris representations that follow. This **value would** ordinarily be 1. See NOTE 4.
6.		Certification flag	MF	MV	0x00	
7.		Number of eyes represented	MF	MV	1 or 2	2 if left and right are known present, else 1 if left or right is known present. If camera does not estimate eye label automatically, these **shall** be manually assigned.
Representation 1: Data for the first eye image follows						
8.	Representation Header + Image Data	Representation Length	MF	MV		Bytes for this representation including the header + image
9.		Capture date and time	MF	MV	2011 onwards.	Capture start time in UTC
10.		Capture device technology identifier	MF	MV		
11.		Capture device vendor ID	MF	MV		Manufacturer ID
12.		Capture device type ID	MF	MV		Vendor assigned make model product ID.
13.		Quality block	MF	OIT		
14.		Representation number	MF	MIT	1 and then, optionally, 2	Representation sequence number
15.		Eye label	MF	MIT	1 or 2	Left, right. If camera does not estimate eye label automatically, these **shall** be manually assigned.
16.		Image type	MF	MV	7	IMAGE_TYPE_CROPPED_AND_MASKED = 7 (07_{Hex}) i.e. a cropped and region-of-interest masked, centered, iris image with (0,6R 0,2R) margins. See NOTE 2
17.		Image format	MF	MV	10 = 0x0A	Compression algorithm and encoding **shall** be JPEG 2000. The format **shall** not be PNG, RAW, or JPEG.
18.		Iris image properties bit field	MF	MIT MIT MV MV	Bits 1-2: 01 or 10 Bits 3-4: 01 or 10 Bits 5-6: 01 Bits 7-8: 01 Bit 1 is the least signif. bit. Bit 8 is the most signif. bit.	Horizontal + vertical orientation **shall** not be undefined Scan type **shall** be progressive. Compression history **shall** be none; i.e. the cropped and masked image **shall** be prepared from an uncompressed parent image.
19.		Image width, W	MF	MIT	288 ≤ W ≤ 448	Dimensions ranges, in pixels, are implied by the exact [IRISSTD] margin requirements based on iris size.
20.		Image height, H	MF	MIT	216 ≤ H ≤ 336	
21.		Bit depth	MF	MV	8	Bit depth in bits per pixel. This **shall** not be used to indicate compression level
22.		Range	MF	OIT		Required field; optionally populated.
23.		Roll angle of eye	MF	OIT	≤ 20	Camera or software should estimate roll angle. Rotation should only be applied if angle is > 20 deg.
24.		Roll angle uncertainty	MF	OIT	≤ 5	
25.		Iris centre, lowest X	MF	MV	W/2 for W odd, else	These values are redundant for Image type = 7 for which image **shall** be exactly centered. The iris center **shall** be estimated by the iris localization code, or if necessary by a human inspector.
26.		iris centre, highest X	MF	MV	W/2+1 for W even	
27.		Iris centre, lowest Y	MF	MV	H/2 for H odd, else	
28.		Iris centre, highest Y	MF	MV	H/2+1 for H even	
29.		Iris diameter, lowest	MF	MIT	D ≥ 180	These two fields are used to express a normative PIV requirement on iris size. See NOTE 3
30.		Iris diameter, highest	MF	MIT	D ≤ 280	
31.		Image length	MF		1 … approx 6KB	Size of the JPEG 2000 encoded image data, in bytes, is limited by container defined in NIST Special Pub 800-73, and the size of its CBEFF header and digital signature.

Representation 2: Data for the second eye image follows
Analogous to Representation 1, above.

Acronym		Meaning
MF	mandatory field	[IRISSTD] requires a field **shall** be present in the FAC
MV	mandatory value	[IRISSTD] requires a meaningful value for a field
OV	optional value	[IRISSTD] allows a meaningful value or allows 0 to be used to connote "unspecified"
MIT	mandatory at time of instantiation	For PIV, mandatory value that **shall** be determined at the time the record is instantiated and **shall** follow the practice specified in [IRISSTD]
OIT	optional at time of instantiation	For PIV, optional header value that may be determined at the time the record is instantiated

NOTE 1 The entire record length plus the CBEFF header and CBEFF signature block length must be less than or equal to size specified in NIST Special Publ. 800-73-3. A single image of 3K or two images of each of size about 3K, or one image of size about 6K, will all fit in this container.

NOTE 2 The specification of a Type 7 image requires that the image captured from the camera has sufficient margin around the iris to support the strict (0.6R, 0.2R) margin requirements of Image Type 7. During enrollment, client capture software might usefully display the result with a prototypical overlay.

NOTE 3 If any captured iris has diameter outside of the range [180,280] pixels, see clause 6.7.1.1.3.

NOTE 4 A single iris can easily satisfy 1:1 comparison accuracy objectives [IREXIII]. Moreover, a single eye will be read faster and its digital signature can be accessed and verified faster. Two eyes will be useful if one of the images is somehow of poor quality, or if one eye is somehow occasionally unavailable for authentication. Quality control of the PIV card imagery is imperative.

6.4 Iris image specification for iris images retained outside the PIV card

This document neither requires nor precludes agencies from retaining iris images. [FIPS] recommends use of iris imagery in cases where fingerprints cannot be captured satisfactorily. In addition, [FIPS] allows iris whenever fingerprints are used, and indicates that iris image data may be available outside the PIV Card for authentication during PIV card re-issuance, replacement and chain-of-trust transactions. If agencies elect to retain images, they **shall** be stored in the format specified in this clause. This clause establishes a profile of ISO/IEC 19794-6:2011 suited for retention of iris images outside the PIV Card. The format specification includes the [CBEFF] header of clause 8, and this requires integrity protection and allows for encryption of the image records.

Retention of data supports, for example, detection of duplicate identities.

Table 12 – ISO/IEC 19794-6 profile for iris images stored outside PIV Cards

		Clause or field of ISO/IEC 19794-6	ISO/IEC 19794-6		PIV Conformance	Remarks
			Field	Value	Values Allowed	
1.		CBEFF Header (5.3)	MF	MV	Patron format PIV	Multi-field CBEFF Header. Sec. 8.
2.	Iris General Header	Format identifier	MF	MV	0x49495200	IIR\0 Four byte format identifier including null terminator.
3.		Version number	MF	MV	0x30323000	020\0 Second 19794-6 version - not the 2005 standard
4.		Length of record	MF	MV		The length (in bytes) of the entire iris image data.
5.		Number of iris representations	MF	MV	1 or 2	Number of iris representations that follow. One iris is ample for verification tasks.
6.		Certification flag	MF	MV	0x00	Is certification information present in the representation headers?
7.		Number of eyes represented	MF	MV	1 or 2	2 if left and right are known present, else 1 if left or right is known present.
Representation 1: Data for the first eye image follows						
8.	Representation Header	Representation Length	MF	MV		Bytes for this representation including the header + image
9.		Capture date and time	MF	MV	2011 onwards.	Capture start time in UTC
10.		Capture device technology identifier	MF	MV	0x00 0x01	Unknown or Unspecified CMOS/CCD
11.		Capture device vendor ID	MF	MV		Manufacturer ID
12.		Capture device type ID	MF	MV		Vendor assigned make model product ID.
13.		Quality block	MF	OIT		
14.		Representation number	MF	MIT	1 and then 2	Representation sequence number
15.		Eye label	MF	MIT	1 or 2	Left, right. If camera does not estimate eye label automatically,

						these **shall** be manually assigned.
16.		Image type	MF	MV	2	IMAGE_TYPE_VGA = 0x02 i.e. 640 x 480 pixels. See [IRISSTD]
17.		Image format	MF	MV	14 = 0x0E	Compression and encoding **shall** be PNG or RAW.
18.		Iris image properties bit field	MF	MIT MIT MV MV	Bits 1-2: 01 or 10 Bits 3-4: 01 or 10 Bits 5-6: 01 Bits 7-8: 01 Bit 1 is the least signif. bit. Bit 8 is the most signif. bit.	Horizontal + vertical orientation **shall** not be undefined Scan type **shall** be progressive. Compression history **shall** be none
19.		Image width, W	MF	MIT	> 0	width in pixels, W
20.		Image height, H	MF	MIT	> 0	height in pixels, H
21.		Bit depth	MF	MV	8	Bit depth in bits per pixel. This **shall** not be used to indicate compression level
22.		Range	MF	OIT		Required field; optionally populated.
23.		Roll angle of eye	MF	OIT	≤ 20	Camera or software should estimate roll angle. Rotation should only be applied if angle is > 20 deg.
24.		Roll angle uncertainty	MF	OIT	≤ 5	
25.		Iris centre, lowest X	MF	MIT		Iris need not be centered for Image type 2 but iris centre must be in a range such that margin requirements of Note 1 are met.
26.		iris centre, highest X	MF	MIT		
27.		Iris centre, lowest Y	MF	MIT		
28.		Iris centre, highest Y	MF	MIT		
29.		Iris diameter, lowest	MF	MIT	≥ 180	These two fields are used to express a normative PIV requirement that iris diameter **shall** be no smaller than 180 pixels, and no larger than 280 pixels. See NOTE 2
30.		Iris diameter, highest	MF	MIT	≤ 280	
31.		Image length	MF	MIT		Size of the PNG encoded image data, in bytes, is unlimited
Representation 2: Data for the second eye image follows						
Analogous to Representation 1, above.						

NOTE 2 If any captured iris has diameter outside of the range [180,280] pixels, see clause 6.7.1.1.3.

6.5 Conformance of ISO/IEC 19794-6:2011 records

For the standard records of clauses 6.3 and 6.4, implementers may wish to download parts of NIST-developed conformance test suites [BIOCTS] and maintained open-source software for testing the syntactic correctness of the record. The software exists in two forms: One runs under a conformance testing architecture; the other runs as a standalone. They can run in single-instance or batch mode.

