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Guidance for biometric enrolment

Directives pour l'inscription biométrique

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, Subcommitee SC 37, *Biometrics*.

Introduction

One of the most important contributions to a successful biometric-based recognition system is a consistent enrolment service that generates the biometric data required for subsequent recognition of individuals. Subsequent verifications or identifications will be compared with the biometric data collected at enrolment. If the quality of capture at enrolment is not maintained consistently, the operators of a recognition system which depends on a good enrolment are likely to experience unreliable performance. For those who are enrolled in a verification system, a poor quality enrolment will result in inconvenience should they fail to be recognized. (Readers of this report should note that quality has a specific meaning when applied to biometric systems; a high quality capture is one that results in biometric data that provides good match scores when compared with other high quality images from the same biometric feature.)

By analysing the requirements for a good enrolment from the perspectives of a range of stakeholders, it is possible to derive a set of principles to guide the development of a biometric enrolment policy and the deployment of a service. Where enrolment is outsourced to a third party, it is extremely important to be able to measure quality metrics rather than quantity metrics, since the technical and business objectives of the two organisations (the Relying Party and the Enrolment Authority as defined in this document) may, in general, not be aligned.

Although the recommendations and guidelines in this report are directed in the main at the parties responsible for the enrolment itself and for management of the enrolment service (noting that these two entities may be one and the same), they will also be of value to the designers and developers of enrolment systems.

Guidance for biometric enrolment

1 Scope

This report consolidates information relating to successful, secure and usable implementation of biometric enrolment processes, while indicating areas of uncertainty that organisations proposing to use biometric technologies will need to address during procurement, design, deployment and operation. Much of the information is generic to many types of application e.g. from national scale commercial and government applications, through to closed user group systems for in-house operations, and to consumer applications where convenience rather than security is the primary driver for adoption of biometric technologies.

The report points out the differences in operation relating to specific types of application, e.g. where self-enrolment is more appropriate than attended operation. This report will focus in the main on fixed location enrolments at a number of sites in an organization, where there is an attendant who supports the biometric applicant in effecting a successful enrolment, and where enrolment is a mandatory requirement. In summary, this report consolidates information relating to better practice implementation of biometric enrolment capability in various business contexts including considerations of legislation, policy, process, function (system) and technology.

The report provides guidance as to the collection and storage of biometric enrolment data and the impact on dependent processes of verification and identification. This report will not aim to include material specific to forensic and law enforcement applications.

The recommendations contained in the report are not mandatory.

2 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 2382-37 and the following apply.

2.1
biometric applicant
individual seeking to be enrolled in a biometric enrolment database

2.2
designers and developers
organization or individuals responsible for the design, development, (and deployment, if applicable) of the enrolment system

2.3
duty officer
individual acting on behalf of either the enrolment authority or operator either present in the vicinity of one or more enrolment stations, or available on line or by telephone, trained to provide advice and guidance to an enrolment officer in case of difficulty

Note 1 to entry: The duty officer may also have a role in determining exception handling routines.

2.4
enrolment authority
organisation (or other entity) with legal and contractual responsibilities for the completion of enrolment processes

2.5
enrolment officer
agent of the operator responsible for the secure and effective enrolment service at one or more enrolment points

2.6
identity provider
entity storing and managing the biometric data obtained directly or indirectly from the biometric enrolment

2.7
operator
organization (or other entity) responsible for delivering the enrolment service on behalf of the enrolment authority

2.8
performance manager
person responsible for managing the enrolment service to ensure it meets its specified enrolment performance criteria

Note 1 to entry: This will typically include actions such as monitoring enrolment performance (quality as well as quantity metrics), applying corrective measures where necessary and reporting enrolment performance achievement to the enrolment authority.

2.9
personal assistant
individual accompanying the biometric applicant at the enrolment session for one or more purposes

Note 1 to entry: Such purposes might include: translation of instructions from the enrolment officer into the native language of the applicant; support for a disabled applicant to enable the applicant to undertake an enrolment successfully; to fulfil a legal requirement such as a parent present at the enrolment of a child.

2.10
relying party
entity operating a biometrically-enabled application for which the enrolment process provides biometric references

2.11
specialist support staff
trained attendant(s) present at the enrolment session on behalf of the enrolment authority or operator to assist with the enrolment of applicants with disabilities, or to fulfil service or legal requirements in respect of gender, religious observance, or age of the applicant

2.12
vendor
entity providing hardware and/or software biometric functionality

3 Abbreviated terms

KPI Key Performance Indicator. A metric quantifying one or more aspects of the successful operation of a process

NFIQ NIST Fingerprint Image Quality

SLA Service Level Agreement. An agreement between a service provider and a customer defining a target level of service, mutual responsibilities of service provider and customer, together with other requirements for the delivery of a service

4 Role of Enrolment in a Biometric System

Given the variety of applications and technologies, it might seem difficult to draw any generalizations about biometric systems. All such systems, however, have many elements in common. Captured biometric samples are acquired from a subject by a sensor. The sensor output is sent to a processor that extracts the distinctive but repeatable measures of the sample (the biometric features), discarding all other components. The resulting features can be stored in the biometric enrolment database as a biometric reference or (in this case) a biometric template. In other cases the sample itself (without feature extraction) may be stored as the reference. A subsequent probe biometric sample can be compared to a specific reference, to many references or to all references already in the database to determine if there is a match. A decision regarding the biometric claim is made based upon the similarities or dissimilarities between the features of the biometric probe and those of the reference or references compared.