6.6 Iris image quality control

Agencies electing to store iris on PIV Cards should require PIV Applicants to:

1. remove eyeglasses, hard contact lenses, or patterned contact lenses during initial enrolment;

2. perform a one-to-one verification of a newly captured iris with the image that is, or will be stored, on the Card. If this authentication fails, the client software **shall** recapture an image and repeat the matching procedure. The camera and associated software might collect several images and cross match them. Additionally the operator might

- inspect captured images to verify that the eyes are open, not blurred, looking toward the camera, and that the iris is centered,
- instruct the PIV Cardholder to open their eyes widely, remain still and look into the camera as designed.

6.7 Performance specifications for PIV compliance

The core cross-vendor interoperability specification is met by establishing requirements on iris cameras and on components preparing and matching [IRISSTD] records as described in sub-clauses 6.7.1.1, 6.7.1.3, and 6.7.1.4

6.7.1.1 Properties of iris cameras

EDITOR'S NOTE The requirement for the camera to pass a biometric performance test is instituted until such time as imaging specifications and associated test methods are developed. NIST anticipates that the ISO/IEC 29794-6 standard, now under development, will include sufficient specifications.

Imaging specifications exist today only for ten-print fingerprint scanners [APP/F]. Only certain elements are currently available for iris cameras.

973

974 **6.7.1.1.1 Scope**

975 The following sub-clauses support interoperable recognition by specifying iris camera and iris image properties, and
976 iris camera performance.

977 **6.7.1.1.2 Rectilinear imaging and aspect ratio**

978 The output of the camera **shall** be a rectilinear image of the iris region. The digital representation of the iris **shall**
979 exhibit minimal projective distortion such that the vertical and horizontal scale factors are uniform to within ±2%
980 throughout the image.

981 **6.7.1.1.3 Format**

982 It produces, possibly in conjunction with client-side software, conformant Table 12 [IRISSTD, Image Type 2] instances
983 (suitable for use in an authentication transaction).

984 **6.7.1.1.4 Iris size**

985 All iris images prepared in PIV (for cards, for authentication and other purposes) **shall** have an iris diameter between
986 180 and 280 pixels. If the camera or client software detects an iris of radius outside this range, re-capture of the PIV
987 cardholder should be attempted at least two times. The recapture requirement is intended to correct out-of-focus
988 irises that have incorrect diameter.

989 Interpolation of iris images to increase size **shall** not be performed, unless the physical iris size is actually below 9mm.
990 Thus the optical design of the camera **shall** ensure that an iris of physical dimension 9 mm produces an iris of diameter
991 180 pixels in the digital image.

992 **6.7.1.1.5 Spectral properties of the illuminant**

993 The iris camera **shall** use one or more dedicated infra-red illuminators. The spectrum **shall** be such that

994 — 90% of the power **shall** be between 700 and 900nm, and
995 — 35% of the power **shall** be between 700 and 800nm, and
996 — 35% of the power **shall** be between 800 and 900nm.

997 The spectral measurement **shall** be time-averaged over an interval comparable with the duration of an iris capture
998 attempt.

999 **6.7.1.1.6 Safety of the illuminant**

1000 The camera **shall** conform to the (irradiance and exposure duration) limits specified for infrared illumination given in
1001 [ICNIRP-LED, ICNIRP-BB] and the threshold limit values specified in [IECLED].

1002 **6.7.1.2 Performance of PIV cameras**

1003 The camera **shall** support accurate recognition. An iris camera **shall** be certified if it completes the performance test
1004 defined in Annex B, with the following results:

1005 — the proportion of subjects, executing up to three enrolment attempts, for which zero eyes can be captured (i.e.
1006 failure-to-enrol rate, FTE) is at or below 0.01, and
1007 — the proportion of genuine verification transactions, each embedding up to three verification attempts, that are
1008 falsely rejected (i.e. FRR) is at or below 0.01 given a configuration consistent with FAR < 0.00003 using only a PIV
1009 compliant [IRISSTD] generator and matcher.
1010 — retains all [IRISSTD] images to be used in offline comparisons and confirmation of the online results for which
1011 FMR **shall** be at or below 0.00001.

1012 These performance specifications apply to one-to-one authentication[14].

[14] This performance specification should also be suitable for one-to-many identification, which is outside of the PIV scope. However, identification requires proportionally much lower false match rates which are attainable using more stringent thresholds. These may be estimated via a calibration procedure [IREXIII].

6.7.1.3 Specifications for iris record generators

Production of the standard PIV records of clause 6.3 is a non-trivial task because it requires iris detection, and localization, and preparation of the Figure 5B image. A standard record generator **shall** be certified if:

1. it converts all PIV-representative[15] captured images to syntactically conformant Table 11 [IRISSTD, Image Type 7] instances (suitable for enrollment on PIV cards), and
2. the median time taken to convert PIV-representative captured images to Table 11 [IRISSTD] records is below 0.5 seconds[16] each, and
3. at least one matcher verifies its uncompressed Table 11 records with FNMR no higher than the FNMR for the parent Table 12 images, for FMR set to 0.00001.

6.7.1.4 Specifications for iris image matchers

A recognition algorithm is certified on the basis of its speed of computation, and on the error rates observed when it matches records. A recognition algorithm **shall** be certified if:

1. the median time taken to execute comparisons of genuine template pairs is below 0.05 seconds, and
2. it matches both compressed Table 11 and Table 12 [IRISSTD] records from all certified record generators with FNMR less than or equal to 0.01 at a FMR of 0.00001, and

6.7.1.5 Test methods

The performance specifications of clauses 6.7.1.3 and 6.7.1.4 **shall** be tested in an offline test using sequestered image data.

Editor's NOTE NIST expects to establish an activity under the IREX program to implement this test.

6.8 Performance specifications for PIV operations

Iris authentication implementations **shall** be configured according to the specifications of clause 10.

[15] These are 640x480 images conforming to Image Type 2 of [IRISSTD].

[16] This specification applies to a commercial-off-the-shelf PC procured in 2010 and equipped with a 2GHz processor and 8GB of main memory. This specification **shall** be adjusted by the testing organization to reflect significant changes of the computational platform.

7. Facial image specifications

7.1 Scope

[FIPS] establishes requirements and options for agency-collection, storage, and use of a facial image from PIV applicants. The facial imagery **shall** be stored in the format specified here. The face specification has a very similar format, and is functionally identical to, the ISO/IEC 19794-5:2005 face image adopted by the International Civil Aviation Organization for e-Passports. The image is suitable for automated face recognition: Implementations **shall** conform to the accuracy specifications given in this clause. However, note that two images are involved in one-to-one applications:

- Enrollment image: The PIV image as specified here.
- Authentication image: Additional specifications for the collection of this image are typically necessary to address subject height variations and the illumination environment (see [BSI-FACE], for example).

7.2 Acquisition and format

This clause provides specifications for the retention of facial images. Facial images collected during PIV Registration **shall** be formatted such that they conform to INCITS 385-2004 [FACESTD]. In addition to establishing a format, [FACESTD] specifies how a face image should be acquired. This is done to improve image quality and, ultimately, performance. The images **shall** be embedded within the CBEFF structure defined in Clause 8. Because [FACESTD] is generic across applications it includes clauses that have either-or requirements. Table 13 is an application profile of [FACESTD] tailored for PIV. It gives concrete specifications for much of the generic content. Column 3 references the clauses of [FACESTD] and columns 4 and 5 give [FACESTD] requirements. For PIV, column 6 of Table 13 gives normative practice or value specifications. The table is not conformant with the Implementation Conformance Statement [ICS] standard. Particularly it extends the function of ICS but because it has the needed rows it may be useful in construction of a traditional ICS. Nevertheless the addition of a "values supported column" as specified in Clause 9.1 of [ICS] should be used by implementers for checking conformance to the specifications.

INCITS 385 is likely to be revised by the INCITS M1 committee. Such revisions are irrelevant to PIV; however implementations should respect the version number on Line 5 of Table 13.

Table 13 – INCITS 385 profile for PIV facial images

		Clause title and/or field name (Numbers in parentheses are [FACESTD] clause numbers)	INCITS 385-2004		PIV Conformance	Informative Remarks
			Field or content	Value Required	Values Allowed	
1.		Byte Ordering (5.2.1)	NC		A	Big Endian
2.		Numeric Values (5.2.2)	NC		A	Unsigned Integers
3.	CBEFF	CBEFF Header (5.3)	MF	MV	Patron format PIV	Multi-field CBEFF Header. Sec. 7.3.
4.	Facial Header	Format Identifier (5.4.1)	MF	MV	0x46414300	i.e. ASCII "FAC\0"
5.		Version Number (5.4.2)	MF	MV	0x30313000	i.e. ASCII "010\0"
6.		Record Length (5.4.3)	MF	MV	MIT	See Note 1
7.		Number of Facial Images (5.4.4)	MF	MV	≥ 1	One or more images (K ≥ 1). See Notes 2 and 3, and also line 20.
8.	Facial Info. Single instance of subject-specific info.	Facial image Block Length (5.5.1)	MF	MV	MIT	
9.		Number of Feature Points (5.5.2)	MF	MV	≥ 0	Positive, if features computed
10.		Gender (5.5.3)	MF	OV	OIT	These fields populated with meaningful values at agency discretion, otherwise 0 for unspecified.
11.		Eye color (5.5.4)	MF	OV	OIT	
12.		Hair color (5.5.5)	MF	OV	OIT	
13.		Feature Mask (5.5.6)	MF	OV	OIT	
14.		Expression (5.5.7)	MF	OV	1	Neutral
15.		Pose Angles (5.5.8)	MF	OV	0	Unspecified = Frontal
16.		Pose Angle Uncertainty (5.5.9)	MF	OV	0	Attended operation so should be frontal.
17.	Features	MPEG4 Features (5.6.1)	NC		OIT	
18.		Center of Facial Features (5.6.2)	NC		OIT	
19.		The Facial Feature Block Encoding (5.6.3)	OF	OV	OIT	
20.	Image Info. Each instance has	Facial Image Type (5.7.1)	MF	MV	1	See Note 4.
21.		Image Data Type (5.7.2)	MF	MV	0 or 1	See Note 5. Compression algorithm.