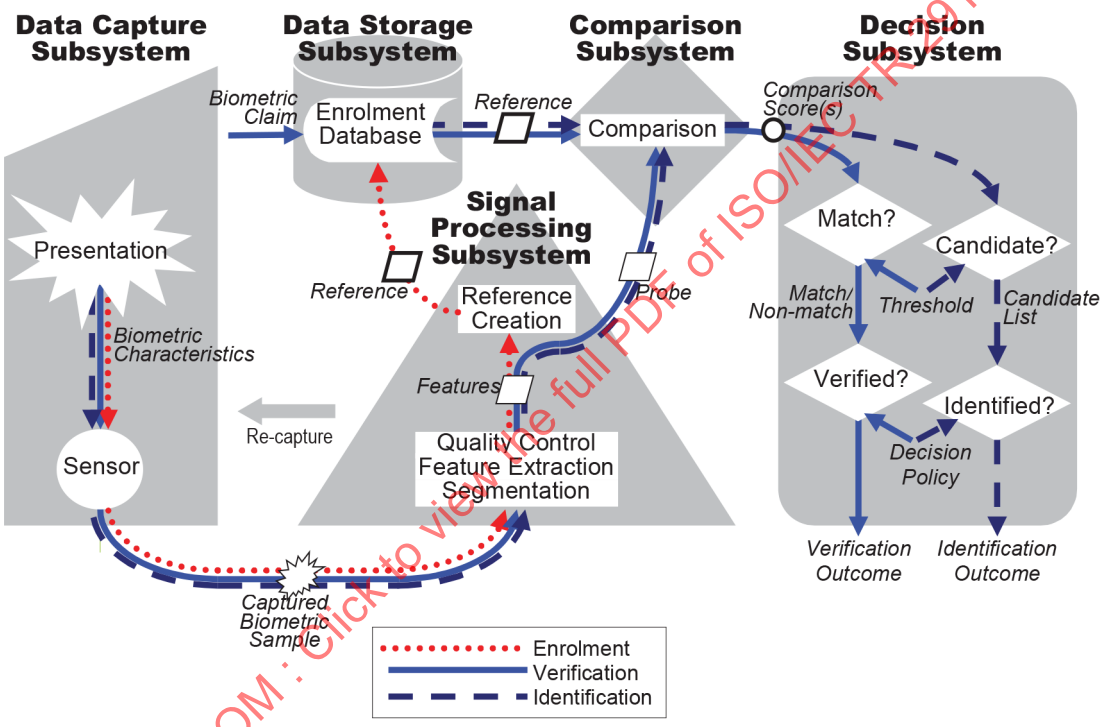

Figure 1 — Components of general biometric system

Figure 1 (which is functional in nature and has no implications for physical location) illustrates the information flow within a general biometric system, showing a general biometric system consisting of data capture, signal processing, data storage, comparison and decision subsystems. This diagram illustrates both enrolment, and the operation of verification and identification systems. The following subclauses describe each of these subsystems in more detail. However, it should be noted that in any implemented system, some of these conceptual components may be absent, or may not have a direct correspondence with a physical or software entity.

The data capture subsystem collects an image or signal of a subject's *biometric characteristics* that they have presented to the *biometric sensor*, and outputs this image/signal as a *captured biometric sample*.

The transmission subsystem (not portrayed in the diagram and not always present or visibly present in a biometric system) will transmit *samples, features, probes* and *references* between different subsystems. The captured biometric sample may be compressed and/or encrypted before transmission, and expanded and/or decrypted before use. A captured biometric sample may be altered in transmission due to noise in the transmission channel as well as losses in the compression/expansion process. Data may be transmitted using standard biometric data interchange formats, and cryptographic techniques

may be used to protect the authenticity, integrity, and confidentiality of stored and transmitted biometric data.

Signal processing may include processes such as:

— *enhancement*, i.e. improving the quality and clarity of the captured biometric sample,

— *segmentation*, i.e. locating the signal of the subject's biometric characteristics within the captured biometric sample,

— *feature extraction,* i.e. deriving the subject's repeatable and distinctive measures from the captured biometric sample, and

— *quality control,* i.e. assessing the suitability of samples, features, references, etc. and possibly affecting other processes, such as returning control to the data capture subsystem to collect further *samples*; or modifying parameters for segmentation, feature extraction, or comparison.