			Clause title and/or field name (Numbers in parentheses are [FACESTD] clause numbers)		INCITS 385-2004	PIV Conformance	Informative Remarks
					Field or content	Value Required	Values Allowed	
22.	image-specific info.		Width (5.7.3)		MF	MV	MIT	See Note 7.
23.			Height (5.7.4)		MF	MV	MIT	
24.			Image Color Space (5.7.5)		MF	MV	1	sRGB. See Note 8.
25.			Source Type (5.7.6)		MF	MV	2 or 6	Digital still or digital video
26.			Device Type (vendor supplied device ID) (5.7.7)		MF	MV	MIT	
27.			Quality (5.7.8)		MF	0-100	A	[FACESTD] requires 0 (unspecified) but allowed here.
28.	Image Data		Data Structure (5.8.1)		MF	MV	MIT	Compressed Data
29.	Basic (clause 6)	Inheritance	Inheritance (6.1)		NC		A	
30.			Image Data Encoding (6.2)		NC		A	See Note 5
31.			Image Data Compression (6.3)		NC		A	See Notes 5+6
32.		Format	Facial Header (6.4.1)		NC		A	Include 4 fields
33.			Facial Information (6.4.2)		NC		A	Include 9 fields
34.			Image Information (6.4.3)		NC		A	Include 8 fields
35.	Frontal (clause 7)	Inheritance	Inheritance (7.1)		NC		A	Inherits Basic
36.		Scene	Purpose (7.2.1)		NC		A	frontal Annex A
37.			Pose (7.2.2)		NC		Frontal	+/- 5 degrees
38.			Expression (7.2.3)		NC		Neutral	
39.			Assistance in positioning face (7.2.4)		NC		A	Only the subject appears
40.			Shoulders (7.2.5)		NC		A	Body + Face toward camera
41.			Backgrounds (7.2.6)		NC		Annex A.4.3	Uniform
42.			Subject and scene lighting (7.2.7)		NC		A	Uniform
43.			Shadows over the face (7.2.8)		NC		A	None
44.			Eye socket shadows (7.2.9)		NC		A	None
45.			Hot spots (7.2.10)		NC		A	Should be absent. Diffuse light.
46.			Eye glasses (7.2.11)		NC		A	Subject's normal condition
47.			Eye patches (7.2.12)		NC		A	Medical only
48.		Photographic	Exposure (7.3.2)		NC		A	No saturation
49.			Focus and Depth of Field (7.3.3)		NC		A	In focus
50.			Unnatural Color (7.3.4)		NC		A	White balance
51.			Color or grayscale enhancement (7.3.5)		NC		A + no recompress	No post-processing
52.			Radial Distortion of the camera lens (7.3.6)		NC		A + Follow Annex A.8	
53.		Digital	Geometry	aspect ratio (7.4.2.1)			A	1:1 pixels
54.				origin (7.4.2.2)			A	top left is 0,0
55.			Color Profile	Density (7.4.3.1)	NC		A	7 bits dynamic range in gray
56.				Color Sat (7.4.3.2)	NC		A	7 bits dynamic once in grayscale
57.				Color space (7.4.3.3)	NC		24 bit RGB	Option a, reported in color space field above. See Note 8
58.			Video Interlacing (7.4.4)		NC		A	Interlaced sensors are not permitted.
59.	Full Frontal (clause 8)	Inheritance	Inheritance (8.1)		NC		A	Inherits Frontal + Basic
60.		Scene	Scene (8.2)		NC		A	Inherits Frontal + Basic
61.		Photographic	Centered Image (8.3.2)		NC		A	Nose on vertical centerline
62.			Position of Eyes (8.3.3)		NC		A	Above horizontal centerline
63.			Width of Head (8.3.4)		NC		A	See Note 7
64.			Length of Head (8.3.5)		NC		A	See Note 7
65.		Digital	Resolution (8.4.1)		NC		CC ≥ 240	See Note 7
66.		Format	Inheritance (8.5.1)		NC		A	
67.			Image Information (8.5.2)		NC		A	
END OF TABLE								

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Acronym		Meaning
FAC	Face Information Record	Facial header + facial info + repetition of (image info + image data)
MF	mandatory field	[FACESTD] requires a field **shall** be present in the FAC
OF	optional field	[FACESTD] allows a field to be present in record
MV	mandatory value	[FACESTD] requires a meaningful value for a field
OV	optional value	[FACESTD] allows a meaningful value or allows 0 to be used to connote "unspecified"
NC	normative content	[FACESTD] gives normative practice for PIV. Such clauses do not define a field in the FAC.

A	as required	For PIV, value or practice is as specified in [FACESTD]
MIT	mandatory at time of instantiation	For PIV, mandatory value that **shall** be determined at the time the record is instantiated and **shall** follow the practice specified in [FACESTD]
OIT	optional at time of instantiation	For PIV, optional header value that may be determined at the time the record is instantiated

NORMATIVE NOTES:

1. If facial imagery is stored on the PIV Card, the length of the entire record **shall** fit within the container size limits specified in [800-73]. These limits apply to the entire CBEFF wrapped and signed entity, not just the [FACESTD] record. Key lengths and signing algorithms are specified in [800-78]. The size of the digital signature scales with the key length; it does not scale with the size of the biometric record.
2. More than one image may be stored in the record. It may be appropriate to store several images if appearance changes over time (beard, no beard, beard) and images are gathered at re-issuance. The most recent image **shall** appear first and serve as the default provided to applications.
3. When facial imagery is stored on the PIV Card, only one image **shall** be stored.
4. PIV facial images **shall** conform to the Full Frontal Image Type defined in Clause 8 of [FACESTD].
5. Facial image data **shall** be formatted in either of the compression formats enumerated in Clause 6.2 of [FACESTD]. Both whole-image and single-region-of-interest (ROI) compression are permitted. This document ([800-76]) recommends that newly collected facial image should be compressed using ISO/IEC 15444 (i.e. JPEG 2000). This applies when images will be input to automated face recognition products for authentication, and when images are stored on PIV Cards. In this latter case, ROI compression should be used. The older ISO/IEC 10918 standard (i.e. JPEG) should be used only for legacy images.
6. Facial images **shall** be compressed using a compression ratio no higher than 15:1. However, when facial images are stored on PIV Cards JPEG 2000 should be used with ROI compression. The innermost region should be centered on the face and compressed at no more than 24:1.
7. Face recognition performance is a function of the spatial resolution of the image. [FACESTD] does not specify a minimum resolution for the Full Frontal Image Type. For PIV, faces **shall** be acquired such that a 20 centimeter target placed on, and normal to, a camera's optical axis at a range of 1.5 meters **shall** be imaged with at least 240 pixels across it. This ensures that the width of the head (i.e. dimension CC in Figure 8 of [FACESTD]) **shall** have sufficient resolution for the printed face element of the PIV Card. This specification and Clause 8.3.4 of [FACESTD] implies that the image width **shall** exceed 420 pixels. This resolution specification **shall** be attained optically without digital interpolation. The distance from the camera to the subject should be greater than or equal to 1.5 meters (for distortion reasons discussed in [FACESTD, Annex A.8]). The size specification is a minimum: When images are to be used for automated face recognition higher resolution is likely to yield lower error rates.
8. Facial image data **shall** be converted to the sRGB color space if it is stored. As stated in Clause 7.4.3.3 of [FACESTD] this requires application of the color profile associated with the camera in use.

7.3 Performance specifications for PIV operations

[FIPS] allows automated face recognition for certain authentication purposes. Automated face recognition implementations **shall** be configured according to the specifications of clause 10.

NOTE: This standard does not establish qualification criteria for face recognition algorithms

8. Biometric sensor interface specifications

8.1 Scope

This section guides implementers of biometric enrollment and authentication applications that use biometric sensors.

8.2 Available specifications and standards

The Biometric Identity Assurance Services standard [BIAS] standardizes remotely invoked biometric services, particularly it defines a framework for deploying and invoking biometrics-based identity assurance capabilities that can be readily accessed using services-based frameworks (e.g., web services). Excluded from the scope is a) single platform functionality (e.g., client-side capture) and b) integration of biometric services within an authentication protocol.

NIST Special Publication 500-288 [WSBD] establishes specifications that support access to, and command and control of, a target biometric sensor by enrollment or recognition clients via web services. As such, it leverages formal standardization of web services, and the wide availability of infrastructure and resources supporting such, to allow PIV implementers to maximize device-interface level interoperability i.e. the ability to replace a biometric sensor with minimal specialization. PIV implementers should consider the utility of [WSBD] and its supporting tools and documents.

PIV implementers should also note the availability of the BioAPI standards [BIOAPI, BIOAPI-GUI, BIOAPI-FPI, BIOAPI-FF, BIOAPI-SEC] and their simpler version 1 predecessor [BIOAPI-US]. These have similar goals to those of [WSBD] but take a different approach.

Editor's NOTE For iris capture and processing, the C# interface that appeared in the April 2011 draft of this standard remains under-development as part of the IREX program. It defined abstraction layers around cameras and iris recognition components http://iris.nist.gov/irex

9. Common header for PIV biometric data

9.1 Scope

All PIV biometric data **shall** be embedded in a data structure conforming to Common Biometric Exchange Formats Framework [CBEFF]. This specifies that all biometric data **shall** be digitally signed and uniformly encapsulated. This covers the following static data:

- the PIV Card fingerprints mandated by [FIPS];
- the PIV Card facial image mandated by [FIPS];
- any other biometric data agencies elect to place on PIV Cards (e.g. iris);
- any biometric records that agencies elect to retain (including purely proprietary, or derivative, elements); and
- any biometric data retained by, or for, agencies or Registration Authorities.