In the case of enrolment, the signal processing subsystem creates a biometric reference. Sometimes the enrolment process requires features from several presentations of the individual's biometric characteristics. Sometimes the reference comprises just the features, in which case the reference may be called a "template". Sometimes the reference comprises just the sample, in which case feature extraction from the reference occurs immediately before comparison.

In the case of verification and identification, the signal processing subsystem creates a biometric probe.

Sequencing and iteration of the above-mentioned processes are determined by the specifics of each system.

References are stored within an *enrolment database* held in the data storage subsystem. Each reference might be associated with some details of the enrolled subject or the enrolment process. It should be noted that prior to being stored in the *enrolment database*, *references* may be reformatted into a biometric data interchange format. *References* may be stored within a biometric capture device, on a portable medium such as a smart card, locally such as on a personal computer or local server, or in a central database.

In the comparison subsystem, *probes* are compared against one or more *references* and *comparison scores* are passed to the decision subsystem. The *comparison scores* indicate the similarities or dissimilarities between the *features* and *reference/s* compared. In some cases, the *features* may take the same form as the stored *reference*. For verification, a single specific claim of subject enrolment would lead to a single *comparison score*. For identification, many or all *references* may be compared with the *features*, and output a *comparison score* for each comparison.

The decision subsystem uses the *comparison scores* generated from one or more attempts to provide the decision *outcome* for a verification or identification transaction.

In the case of verification, the *features* are considered to *match* a compared *reference* when (assuming that higher scores correspond to greater similarity) the *comparison score* exceeds a specified *threshold*. A biometric claim can then be verified on the basis of the *decision policy*, which may allow or require multiple attempts.

In the case of identification, the enrolee reference is a potential *candidate* for the subject when (assuming that higher scores correspond to greater similarity) the *comparison score* exceeds a specified *threshold*, and/or when the *comparison score* is among the highest ranked values generated during comparisons across the entire database. The *decision policy* may allow or require multiple attempts before making an identification decision.

NOTE Conceptually, it is possible to treat multibiometric systems in the same manner as unibiometric systems, by treating the combined captured biometric *samples/references/scores* as if they were a single *sample/reference/score* and allowing the decision subsystem to operate score fusion or decision fusion as and if appropriate. (See also ISO/IEC/TR 24722:2007.)

The administration subsystem (not portrayed in the diagram) governs the overall policy, implementation and usage of the biometric system, in accordance with the relevant legal, jurisdictional and societal constraints and requirements. Illustrative examples include

— providing feedback to the subject during and/or after data capture,

— requesting additional information from the subject,

— storing and formatting of the biometric *references* and/or biometric interchange data,

— providing final arbitration on output from decision and/or scores,

— setting *threshold* values,

— setting biometric system acquisition settings,

— controlling the operational environment and non-biometric data storage,

— providing appropriate safeguards for subject privacy, and

— interacting with the application that utilizes the biometric system.

The biometric system may or may not interface to an external application or system via an Application Programming Interface, a Hardware Interface or a Protocol Interface.

In enrolment, a transaction by a Biometric Capture Subject is processed by the system in order to generate and store an enrolment reference for that individual.

Enrolment typically involves

— sample acquisition,

— sample restoration or enhancement,

— segmentation,

— feature extraction,

— quality checks (which may reject the sample/features as being unsuitable for creating a reference, and require acquisition of further samples),

— reference creation (which may require features from multiple samples), possible conversion into a biometric data interchange format,

— storage,

— test verification or identification attempts to ensure that the resulting enrolment is usable, and

— allowing repeat enrolment attempts, should the initial enrolment be deemed unsatisfactory (dependent on the enrolment policy).

A Biometric Capture Subject can also be required to present additional data specific to the enrolment. This additional data might be a legal name, contact information, credentials, identity documents and the like, although there are some biometric applications that may require no additional data whatsoever to be collected at the time of enrolment beyond the biological and behavioural characteristics.

5 Stakeholders and approaches for enrolment

5.1 Enrolment Stakeholders

The successful operation of a biometric enrolment service depends on the co-operation of a large number of stakeholders as listed in Table 1. (See also Figure 2 below showing that Enrolment Officers

work on behalf of the Operator, which has a relationship with the Enrolment Authority; Personal Assistants support the Biometric Capture Subject of the enrolment).Note that systems may be far simpler than illustrated, for example, the Enrolment Authority may also be the Operator of the service, as well as being the Relying Party in an enterprise access control system.

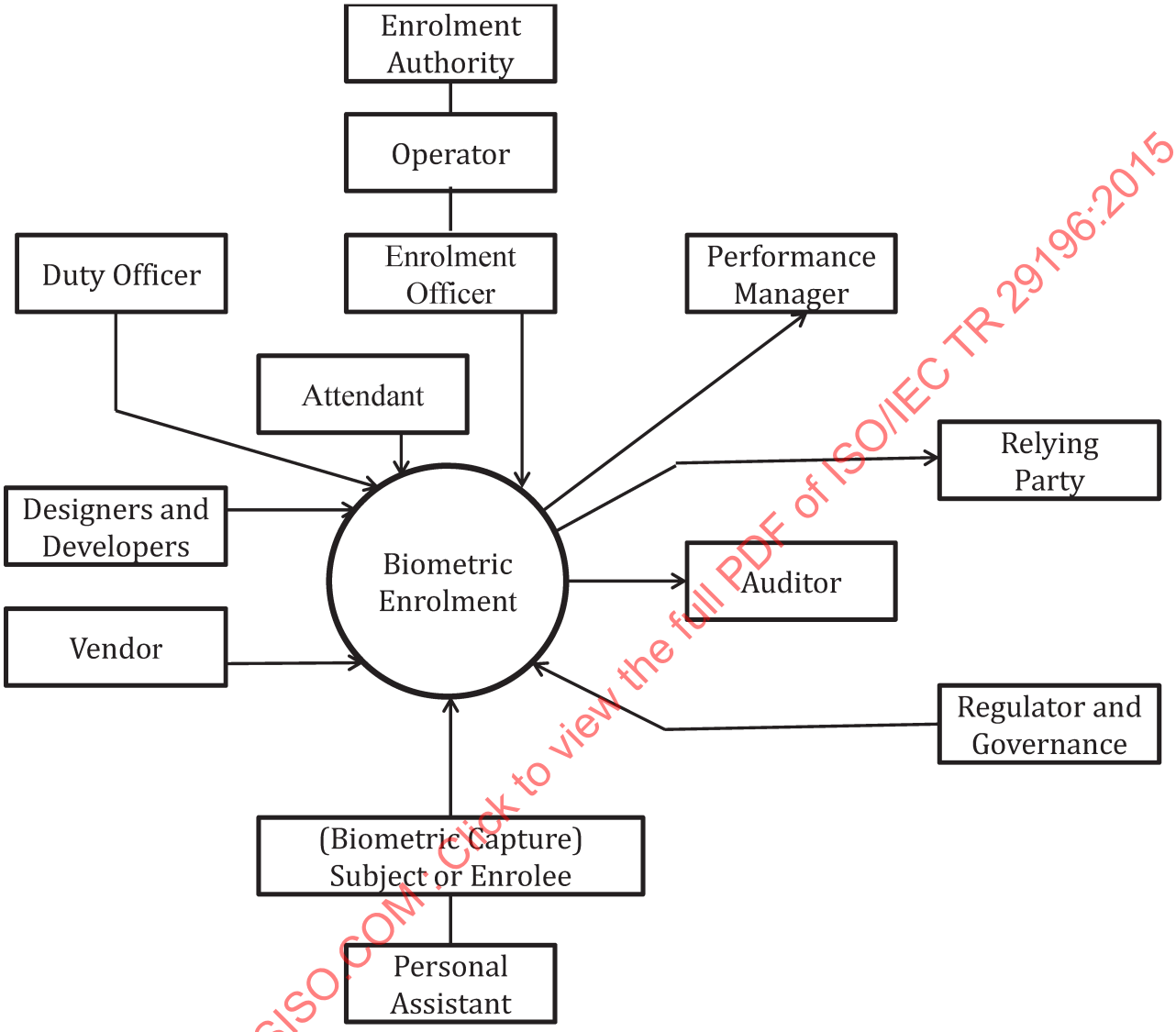

Figure 2 — Stakeholders at Enrolment

Table 1 — Functional Description of Stakeholder roles

Stakeholder	Function description
Enrolment Authority	Responsibility for ensuring the quality of biometric enrolment samples and other KPIs are in accordance with SLA agreements or contractual requirements. Instigating appropriate action if these fall outside the agreed targets. Ensuring compliance with legal requirements. Ensuring that the cultural implications of operating an enrolment service are taken into consideration.