There are three exemptions to this

- the [EBTS] data of clause 3.5 sent for background checks,
- the OCC data of clause 5.4 that is stored oplaced on the PIV Card
- data captured and transmitted during a local biometric comparison (but see [FIPS] for cryptographic protection of such data),

For the relevant data above, integrity **shall** be protected by pre-pending the data with a CBEFF header and appending with a signature stored in the CBEFF signature block as depicted in the linear structure of Table 14.

Table 14 – CBEFF concatenation structure

CBEFF_HEADER	CBEFF_BIOMETRIC_RECORD	CBEFF_SIGNATURE_BLOCK
Clause 9.2	Clauses 3.3.1, 3.4, 6.3. 6.4 and 7.2	Clause 9.3
INCITS 398 5.2.1	INCITS 398 5.2.2	INCITS 398 5.2.3

9.2 The CBEFF Header

The CBEFF Header specified in Table 15 and its notes will be established by NIST as Patron Format "PIV". This format will be established as a formal Patron Format per the provisions of [CBEFF, 6.2]. It adds definitive data types and the FASC-N field mandated by [FIPS] to a subset of the fields given in Patron Format A [CBEFF, Annex A]. It exists independently of Patron Format A. All fields of the format are mandatory.

Table 15 – Patron format PIV specification

	Patron Format PIV Field (Numbers in parentheses are [CBEFF] clauses)	Length Bytes	PIV Data Type	PIV Conformance Required Value
1.	Patron Header Version (5.2.1.4)	1	UINT	0x03
2.	SBH Security Options (5.2.1.1, 5.2.1.2)	1	Bitfield	See Note 2
3.	BDB Length	4	UINT	Length, in bytes, of the biometric data CBEFF_BIOMETRIC_RECORD
4.	SB Length	2	UINT	Length, in bytes, of the CBEFF_SIGNATURE_BLOCK. See Note 3
5.	BDB Format Owner (5.2.1.17)	2	UINT	Table 16, row "Biometric Format Owner" – which standards developer
6.	BDB Format Type (5.2.1.17)	2	UINT	Table 16, row "Biometric Format Type" – which standard
7.	Biometric Creation Date (5.2.1.10)	8		See Note 4 for data type
8.	Validity Period (5.2.1.11)	16		See Note 5 for data type
9.	Biometric Type (5.2.1.5)	3	UINT	Table 16, row "Biometric Type" – which modality
10.	Biometric Data Type (5.2.1.7)	1	Bitfield	Table 16, row "Biometric Data Type" – what degree of processing
11.	Biometric Data Quality (5.2.1.9)	1	SINT	[-2,100]. A value of -2 **shall** denote that assignment was not supported by the implementation; A value of -1 **shall** indicate that an attempt to compute a quality value failed. Values from 0 to 100 **shall** indicate an increased expectation that the sample will ultimately lead to a successful match.
12.	Creator (5.2.1.12)	18	Note 6	See Note 6 for data type
13.	FASC-N	25	Note 7	See Note 7 for data type
14.	Reserved for future use	4		0x00000000

1145 **Table 16 – CBEFF content for specific modalities**

Quantity	Fingerprint Images	Fingerprint Templates	Iris Images	Facial Images	Other modalities
Clause	3.3.1	3.4	6	0	-
Biometric Format Owner	0x001B i.e. M1, the INCITS Technical Committee on Biometrics	0x001B i.e. M1, the INCITS Technical Committee on Biometrics	0x0101 i.e. ISO/IEC JTC 1/SC 37 Biometrics	0x001B i.e. M1, the INCITS Technical Committee on Biometrics	For other biometric data on PIV Cards, or retained by agencies, this field **shall** be assigned in accordance with [CBEFF, 5.2.1.17].
Biometric Format Type	0x0401	0x0201	0x0009	0x0501	
Biometric Type	0x000008	0x000008	0x000002	0x000010	0x0
Biometric Data Type	b001xxxxx i.e. raw	b100xxxxx i.e. processed	b010xxxxx i.e. Intermediate	b001xxxxx i.e. raw	[CBEFF, 5.2.1.7] has 3 categories for the degree biometric data has been processed.
Quality value	Quality value **shall** be Q = 20(6 - NFIQ) where NFIQ is computed using the method of [NFIQ].		See NOTE 8	[FACESTD] requires 0 this **shall** be coded here as -2. Also 0-100 values are allowed	
	When multiple views or samples of a biometric are contained in the record the largest (i.e. best) value should be reported. For all biometric data, whether stored on a PIV Card or otherwise, the quality value **shall** be a signed integer between -2 and 100 per the text of INCITS 358.				

1146

1147 NORMATIVE NOTES:

1148 1. Unsigned integers are denoted by UINT. Signed integers are denoted by SINT. Multi-byte integers **shall** be in
1149 Big Endian byte order.

1150 2. The security options field has two acceptable values. The value b00001101 indicates that the biometric data
1151 block is digitally signed but not encrypted; the value b00001111 indicates the biometric data block is digitally
1152 signed and encrypted. For the mandatory [MINUSTD] elements on the PIV Card the value **shall** be b00001101.

1153 The fourth bit (mask 0x08) is set per prior versions of this document. The third bit (mask 0x04), which in
1154 each case is set, implements the [CBEFF, 5.2.1.2] requirement that digital signature is differentiated from
1155 message authentication code. The second bit (mask 0x02) indicates the use of encryption. The first bit
1156 (mask 0x01) indicates the use of a digital signature. See [FIPS, 800-78] for specifications on digital signatures.

1157 3. The signature **shall** be computed over the concatenated CBEFF_HEADER and CBEFF_BIOMETRIC_RECORD in
1158 Table 14. The CBEFF_HEADER is given in Table 15. This includes the signature block length (on line 4) which
1159 may not be known before the signature is computed. This problem may be solved by conducting a two
1160 phase computation: First a dummy SB length value is inserted, the signature is computed, the signature
1161 length is written into the SB length field, and the signature recomputed.

1162 4. This date **shall** be date the biometric sample was acquired from the subject. For processed samples (e.g.
1163 templates) this data should be the date of acquisition of the parent sample. Creation Date **shall** be encoded
1164 in eight bytes using a binary representation of "YYYYMMDDhhmmssZ". Each pair of characters (for example,
1165 "DD") is coded in 8 bits as an unsigned integer. Thus 17:35:30 December 15, 2005 is represented as: 00010100
1166 00000101 00001100 00001111 00010001 00100011 00011110 01011010 where the last byte is the binary
1167 representation of the ASCII character Z which is included to indicate that the time is represented in
1168 Coordinated Universal Time (UTC). The field "hh" **shall** code a 24 hour clock value.

1169 When multiple samples (e.g. two single finger minutiae views) are included in one record (e.g. an INCITS 378
1170 record) and the Creation Dates are different, the Creation Date **shall** be the earliest of the multiple views.

1171 5. The Validity Period contains two dates each of which **shall** be coded according to Normative Note 4.

1172 a. The validity period should start at the when the biometric data is available for use (e.g. according to
1173 policy or issuance considerations). It **shall** be no earlier than the Creation Date. Biometric
1174 applications (e.g. authentication) should respect this date.

b. The closing date should ordinarily be eight years[17] after the Creation Date, but may vary with technical or policy factors at agency discretion. Biometric ageing is considered to be a slow continuous process, and therefore a hard closing date is not required. This field therefore serves as an advisory that biometric data should be re-collected from the Cardholder at the next opportunity. This date is not intended to invalidate any function of the card (see [FIPS] for that).

6. For PIV the Creator field has length 18 bytes of which the first K ≤ 17 bytes **shall** be printable ASCII characters, and the first of the remaining 18-K **shall** be a null terminator (zero).

7. This field **shall** contain the 25 bytes of the FASC-N component of the CHUID identifier, per [800-73, 1.8.{3,4}].

8. Iris quality may be set to [-2-100]. Note that formal standardization of iris image properties and quality metrics are pending in the ISO/IEC 29794-6 standard with publications expected in late 2013 or early 2014. The value -2 indicates a failure to compute, and -1 indicates no attempt to compute quality.

9.3 The CBEFF Signature Block

The CBEFF_SIGNATURE_BLOCK contains the digital signature of the biometric data and thus facilitates the verification of integrity of the biometric data. The process of generating a CBEFF_SIGNATURE_BLOCK is described as follows. The CBEFF_SIGNATURE_BLOCK **shall** be encoded as a CMS external digital signature as defined in [RFC5652]. The digital signature **shall** be computed over the entire CBEFF structure except the CBEFF_SIGNATURE_BLOCK itself (which means that it includes the CBEFF_HEADER and the biometric records). The algorithm and key size specifications for the digital signature **shall** be implemented according to [800-78].

The CMS encoding of the CBEFF_SIGNATURE_BLOCK is as a SignedData type, and **shall** include the following information:

- The message **shall** include a version field specifying version v3
- The digestAlgorithms field **shall** be as specified in [SP 800-78]
- The encapcontentInfo **shall**
- Specify an eContentType of id-PIV-biometricObject
- Omit the eContent field
- If the signature on the biometric was generated with the same key as the signature on the CHUID, the certificates field **shall** be omitted
- If the signature on the biometric was generated with a different key than the signature on the CHUID, the certificates field **shall** include only a single certificate, which can be used to verify the signature in the SignerInfo field
- The crls field **shall** be omitted
- signerInfos **shall** be present and include only a single SignerInfo
- The SignerInfo **shall**
- Use the issuerAndSerialNumber choice for SignerIdentifier
- Specify a digestAlgorithm in accordance with [800-78]
- Include at a minimum the following signed attributes:
- A MessageDigest attribute containing the hash of the concatenated CBEFF_HEADER + Biometric Record
- A pivFASC-N attribute containing the FASC-N of the PIV Card (to link the biometric data and PIV Card)
- A pivSigner-DN attribute containing the subject name that appears in the PKI certificate for the entity that signed the biometric data
- Include the digital signature.

[17] The eight year duration comes from a study of the effect of face ageing on recognition accuracy [FACEPERF]. Because face-based manual verification is common, this duration is adopted as a default. No large-population studies of iris and fingerprint ageing are available.

10. Minimum accuracy specifications

10.1 Scope

This clause establishes specifications for *configuration* of deployed biometric verification algorithms. In previous clauses[18], this document includes performance specifications for *qualification* of components that influence recognition outcomes. This clause establishes minimum accuracy specifications and performance parameters for components configured and used in operational PIV biometric authentication subsystems.

NOTE [FIPS] establishes options and requirements for all PIV functions including authentication. It allows only certain modalities to be used in PIV contexts.

10.2 Approach

FIPS 140-2 establishes minimum requirements for authentication for activation of crypto-modules. This clause defines analogous specifications for biometric person authentication. The specifications implement the primary security objective of using biometrics as an authentication factor.

The approach is to require recognition algorithm *operating thresholds* to be set to achieve false match rates (FMR) no higher than those advanced here. These false match rates apply to zero-effort authentication, i.e. the one-to-one comparison of sample pairs from randomly selected different persons[19]. The false match criteria implement the core biometric security objectives. These are the primary interest of a security policy.

While any false match criterion can always be met by setting a stringent[20] comparison threshold, the adoption of stringent thresholds will imply elevated false non-match error rates (FNMR) because of the error-rate tradeoff. High FNMR error rates will inconvenience legitimate users, and it is therefore imperative that biometric systems offering sufficient performance are user – see clause 10.5.

10.3 Operating threshold specification

The threshold applied to scores from the biometric comparison algorithms **shall** be set to achieve false match rates at or below the respective values in Table 17. The threshold **shall** be calibrated in tests conformant to Annex A[21]. Agencies may require lower (more secure) FMR values; particularly some implementations can attain lower false match rates.

Table 17 – Maximum allowed false match rates by modality

Modality	Authentication	False match rate	Notes
Fingerprint minutia matching	Off-card	0.001	Applies to a one comparison with one finger. See NOTE and clause 10.5
Fingerprint minutia matching	On-card	0.001	
Iris image matching	Off-card	0.00001	Applies to one comparison with one eye. See NOTE and clause 10.5
Face image matching	Off-card	0.001	Applies to one comparison. See NOTE and clause 10.5

NOTE Transactional false accept rates will be higher than these values if the transaction includes multiple presentations of a multiple biometrics.

[18] Those clauses, 4.5.3 and 4.5.4 for off-card fingerprint comparison, and 5.7.3.2 and 5.7.4 for on card comparison, qualify components requiring core minutiae-based interoperable accuracy. They do this in laboratory tests. The accuracy criteria were never intended to be adopted as operational verification criteria – particularly the FMR = 0.01 threshold was instituted to bar non-interoperable minutia detection algorithms and matchers – but is not appropriate as an Agency security policy.

[19] This represents the case where a lost card is found by someone who casually attempts a biometric authentication.

[20] For fingerprints and face, industry convention is for recognition algorithms to produce similarity scores, for which higher thresholds produce fewer false matches. For iris, the convention is to produce distance or dis-similarity scores, for which lower thresholds produce fewer false matches.

[21] The Level 2 accuracy test embedded in NIST's MINEX IV program estimates these thresholds [MINEX-III]

10.4 Conformance to accuracy specifications

The false match rate requirements **shall** be assured as follows. Biometric comparison algorithms **shall** be submitted to the test and calibration programs given in Table 18. Those programs **shall** provide the algorithm developer with a tabulation of false match rate vs. threshold calibration.

Table 18 – Example performance test and threshold calibration programs

Modality	Authentication	Test + Calibration Program	Status
Fingerprint minutia matching	Off-card	MINEX III	This program was formerly known Ongoing MINEX. It includes an interoperability component (Level 1 certification) and an operational support component (Level 2 certification).
	On-card	MINEX IV	This program follows the MINEX II protocol [MINEXII] to implement the Level 1 and 2 components described in MINEX III.
Iris image matching	Off-card	IREX x(TBD)	This program follows the IREX I test ensuring correct generation of and matching of PIV Card (Image Type 7) standard images.
Face image matching	Off-card	Agencies may reference recent test results from any source.	Examples of such tests are [FACEPERF].

The test measurements are typically obtained by running algorithms on commodity PC hardware.

Thereafter, the algorithm provider or integrator **shall** provide documented attestation that:

- All components of the recognition software (including template generation and comparison algorithms) are functionally identical to those submitted to the recognized test and calibration program. The use of recognition algorithms on other platforms, such as wall mounted embedded processors, is allowed. The algorithm provider **shall** submit the same software to the test program wherever it is ultimately installed.
- All instances of the fielded comparison algorithms are configured with an operating decision threshold that is at least as strong as that established in FMR vs. threshold calibration.

Agencies might require inspection of source code and instituting appropriate controls to ensure that the source code is indeed that installed in deployed equipment.

Additionally, Agencies could elect to conduct a biometric performance test to confirm the hypothesis that the false match rate is conformant to the specification of clause 10.3.

10.4.1 Use of multiple samples with fixed thresholds

The thresholds are set to target particular false match rates between single fingers, irises or faces of different individuals. However, if agency policy is to allow two fingers or eyes to be used in an authentication attempt, then false match rates will typically be double the calibrated value. Similarly if multiple captures (e.g. of face) are allowed, false acceptance is more likely. However, if a system is configured to always or conditionally require two eyes, then it can theoretically be configured (using different decision or fusion logic) to render false acceptance much less likely.

10.5 Agency consideration of false rejection performance

An authentication transaction may involve several core comparisons each of which will be expected to have failure rates given by FMR (for impostors) and FNMR (for genuine comparisons). These are matching error rates defined over outcomes of sample *comparisons*. Operational authentication performance is quantified in terms of both the false reject rate (FRR) and the false accept rate (FAR) which are defined over outcomes of *transactions*[22]: In PIV, FRR is the proportion of legitimate cardholders incorrectly denied access; FAR would be the proportion of impostors incorrectly allowed access. The error rates depend on a number of factors including: the environment, the number of attempts (i.e. finger placements on the sensor), the sensor itself, the quality of the PIV Card templates' parent images, the number of fingerprints invoked, and the familiarity of users with the process. The use of two fingers in all authentication transactions offers substantially improved performance over single-finger authentication.

This document does not establish false rejection performance criteria – how often genuine users are unable to successfully authenticate – because it does not represent a direct security objective. Agencies are cautioned that false rejection performance is operationally vital in access control applications and is achieved by using high

[22] A transaction might include several comparisons from repeated presentations of multiple fingers or irides.

performance cameras and algorithms, by ensuring good quality enrolment, by correct control of the environment, by adherence to enrolment specifications, by subject and operator instruction, and by subject habituation. Agencies are therefore strongly encouraged to consider:

- Establishing a policy on how many times a subject can attempt to authenticate
- Establishing false rejection accuracy criteria against which tests and qualification procedures can be conducted
- Referring to false rejection performance measures reported for algorithms passing the IREX test and calibration procedure.
- Referring to false rejection performance measures reported for algorithms conforming to the MINEX test and calibration procedure.
- Conducting their own supplementary tests. These might be performance tests of single products or interoperability tests, and might be used to estimate application-specific performance. The execution of tests conforming to one or more parts of the ISO/IEC 19795 standard is strongly recommended because biometric testing is a specialized discipline. Particularly a number of subtleties and difficulties exist that can potentially fatally undermine a test.
- Requiring the use of multiple samples (e.g. two fingers),
- Using an alternative modality for authentication (e.g. iris instead of fingerprint)
- Using an additional modality for authentication (e.g. iris and fingerprint).

This specification does not:

- Preclude agencies from establishing more stringent false match criteria. The false match criteria can always be met by setting a high (i.e. stringent) comparison threshold. However, higher thresholds imply elevated false rejection errors because of the error-rate tradeoff. One mitigation is to use two fingers or two eyes.

11. Conformance to this specification

11.1 Conformance

Conformance to this specification will be achieved if an implementation and its associated data records conform to the normative ("**shall**") clauses of clauses 3 through 6. The following text summarizes these statements.

11.2 Conformance to PIV registration fingerprint acquisition specifications

Conformance to Clause 3.2 requires the use of an [EBTS, Appendix F] certified scanner to collect a full set of fingerprint images and the application of a segmentation algorithm and the [NFIQ]-based quality assurance procedure. Images **shall** be conformant to this specification if:

- The acquisition procedures of 3.2 are followed. This may be tested by human observation.
- The images are conformant to [FINGSTD] as profiled by Table 4 and its normative notes.

11.3 Conformance of PIV Card fingerprint template records

Conformance to Clause 3.3.1 is achieved by conformance to all the normative content of the clause. This includes production of records conformant to [MINUSTD] as profiled in Clause 3.3.1. Conformance **shall** be tested by inspection of the records and performing the test assertions of the "PIV Conformance" column of Table 6. Performance certification according to clause 4.5.2.1 is necessary.

11.4 Conformance of PIV registration fingerprints retained by agencies

Conformance to Clause 3.4 is achieved by conformance to all the normative content of the clause. This includes production of records conformant to [FINGSTD] as profiled in Clause 3.4. Conformance **shall** be tested by inspection of the records and performing the test assertions of the "PIV Conformance" column of Table 4. Quality values [NFIQ] **shall** be checked against the NIST reference implementation.