Table 1 *(continued)*

Operator	Organization delivering enrolment service on a day-to-day basis. Responsible to the Enrolment Authority for quality and security of the enrolment service. Taking remedial measures if KPIs, including quality and performance metrics, fall outside the agreed targets.
Performance Manager	Monitoring the performance of the enrolment service. Proposing corrective actions. Reporting back on the results of corrective actions.
Enrolment Officer	Agent of the Operator responsible for the secure and effective enrolment service at one or more enrolment points. Ensures the day-to-day maintenance of equipment used in enrolment. Interfaces with the subjects/Applicants and provides any relevant information to them. Enters any biographical/contextual data (although some of these details may already be pre-populated). Ensures that the quality of the enrolment feature collected by the sensor/camera meets the enrolment standards (usually through requesting the subject to re-enrol if the standard is not achieved). Providing advice and support to the subject to achieve a high standard of enrolment. Notes any exceptional circumstances.
Duty Officer	Provide technical and/or operational advice and guidance to an Enrolment Officer.
Attendant	Assist the Enrolment Officer in obtaining the best available quality biometric sample through following procedures set for subjects with accessibility needs or who have special requirements (in respect of age, gender, religious observance, etc).
The Biometric Capture Subject / Biometric Enrollee, hereafter termed subject and Enrollee respectively	Provide biometric sample to the system.
Personal Assistant	Provide support for the Applicant/Enrollee, e.g. translation of instructions from the Enrolment Officer, support for a disabled Applicant or to fulfil a legal requirement such as a parent present at the enrolment of a child.
Designers and Developers	Designing the enrolment system as part of the enrolment service using systems engineering principles wherever possible. Developing enrolment system, service and process. Specifically developing an interaction protocol for enrolee. Specifically, developing the service for production and distribution of any token used as storage for biometric reference(s), or a pointer to where biometric reference(s) is/are stored.

Table 1 *(continued)*

Vendor	Providing hardware and software. Providing (either directly or through an agent) technical support e.g. for upgrades or rectification of faults, if under contract to do so.
Regulators and other Governance Bodies	Assuring the enrolment process is operated according to laws, regulations, codes of practice, contracts, etc.
Auditor	Audit enrolment protocol.
Identity Provider	Processing the biometric features into references, performing any quality and de-duplication checks and storing references and images.
Relying Party	Using the biometric data obtained from the enrolment service in a biometric recognition service as part of a business-oriented application.

5.2 Enrolment Approaches

Enrolment for biometric services can take the form of many differing approaches depending upon context, complexity, requirements of the Relying Party, etc.

— In-house or outsourced.

— Multiple or single location.

— Fixed, mobile or remote.

— Attended, semi-attended (one enrolment officer overseeing a number of enrolments in parallel) or unattended (e.g. self-enrolment[1)]).

— Mandatory, optional (opt-in), or unaware (e.g. for surveillance/tracking).

— Using a single modality or multiple biometric modalities.

— Designed to provide enrolments for either multiple applications or for a specific application. Enrolment is an expensive part of a biometric service thus in order to reduce costs enrolment may at times be undertaken for multiple Relying Parties, each with differing business, technical and functional requirements. For example the enrolled facial image for a passport may be re-used for a driving licence application. Other enrolment processes may be required to be more specific in design – e.g. access control 'Offline' or 'batch' enrolment where the biometric sample capture process is separate from the enrolment stage, or an integrated credential proofing/acquisition/enrolment process.

— Duration/complexity of the enrolment process, from a simple single modality process (against pre-assigned identity), to a complex process consisting of checks on identity using breeder documents, followed by collection of features relating to multiple modalities and a verification check on the effective operation of the collected features.

Based upon how the system is influenced by the above factors, there will be different requirements and operational guidance.

1) Self-enrolment may be with the active participation of the subject, or can even be acquired with stand-off systems not requiring direct interaction with the subject.

6 Key Stakeholder perspectives

6.1 Summary of key observations

A reproducible biometric enrolment process is a prerequisite for the successful use of biometric recognition in one or more applications at a subsequent time. A poor quality enrolment, e.g. one in which the Biometric Applicant's biometric features have not been collected in line with best practice, will present difficulties when the reference derived from these features is compared with biometric data collected in the context of the application. (Biometric Applicant is termed Applicant hereafter.) For instance, if a thumb is presented and registered in an enrolment for access control and the Biometric Capture Subject (hereafter termed subject) uses one of the index fingers as instructed by a biometric verification unit at a door, the biometric comparison will fail. The subject will therefore be inconvenienced, in having to use an exception-handling process provided by the Operator of the access control system.

Such problems are likely to occur more often when the Enrolment Authority (and/or operator) for the enrolment service is not the same as that managing the subsequent application that uses biometric recognition (the Relying Party). In this case, the Enrolment Authority bears the costs of ensuring that the quality of enrolments is maintained while the benefits of good quality enrolments accrue to the Relying Party (or Parties). Rather than setting this cost/benefit pivot at the interface between the two organizations, a better strategy is to move it to the enrolment service, incentivizing the Enrolment Authority to deliver high quality enrolments. This will usually entail clear and correct specification of metrics for the enrolment performance in any contracts or agreements between these two organizations.