11.5 Conformance of PIV background check records

Conformance to Clause 3.5 is achieved by conformance to all the normative content of the clause. This necessitates conformance to the normative requirements of the FBI for background checks. These **shall** be tested by inspection of the transactions submitted to the FBI. This inspection may be performed either by capturing the transactions at the submitting agency or at the FBI.

11.6 Conformance to PIV authentication fingerprint acquisition specifications

Conformance to Clause 4.7 **shall** be achieved if certification according to [SINGFING] is achieved, and if the resolution and area specifications are met. The [SINGFING] certification process entails inspection of output images.

11.7 Conformance of PIV facial image records

Conformance to Clause 6 **shall** be achieved by conformance to all the normative content of the clause. This includes production of records conformant to [FACESTD] as profiled in Clause 7.2. Conformance **shall** be tested by inspection of records and performing the test assertions of the "PIV Conformance" column of Table 13.

11.8 Conformance of CBEFF wrappers

A PIV implementation will be conformant to clause 8 if all biometric data records, whether or not mandated by this document or [FIPS], are encapsulated in conformant CBEFF records. CBEFF records **shall** be conformant if:

- the fields of the Table 15 header are present;
- the fields of Table 15 contain the allowed values as governed by its normative notes;
- a digital signature conformant to [800-78] is present;
- the values are consistent with the enclosed biometric data and the trailing digital signature.

An application that tests conformance of PIV biometric data **shall** be provided with appropriate keys to decrypt and check the digital signature.

1346 # 12. References

1347

Citation	Document
800-73	NIST Special Publication 800-73-3, Interfaces for Personal Identity Verification. There are currently four parts: Pt. 1- End Point PIV Card Application Namespace, Data Model & Representation Pt. 2- PIV Card Application Card Command Interface Pt. 3- PIV Client Application Programming Interface Pt. 4- The PIV Transitional Interfaces & Data Model Specification http://csrc.nist.gov/publications/PubsSPs.html
800-78	NIST Special Publication 800-78-3, Cryptographic Algorithms and Key Sizes for Personal Identity Verification http://csrc.nist.gov/publications/PubsSPs.html
APP/F	See EBTS entry below.
BAZIN	A. Bazin and T. Mansfield. An investigation of minutiae interoperability. In Proc. Fifth IEEE Workshop on Automated Identification Advanced Technologies, June 2007. AUTO-ID 2007, Alghero Italy.
BIAS	Biometric Identity Assurance Services (BIAS) SOAP Profile ver. 1.0, Committee Specification 01, November 4, 2011. http://docs.oasis-open.org/bias/soap-profile/v1.0/cs01/biasprofile-v1.0-cs01.pdf NOTE: This normatively cites the INCITS 442:2010 standard for higher level requirements and architecture, biometric operations, and data element for biometrics. INCITS 442 will be succeeded by ISO/IEC 30108 now under development. A reference implementation is available here: http://nist.gov/itl/iad/ig/upload/BIAS_20110608.zip
BIOAPI	ISO/IEC 19784-1:2006[2007] BioAPI – Biometric Application Programming Interface – Part 1: BioAPI Specification http://webstore.ansi.org/
BIOAPI-GUI	ISO/IEC 19784- 1:2006/AM1 -2007 [2008], Information technology - BioAPI - Biometric Application Programming Interface - Part 1: BioAPI Specification - Amendment 1: BioGUI specification
BIOAPI-FPI	ISO/IEC 19784-2:2007[2008] Biometric Application Programming Interface (BioAPI) – Part 2: Biometric Archive Function Provider Interface http://webstore.ansi.org/
BIOAPI-FF	ISO/IEC 19784-1, Amd. 2 19784-1:2006, Amd. 2:2009 [2009] - - Information technology - Biometric application programming interface – Part 1: BioAPI specification – Amendment 2: Framework-free BioAPI http://webstore.ansi.org/
BIOAPI-SEC	ISO/IEC 19784-1, Amd. 3 19784-1:2006, Amd. 3:2010 - Information technology -Biometric application programming interface – Part 1: BioAPI specification – Amendment 3: Support for interchange of certificates and security assertions, and other security aspects http://webstore.ansi.org/
BIOAPI-US	ANSI INCITS 358-2002 (R2007) Information technology - BioAPI Specification (Version 1.1) and its amendment ANSI INCITS 358-2002/AM1-2007 - Amendment 1: Support for Biometric Fusion.
BIOCTS	F. Podio, NIST/ITL CSD Conformance Test Architectures (CTA) and Test Suites (CTS) for Biometric Data Interchange Formats http://www.nist.gov/itl/csd/biometrics/biocta_download.cfm
BSI-FACE	Markus Nuppeney, Marco Breitenstein and Matthias Niesing, EasyPASS - Evaluation of face recognition performance in an operational automated border control system. BSI and Secunet, DE. http://biometrics.nist.gov/cs_links/ibpc2010/pdfs/Nuppeney_Marcus_IBPC2010_EasyPASS_Talk_Website.pdf This presentation is accompanied by a supporting paper. http://biometrics.nist.gov/cs_links/ibpc2010/pdfs/Nuppeney2_Marcus_IBPC2010_EasyPASS_Paper_final.pdf
CARD-CMD	ISO/IEC 7816-4:2005 Identification cards -- Integrated circuit cards -- Part 4: Organization, security and commands for interchange http://webstore.iec.ch/preview/info_isoiec7816-4%7Bed2.0%7Den.pdf
CARD-BIO	ISO/IEC 7816-11:2004 Identification cards -- Integrated circuit cards -- Part 11: Personal verification through biometric methods http://webstore.iec.ch/preview/info_isoiec7816-11%7Bed1.0%7Den.pdf
CARD-MIN	ISO/IEC FDIS 19794-2:2011 Information technology -- Biometric data interchange formats -- Part 2: Finger minutiae data. This standard is NOT INCITS 378 and not ISO/IEC 19794-2:2005.
CBEFF	INCITS 398-2005, American National Standard for Information Technology - Common Biometric Exchange Formats Framework (CBEFF) http://webstore.ansi.org
EBTS	AFIS-DOC-01078-9.1 CJIS-RS-0010 (V9.1) – Electronic Biometric Transmission Specification, Criminal Justice Information Services, Federal Bureau of Investigation, Department of Justice, May 25, 2010. Linked from here

Citation	Document
	https://www.fbibiospecs.org/docs/EBTS_v9-1_Final.pdf Implementers should consult https://www.fbibiospecs.org/ or request the full EBTS documentation, including Appendix N, from the FBI.
FFSMT	ANSI/NIST-ITL 1-2011 – Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo (SMT) Information, NIST Special Publication 500-290, 2011. This supersedes SP 500-245. http://www.nist.gov/itl/iad/ig/ansi_standard.cfm
FINGSTD	INCITS 381-2004, American National Standard for Information Technology - Finger Image-Based Data Interchange Format http://webstore.ansi.org
FIPS	FIPS 201-2, Personal Identity Verification, National Institute of Standards and Technology, 2011. FIPS 201-1 is currently the formal published standard. FIPS 201-2 was released as a second draft June, 2012. http://csrc.nist.gov/publications/PubsFIPS.html
MANSFIELD	T. Mansfield et al. Research report on minutiae interoperability tests. Technical report, Minutiae Template Interoperability Testing, 2007. http://www.mtitproject.com/DeliverableD62.pdf
FACEPERF	P. Grother, G.W. Quinn, and P. J. Phillips. Evaluation of 2D still-image face recognition algorithms. NIST Interagency Report 7709, National Institute of Standards and Technology, August 2010. http://face.nist.gov/mbe.
MINUSTD	INCITS 378-2004, American National Standard for Information Technology - Finger Minutiae Format for Data Interchange http://webstore.ansi.org
FACESTD	INCITS 385-2004, American National Standard for Information Technology - Face Recognition Format for Data Interchange http://webstore.ansi.org
ICS	Methods for Testing and Specification (MTS); Implementation Conformance Statement (ICS) Proforma style guide. EG 201 058 V1.2.3 (1998-04)
ICNIRP-LED	ICNIRP Statement on Light-Emitting Diodes, Implications for Hazard Assessment http://www.icnirp.de/documents/led.pdf
ICNIRP-BB	ICNIRP Statement on Light-Emitting Diodes, Guidelines on Limits of Exposure to Broadband Incoherent Optical Radiation, http://www.icnirp.de/documents/broadband.pdf
IREX I	P. Grother, E. Tabassi, G. W. Quinn, and W. Salamon. IREX I: Performance of Iris Recognition Algorithms on Standard Images. Technical Report NIST Interagency Report 7629, National Institute of Standards and Technology, http://iris.nist.gov/irex/, October 2009.
IREX III	P. Grother, G.W. Quinn, J. Matey, M. Ngan, W. Salamon, G. Fiumara, C. Watson, Iris Exchange III, Performance of Iris Identification Algorithms, NIST Interagency Report 7836, April 9, 2012. http://iris.nist.gov/irex
IECLED	IEC 62471 Ed. 1.0 b:2006 Photobiological safety of lamps and lamp systems, Edition: 1.0 International Electrotechnical Commission / 26-Jul-2006 / 89 pages This document derives some of its content from: Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices, 2007, ACGIH Worldwide www.acgih.org (American Conference of Governmental Industrial Hygienists). ANSI/IESNA RP-27.1-05 Recommended Practice for Photobiological Safety for Lamps and Lamp Systems, http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2FIESNA+RP-27.1-05
IRISSTD	ISO/IEC 19794-6:2011 Information technology -- Biometric data interchange formats -- Part 6: Iris image data This document revises and replaces the 2005 iris standard.
MINEX	P. Grother et al., Minutiae Interoperability Exchange Test, Evaluation Report: NISTIR 7296 http://www.nist.gov/itl/iad/ig/ominex.cfm
MINEX II	P. Grother, W. Salamon, C. Watson, M. Indovina, and P. Flanagan, MINEX II Performance of Fingerprint Match-on-Card Algorithms Phase II / III / IV Report NIST Interagency Report 7477 (Revision I+II) http://www.nist.gov/itl/iad/ig/minexii.cfm
NFACS	IAFIS-DOC-07054-1.0, Criminal Justice Information Services, Federal Bureau of Investigation, Department of Justice, April 2004.
NFIQ	E. Tabassi and C. Wilson - NISTIR 7151 - Fingerprint Image Quality, NIST Interagency Report, August 2004 http://www.nist.gov/itl/iad/ig/bio_quality.cfm
NFIQ SUMMARY	E. Tabassi and P. Grother - NISTIR 7422 Quality Summarization - Recommendations on Biometric Quality Summarization across the Application Domain

Citation	Document
PERFSCEN	ISO/IEC 19795-2:2007 Information technology -- Biometric performance testing and reporting -- Part 2: Testing methodologies for technology and scenario evaluation http://webstore.ansi.org
PERFSWAP	ISO/IEC 19795-4:2008 Information Technology -- Biometric Performance Testing and Reporting -- Part 4: Interoperability Performance Testing http://webstore.ansi.org
REVFING	Jianjiang Feng, A. K. Jain, A.K. *Fingerprint Reconstruction: From Minutiae to Phase,* IEEE Transactions on Pattern Analysis and Machine Intelligence, Volume: 33 , Issue: 2, pp. 209 – 223. Feb. 2011 R. Cappelli, A. Lumini, D Maio, *Evaluating Minutiae Template Vulnerability to Masquerade Attack* IEEE Workshop on Automatic Identification Advanced Technologies, 7-8 June 2007 pp. 174 - 179
REVIRIS	S. Venugopalan, M. Savvides, *How to Generate Spoofed Irises From an Iris Code Template,* IEEE Transactions on Information Forensics and Security, Volume: 6 , Issue: 2, pp. 385 – 395, June 2011,
REVFACE	A. Adler, *Sample images can be independently restored from face recognition templates*, Proc. Canadian Conference Electronic and Computer Engineering, 1163–1166 (2003)
SBMOC	D. Cooper, H. Dang, P. Lee, W. MacGregor, and K. Mehta. Secure Biometric Match-on-Card Feasibility Report. Technical report, National Institute of Standards and Technology, November 2007. Published as NIST Interagency Report 7452.
SINGFING	See "Personal Identity Verification (PIV): Image Quality Specifications For Single Finger Capture Devices". https://www.fbibiospecs.org/docs/pivspec.pdf
WSBD	Ross J. Micheals, Kevin Mangold, Matt Aronoff, Kayee Kwong, and Karen Mar**shall**, Specification for WS-Biometric Devices (WS-BD), NIST Special Publication 500-288, Version 1, 3/27/2012, http://www.nist.gov/itl/iad/ig/bws.cfm
WSQ31	WSQ Gray-Scale Fingerprint Image Compression Specification, IAFIS-IC-0110(V3), October 4, 2010. https://www.fbibiospecs.org/docs/WSQ_Gray-scale_Specification_Version_3_1.pdf

A Fingerprint minutiae performance testing and certification procedures

A.1 Scope

This clause gives normative specifications for tests used to certify implementations that generate and/or match the mandatory minutia-based biometric elements specified by [FIPS], i.e. the two fingerprint minutiae templates placed on the PIV Card. That is, this clause regulates the test itself, and the testing laboratory, not the products under test, and the data specifications here should not be confused with those given in Clause 3 for fielded PIV implementations.

A.2 PIV authentication

The fingerprint templates conform to [MINUSTD] as profiled in clause 3.3.1. The use cases given in [800-73, Appendix C] detail how the templates and the PIV Card are used for interoperable authentication. Authentication may involve one or both of the PIV Card templates. These will be compared with newly acquired (i.e. live) fingerprint images of either or both of the primary and secondary fingers. The inclusion of the finger position in the [MINUSTD] header allows the system to prompt the user for one or more specific fingers.

Authentication performance is quantified in terms of both the false reject rate (FRR) and the false accept rate (FAR). In PIV, FRR is the proportion of legitimate cardholders incorrectly denied access; the latter would be the proportion of impostors incorrectly allowed access. The error rates depend on a number of factors including: the environment, the number of attempts (i.e. finger placements on the sensor), the sensor itself, the quality of the PIV Card templates' parent images, the number of fingerprints invoked, and the familiarity of users with the process. The use of two fingers in all authentication transactions offers substantially improved performance over single-finger authentication. The intent of the [FIPS] specification of an interoperable biometric is to support cross-vendor and cross-agency authentication of PIV Cards. This plural aspect introduces a source of variation in performance.

A.3 Test overview

This clause specifies procedures for the certification of generators and matchers of [MINUSTD] templates.

Interoperability testing requires exchange of templates between products, which **shall** therefore be tested as a group. Accordingly, the testing laboratory **shall** conduct a first round of testing to establish a primary group of interoperable template generators and matchers. Certification **shall** be determined quantitatively at the conclusion of the test. Thereafter certification requires interoperability with previously certified products.

The certification procedure **shall** be conducted offline. This allows products to be certified using very large biometric data sets, in repeatable, deterministic and therefore auditable evaluations. Offline evaluation is needed to measure performance when template data is exchanged between all pairs of interoperable products. Large populations **shall** be used to quantify the effect of sample variance on performance. A template generator is logically a converter of images to templates. A template matcher logically compares one or two templates with one or two templates to produce a similarity score. Template generators and template matchers **shall** be certified separately. This aspect is instituted because:

1. Template generation is procedurally, algorithmically and physically distinct from matching.
2. Template generation is required by [FIPS], but matching is not.
3. Fingerprint template interoperability is dependent on the quality of the PIV Card templates. The full benefits of an interoperable template will not be realized if a supplier is required to produce both a high performing generator and a high performing matcher.
4. Once a template generator is certified and deployed, its templates will be in circulation. It is necessary for all matchers to be able to process these templates. Subsequent certification rounds will be complicated if generators and matchers are certified together.

Separate certification means that a supplier may submit one or more template generators and zero or more matchers for certification. Zero or more of the submitted products **shall** ultimately be certified.

This test design conforms to the provisions of the currently draft ISO/IEC 19795-4 [PERFSWAP] standard, as profiled by this document. One clause of that standard deals with blind testing. For PIV testing the template matcher **shall** not be able to discern the source of the enrollment templates.

A.3.1 Template generator

A template generator **shall** be certified as a software library. For PIV, a template generator is a library function that **shall** convert an image into a minutiae record. The input image represents a PIV enrollment plain impression. The output template represents a PIV Card template. A supplier's implementation, submitted for certification, **shall** satisfy the requirements of an application programming interface (API) specification to be published by the test organizer. The API specification will require the template generator to accept image data and produce [MINUSTD] templates conformant to Table 19. Where values or practices are not explicitly stated in Table 19, the specifications of clause 4.3 and Table 6 apply (e.g. on minutiae type). The CBEFF header and CBEFF signature **shall** not be included.

The testing laboratory **shall** input images to the generator. The template generator **shall** produce a conformant template regardless of the input. Such a template may contain zero minutiae. This provision transparently and correctly accounts for failures to enroll. In a deployed system, if quality assessment or image analysis algorithms made some determination that the input was unmatchable a failure to enroll might be declared. In an offline test such a determination **shall** result in at least a template containing zero minutiae. However, because in PIV other suppliers' matchers may be capable of handling even poor templates, it is recommended that a template generator submitted for testing should deprecate any internal quality acceptance mechanism, and attempt production of a viable template.

Table 19 – INCITS 378 specification for PIV Card template generator and matcher certification

#	Clause title and/or field name (Numbers in parentheses are [MINUSTD] clause numbers)	PIV Conformance Values Allowed	Informative Remarks
1.	Format Identifier (6.4.1)	0x464D5200	i.e. ASCII "FMR\0"
2.	Version Number (6.4.2)	0x20323000	i.e. ASCII " 20\0".
3.	Record Length (6.4.3)	26 ≤ L ≤ 800	26 byte header, max of 128 minutiae. See row 18.
4.	CBEFF Product Identifier Owner (6.4.4)	0	
5.	CBEFF Product Identifier Type (6.4.4)	0	
6.	Capture Equipment Compliance (6.4.5)	0	
7.	Capture Equipment ID (6.4.6)	0	
8.	Size of Scanned Image in x direction (6.4.7)	MIT	Inherited directly from input data
9.	Size of Scanned Image in y direction (6.4.8)	MIT	
10.	X (horizontal) resolution (6.4.9)	197	
11.	Y (vertical) resolution (6.4.10)	197	
12.	Number of Finger Views (6.4.11)	1	
13.	Reserved Byte (6.4.12)	0	
14.	Finger Position (6.5.1.1)	MIT	Inherited directly from input data
15.	View Number (6.5.1.2)	0	
16.	Impression Type (6.5.1.3)	0 or 2	Inherited directly from input data
17.	Finger Quality (6.5.1.4)	MIT	Inherited directly from input data
18.	Number of Minutiae (6.5.1.5)	0 ≤ M ≤ 128	M minutiae data records follow
19.	Minutiae Type (6.5.2.1)	01b, 10b, or 00b	See Note 1 below Table 6
20.	Minutiae Position (6.5.2.2)	MIT	See Note 7 below Table 6
21.	Minutiae Angle (6.5.2.3)	MIT	See Note 8 below Table 6
22.	Minutiae Quality (6.5.2.4)	MIT	This test specification previously required minutia quality values to be zero. This requirement no longer applies. It did not and does not apply to the PIV operational specification.
23.	Extended Data Block Length (6.6.1.1)	0	No bytes **shall** be included following this field.
END OF TABLE			

Acronym		Meaning
MIT	mandatory at time of instantiation	For PIV Certification, a mandatory value that **shall** be determined at the time the record is instantiated and **shall** follow the practice specified in [FINGSTD]

A.3.2 Template matcher

A template matcher **shall** be certified as a software library. For PIV, a matcher is a software function that compares enrollment templates with authentication templates to produce a similarity score. The similarity score **shall** be an integer or real value quantity. The enrollment templates represent the PIV Card templates. The authentication templates represent those extracted from live authentication fingerprints. A supplier's implementation, submitted for certification, **shall** satisfy the API specification published by the test organizer.