In setting the requirements for an enrolment service, the Enrolment Authority should take account of the requirements of the Relying Party as well as other stakeholders as listed in Table 1 and represented schematically in 5.1. (When these requirements are not known in full, e.g. because the recognition system of the Relying Party is still under development, designers of enrolment services should take appropriate measures to mitigate any risks.) The SLA between the Enrolment Authority and the Operator of the enrolment service should include KPIs that relate to the business objectives of the Enrolment Authority as well as those of the Relying Party. Requirements should include quantitative performance measures capable of being tested either by the Enrolment Authority or by an independent testing organization during the acceptance phase of the project, as well as periodically afterwards.

The designers and developers of the enrolment system will use the requirements to source suitable vendors of the biometric components, such as the hardware to collect biometric features, software to process these features and assess their quality, and - if required - verification software to check that the enrolment has been completed satisfactorily.

The security of the biometric enrolment process is also an essential aspect of its success. In preparing for a robust process design, all stakeholders are responsible for addressing security requirements, from the design of the logical technical architecture to the functional components, as well as procedures and checks that directly involve interaction with the Applicant and the Subject.

The Enrolment Authority's designers and developers need to address these requirements, as early as possible in the design, such as the ability to check the identity credentials presented by the Applicant and taking measures to counter spoofing attacks. Note that catering to the needs of Applicants with language difficulties and disabilities will also feature in the design but may impact on the security procedures. These aspects of the enrolment process – and any requirements placed by regulators – should be developed into training materials for Enrolment Officers, attendants, duty officers and the Performance Manager.

After completion of the high level design, and prior to deployment, marketing and other awareness-raising activities should be started, so that representatives of the Applicant population, mass media, regulators and special interest groups have time to comment on the proposals for the enrolment service and for changes in the details of the design of the system to be incorporated.

The enrolment service should be piloted with a representative sample of the user population, both of Applicants as well as Enrolment Officers. The Performance Manager should ensure that acceptance testing has been carried out and that the provisions of the SLA with the designers and developers have been met. Comments and observations collected from the users should be examined. If changes are made to the system or procedures in the light of these tests and comments, a further round of testing may be required.

At some time after the system is deployed, representatives of the Relying Party and the Enrolment Authority should review the performance of the enrolment service, assessing whether the KPIs continue to reflect the requirements of the Relying Party, and making any necessary adjustments.

A system audit may be requested periodically to ensure that the enrolment service operates in line with legal and business rules. Guidelines for the audit process should take account of the particular characteristics of biometric systems.

6.2 Meeting the requirements of Stakeholders

There are numerous stakeholders in any biometric enrolment application, most of whom will benefit from a high quality, securely administered enrolment process with due regard for the needs and expectations of the Applicants of the enrolment.

For each stakeholder described in 5.1, Table 1, there are specific reasons why the enrolment service should be successful. This section describes some of the benefits for these stakeholders.

A strategy for the design, development and deployment of a successful biometric enrolment should take account of numerous issues in a structured manner. The approach favoured in this report is to itemise these issues against the principal stakeholders who are impacted by each issue. One way of examining the benefits to a stakeholder is to consider the operation of the enrolment service from a number of standpoints. Stakeholders will have different perspectives and not every stand point will be relevant to every stakeholder:

— Appropriateness, Effectiveness and Efficiency;

— Convenience and Price;

— Look and Feel;

— Usability, Personalisation / Internationalization;

— Performance (Speed, Accuracy, etc);

— Operational and Environmental;

— Maintainability and Support;

— Security, Privacy and Transparency;

— Cultural and Political;

— Legal.

6.2.1 Supporting the interests of the Subject

The enrolment subject should be presented with a clear and understandable enrolment process that allows the subject to feel safe and alleviate any concerns.

The enrolment process should flow well and be able to handle any possible exceptions. Prior identification of exceptional conditions (e.g. support for disabled persons) can be flagged in the application process to allow for adjustments to be made in advance of enrolment.

It is important to ensure that the enrolment process be safe and provide a positive experience for the subject in order to enhance acceptance of the system.

The enrolment subject should have easy access to information about the accessibility, privacy, usability and other consumer-relevant issues associated with the enrolment process and the biometric system preferably in advance of attending the enrolment session.

A strategy for the design, development and deployment of a successful biometric enrolment should take account of numerous issues in a structured manner. The approach favoured in this report is to itemise these issues against the principal stakeholders who are impacted by each issue.

This section offers a discussion of those issues which affect the enrolment process from the perspective of the Applicant (or subject) addressing the principal objectives listed above and other lesser ones.

On the matter of issues relating to personal privacy, data protection, health and safety and accessibility, the user of this report is referred to ISO/IEC 24714-1:2008.

6.2.2 Information provided to the Applicant

When considering the information to be provided to an applicant, several important considerations need to be acknowledged. In particular, applicants:

— should be notified about policies including, but not limited to, privacy, personal data protection and accessibility;

— should be notified about technical aspects including, but not limited to, security and data encryption;

— should fully understand and consent to any non-repudiation ramifications to subject enroled in the system;

— may expect to be notified about a contact point for further information;

— where required, should be informed that they will need to produce documents that can be authenticated with the Issuing Authority to satisfy the Enrolment Officer of their claimed identify.

NOTE On occasion the Applicant may be unaware of the fact that a biometric enrolment is taking place, e.g. when submitting a photograph for a passport application. Advice should be sought as to whether a legal notice is required, or whether it would be prudent to provide more information to the Applicant.

Information about the enrolment should be provided in a way that is accessible and comprehensible to the Applicants. It may be useful to include the possibility of an FAQ, including information regarding the purpose of enrolment and the organization's privacy policy. Information of various types will be of relevance at different stages of the enrolment: before the enrolment, during the process and afterwards. It may need to be changed as experience is gained so as to ensure that enrolments are an ongoing success.

At enrolment, there may be a need to provide specific information that help Applicants enrol in the system most effectively (e.g. whether they should stand or sit in a particular way, and whether there will be wipes or tissues to clean surfaces and improve the quality of images).

Applicants should be given the opportunity to supply information that may impact on the quality of enrolment, some of which they may regard as personal or confidential. Recording of such information - and the measures taken during enrolment as a result of this information - should be undertaken in a secure manner.

6.2.3 Legal implications of the enrolment service

Any specific local provision relating to documentation in support of proof of identity and authentication thereof, privacy, the protection of personal data, accessibility, security, etc should be identified and incorporated during the requirements capture phase of the enrolment system lifecycle. The safeguarding of enrolment data provided by the applicant in the enrolment system lifecycle is important, particularly if enrolment data are to be shared between organisations.

Therefore, requirements relating to access, use, disclosure and disposal of enrolment data should be carefully considered. Different parties, such as commercial and government, may consider legal implications differently and at times have conflicting requirements for addressing them. Governance procedures may need to be implemented that may in turn place specific requirements on audit logs.

Implications of enrolment also need to be covered, e.g. if there are any non-repudiation ramifications to Applicants enrolled in the system, these may need to be fully explained, understood and consented to by biometric enrolees (hereafter termed enrolees).

6.2.4 Issues related to inclusivity

In order to obtain optimal quality biometric data during the enrolment phase, it is particularly important to ensure that inclusivity issues are addressed. In many cases, it will be more effective to devote additional resources and time at Enrolment with specialized equipment, staff and training for the Applicant. Also to avoid difficulties for the subject in attending and completing an enrolment, information should be provided regarding any accessibility conditions which might result in poor quality outcomes.

Provision will need to be made for personal assistants (and assistant animals) accompanying the Applicant to the enrolment facility.

Note that the enrolment process may reveal hitherto unrecognized conditions that may require sensitive handling by the attendants.

6.2.5 Usability

Enrolment systems should be designed for usability. ISO 9241-11:1998 and ISO 9241-210:2010 define usability as “the effectiveness, efficiency, and satisfaction with which the intended users can achieve their tasks in the intended context of product use.”

A guide to methods of assessing the usability of biometric systems is available that covers effectiveness, efficiency and user satisfaction. (See Bibilography.)

6.2.6 Usability aspects — Effectiveness

In general, the enrolment system should attempt to obtain a biometric reference of the best quality for the target application, consistent with constraints of time allowed for enrolment, costs of arranging the enrolment and availability of equipment and attendants.

Quality is one of the aspects of effectiveness. This term does not necessarily relate to an aesthetically pleasing captured image. For example, if the system is required to ensure that a person is enrolled only once, a high quality capture is one that enables the matching system to other entries on the database to be carried out with the maximum confidence in identifying correct matches. Quality has many additional dimensions such as consistency of presentation, sufficient distinguishing elements in the image, etc.

6.2.7 Usability aspects — Efficiency

The process of enrolment should be carried out in ways that enable the Applicants to perform the task quickly and with as few errors as possible.

6.2.8 Usability aspects — Satisfaction with the enrolment process

This dimension relates to user attitudes, perceptions, feelings and opinions regarding the system, and includes aspects such as

— whether the Applicants are intimidated in any way by the equipment or process;

— the quality of the information and support to Applicants; and

— the extent to which the user interface is designed to avoid user discomfort and frustration;

— the presence of an attendant or not (if the enrolment is manual), noting that the demeanour and helpfulness of the attendant is important.

Questionnaires, focus groups, etc. can be used to measure satisfaction levels, with the aim of maintaining and improving the user experience.

6.2.9 Supporting the interests of the Enrolment Authority

For the Enrolment Authority, its principal objective is ensuring the collection of a representation of the biometric features of a qualified individual to fulfil the requirements of the Relying Party's application using biometrics. In helping to achieve its objective, the authority should develop an enrolment policy.