The API specification will support at a minimum the comparison of one authentication template (from an individual's primary or secondary fingers) with one enrollment template (from either the same or another individual's same finger). Both templates **shall** conform to the Table 6 profile of [MINUSTD].

The test **shall** neither prescribe nor prohibit methods whereby fingers' material **shall** be employed in the core comparison. The only constraint is that all invocations of the matching function **shall** yield a similarity score regardless of the input templates. Larger scores **shall** be construed as indicating higher likelihood that the input data originate from the same person. A failure or refusal to compare the inputs **shall** in all cases result in the reporting of a score. This document recommends implementers report a low score in this case.

The input [MINUSTD] enrollment templates **shall** be prepared by the test agent using software from a supplier. The input [MINUSTD] authentication templates **shall** be the output of the template generation software provided by the supplier of the matcher under test.

A.4 Test procedure

The testing laboratory **shall** publish a test specification document. This document **shall** establish deadlines for submission of products for certification.

The supplier of a template generator **shall** submit a request for certification to the testing laboratory. The testing laboratory **shall** provide a set of image samples to these suppliers. The supplier **shall** submit templates from this data to the testing laboratory. The supplier **shall** submit the template generator to the testing laboratory. The testing laboratory **shall** execute it and check that it produces identical templates to those submitted by the supplier. The testing laboratory **shall** apply a conformance assessor to the templates. The testing laboratory **shall** report to the supplier whether identical templates were produced and whether the templates are conformant to the specifications in Table 19. This validation process may be iterative.

The supplier of a template matcher **shall** submit a request for certification to the testing laboratory. The testing laboratory **shall** provide a set of samples to these suppliers. This set **shall** support debugging and **shall** consist of images representative of those collected in PIV registration. The supplier **shall** submit similarity scores from this data to the testing laboratory. The supplier **shall** submit the template matcher to the testing laboratory. The testing laboratory **shall** execute it and check that it produces identical scores to those submitted by the supplier. The testing laboratory **shall** report to the supplier the result of the check. This validation process may be iterative.

The testing laboratory **shall** apply all template generators to the first biometric sample from each member of the test corpus. The testing laboratory **shall** invoke all template matchers to compare the resulting enrollment templates with second authentication templates from each member of the corpus. The authentication template **shall** be generated by the matcher supplier's generator (i.e. not by another supplier's generator). This **shall** be done for all pair wise combinations of template generators and template matchers. The result is a set of genuine similarity scores for each combination.

The testing laboratory **shall** invoke all template matchers to compare enrollment templates with second authentication templates from members of a disjoint population. The authentication template **shall,** in all cases, be generated by the matcher supplier's generator. This **shall** be done for all pair wise combinations of template generators and template matchers. The result is a set of impostor similarity scores for each combination. The order in which genuine and impostor similarity scores are generated **shall** be randomized (i.e. it is not implied by the order of the last two paragraphs).

The testing laboratory **shall** sum the similarity score obtained from matching of the image of a primary finger with that obtained from matching of the image of a secondary finger. This sum-rule fusion represents two-finger authentication.

A.5 Determination of an interoperable group

The testing laboratory **shall** compute the detection error tradeoff characteristic (DET) for all pair wise combinations of the template generators and template matchers. The testing laboratory **shall** generate a rectangular interoperability matrix (see [PERFSWAP]). The matrix has rows corresponding to the generators and columns corresponding to the matchers. Each element of the interoperability matrix **shall** be the false reject rate at a fixed false accept rate. This value corresponds to one operating point on the DET. As described in clause A.3.1, the DET automatically includes the effect of failure to enroll and acquire.

An interoperable group of template generators and matchers **shall** be established as the largest subgroup of products submitted in an initial certification round for which all elements of the interoperability sub-matrix (i.e. FRR values) are less than or equal to 1% at a fixed 1% FAR operating point. The condition that all pair wise product combinations should be below this threshold is instituted because the PIV application is intolerant of non-interoperable pairs.

B Scenario test supporting certification of an iris camera

An iris camera **shall** be certified only if it demonstrates adequate accuracy and speed in the scenario test defined in this Annex. A laboratory **shall** execute a test in formal conformance to the scenario testing requirements in clause 7 of the ISO/IEC 19795-2:2007 *Testing Methodologies for Technology and Scenario Evaluation* standard [PERFSCEN]. The test laboratory **shall** additionally execute the test given the design and reporting constraints given in Table 20 - the specifications define the scenario under test, and restrict the parameters of the test design to ensure production of actionable performance data while mitigating the cost of the test.

The test laboratory **shall** deliver a test report to the requesting Agency. The test report **shall** conform to the reporting requirements of [PERFSCEN] and should report all accuracy and speed data mentioned in clause 6.7.1.2 of this document.

Table 20 – Profile of ISO/IEC 19795-2 for iris camera testing

#	ISO/IEC 19795-2 clause	Test parameter, topic or requirement	PIV specific scenario; test execution practice
1	7.1.2.1	Concept of operations	A test to represent a physical access control scenario for an habituated population
2	7.1.2.2	Comparison functionality	One-to-one verification, after presentation of a PIV Card or equivalent as an identity claim. The test may proceed without reading iris imagery from the token i.e. it may be stored on a server.
3	7.1.2.3	Evaluation environment	Indoors, entrance, vestibule, atrium, or interior office, without augmentation of the environmental lighting
4	7.1.2.4	Test platform	Not specified
5	7.1.3.1	Test subject instruction	The test crew may be instructed on how to use the biometric system.
6	7.1.3.2	Test subject training	The test crew may execute up to ten enrollment and ten verification attempts before starting the test.
7	7.1.3.3	Attended enrolment	The enrolment attempts may be attended The attendant should be distinct from the laboratory staff involved in the test measurements
8	7.1.3.3	Unattended verification	The verification attempts **shall** be unattended
9	7.1.3.4	Guidance	During enrollment, the operator may guide the user on correct preparation and use of the system
10	7.1.3.5	Test order	The test may proceed with several devices being evaluated in parallel.
11	7.1.3.6	Test subject identifiers	The test should include presentation of a PIV card or similar electronic token that identifies the individual
12	7.1.4.1	Enrolment level of effort	Either or both eyes may be enrolled. The maximum number of presentations allowed for enrolment is three. The maximum duration of the entire enrollment transaction is 60 seconds.
13	7.1.4.2	Verification level of effort	Either or both eyes may be verified. The maximum number of presentations allowed for verification is three. The maximum duration of the biometric part of the entire verification transaction is 12 seconds. This may include presentation of the identity token.
14	7.1.4.3	Reference adaptation	The enrolment data **shall** not be augmented or updated during verification attempts.
15	7.1.4.5	Native configuration	The camera and ancillary software **shall** be pre-configured by the manufacturer prior to the start of the test. The test laboratory **shall** not further customize or reconfigure any component.
16	7.1.5	Multiple transactions	A test subject **shall** execute three attempts to verify as himself. This constitutes a transaction.
17	7.1.5	Multiple visits	A test subject **shall** visit on two separate days. The enrollment and genuine verification transactions **shall** not be conducted on the same day.
18	7.1.6	Executing genuine trials	A test subject **shall** execute two or more genuine transactions.
19	7.1.6	Executing impostor trials	A test subject **shall** execute at least three impostor transactions against different identities by presentation of another individual's identity token. The test subject **shall** not be aware of whether she is making a genuine or impostor presentation.
20	7.1.7	Image and subject identity collection	The test laboratory **shall** retain all collected images. The camera or its ancillary software **shall** export one image per enrollment per eye in ISO/IEC 19794-6:2011 format.
21	7.2.2	Test crew habituation	The test crew should be habituated or pre-trained to mimic habituation. The test crew may

			have prior use of the iris camera and system
22	7.2.3	Test crew composition	The test crew **shall** be comprised of at least 250 individuals who appear on two or more occasions. The test crew **shall** include at least 40% males. The test crew **shall** include at least 40% subjects with age above 40.
23	7.2.4	Test subject management	Each subject **shall** be assigned an identity token.
24	7.3.1	Performance	Specification appear in clause 6.7.1.2
25	7.3.2	Enrolment performance	Failure to enroll rate **shall** be calculated as the fraction of persons for which at least one eye cannot be enrolled
26	7.3.3	Failure-to-acquire performance	Failure to acquire events, if detected, **shall** be counted and reported.
27	7.3.4	Verification performance	False rejection rates **shall** be computed as the fraction of genuine subject-transactions that result in verification failure. If false acceptance occurs, testing should be stopped.
28	7.3.5	Identification metrics	None
29	7.3.6	Generalized error rates including failure to acquire	Failure to acquire events encountered during genuine subject transactions **shall** be combined with false rejects to produce an effective or generalized false rejection rate.
30	7.3.7	Interim analyses	A test may be terminated early if the observed measurements support, at a statistically supported 99% confidence level, the hypothesis that the PIV requirements on FRR and capture time are violated.

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