Note that the Enrolment Authority that enrols the Applicant and the Relying Party that operates the biometric-enabled application may be different organizations. The Enrolment Authority can have legal duties and obligations (e.g. in relation to provision for people with accessibility needs) of which it will need to make the Operator aware, and ensure that the Operator is in compliance. For example, the Enrolment Authority could define the specific duties of the attendant and special assistant and their role in obtaining a good enrolment as part of an inclusive design. Considerations for the Enrolment Authority include:

a) Collection of the biometric samples that give (after further processing by an Identity Provider responsible for storage and matching of the samples) the best possible set (under the circumstances) of biometric references for subsequent verification and identification processes. Such processes may include checks for duplicate enrolments.

b) The establishment and monitoring of the characteristics of success for the end-to-end system.

c) An enrolment process should reduce the cost of the end-to-end system (which covers enrolment, database, and the application operated by the Relying Party), especially for large scale systems, since enrolment costs are likely to be a significant component for such deployments.

6.2.10 Establishing the legal framework for enrolment

The Enrolment Authority should, at an early stage of system design, establish the legal and cultural implications, which include privacy and data protection, compliance with codes of conduct, local laws and by-laws, etc. Laws and regulations relating to these aspects may be both national and regional.

Where appropriate, if the Enrolment Authority cannot be satisfied as to the claimed identity of the applicant then services made available on the basis of enrolment may be withheld or otherwise constrained.

The Enrolment Authority should determine what auditing functions are required. Relevant terms of reference will need to be developed, together with frequency of audit and relationship to other governance activities.

Implications of enrolment also need to be covered, e.g. if there are any non-repudiation ramifications to people enrolled in the system, these need to be legally justified and enforceable, and processes developed to ensure that they are fully explained, understood and consented to by enrolees.

Also there may be legal issues surrounding certain classes of enrolee, including gender, ethnicity, age, disability, culture and religion, legal competence etc.

In many jurisdictions, procurements officials and operators need to be aware of laws and regulations relating to inclusivity; capture of the relevant requirements at an early stage in the process is likely to lead to cost-effective solutions.

The Enrolment Authority (with the help of the auditors) should keep the legal framework under periodic review, since as experience with deployment and operation of biometric applications grows, it is likely that new laws, regulations, and codes of practice will be introduced (or existing ones redrafted) and judicial decisions may affect the operation of services.

6.2.11 Independent review of the operation of the Service

The Enrolment Authority may request an independent review of the delivery and operation of the enrolment service, both of its security and the biometric performance - either with a test group of enrolees before the start of the operation of the service, or during its operation using a representative sample of Applicants. Assessment, testing and reporting the results of such tests for a biometric enrolment service requires specialized knowledge and experience. Only those organisations that can demonstrate their credentials in these areas ought to be considered. Testing should be undertaken against relevant national and ISO standards (such as those in the series of standards in the various parts of ISO/IEC 19795).

6.2.12 Metrics of a successful biometric enrolment

Enrolment is normally a prerequisite to operational use of a biometric system. The quality of enrolments will affect the performance and usability of the operational system. The applicant experience at enrolment is likely to affect an applicant's perception of the operational system and of the organization operating the system, which may also have a knock-on effect on the performance of the operational system.

The enrolment process/service will cost money, time and possibly other resources. Measures to improve enrolment quality or applicant experience will probably have a cost/time implication for the enrolment service. Therefore there will be a need to establish an optimum balance between the cost of the enrolment service and the performance and usability of the operational system.

In order to improve the quality of enrolment, it is vital to have access to data which can be used to monitor the various components of the service, both to ensure that the service is operating to initially developed performance levels, as well as helping to improve the service through addressing the most significant elements of the cost/benefit trade-off. This requires that the design of the biometric enrolment service allows for the right metrics to be collected (and analysed regularly at various levels of granularity).

The performance parameters divide into two broad categories:

a) Parameters that relate to the performance of the enrolment service, e.g. failures to enrol, invalid enrolments, denied enrolments. These are the enrolment failure parameters.

b) Parameters that affect the performance of the Relying Party's operational system using the enrolments from the enrolment service, e.g. FMR, FNMR. FTA. These are (largely) the enrolment quality-dependent parameters.

The two categories are distinct but interrelated and can be in conflict, e.g. a reduction in the FTE rate might lead to an increase in the FNMR. The possibility of conflict may create tension between the enrolment service and the operations of the Relying Party (or Parties) which is likely to be amplified in cases where these are provided by different organisations.

This section of the report provides a framework for a more detailed analysis of poor quality enrolments. A classification of failure modes enrolment is suggested in 6.2.13 based upon the definitions in ISO/IEC 2382-37 provides definitions which relate to the enrolment process. Examples of common causes of enrolment failure are examined against this classification in 6.2.14.

In order to provide the data for such analysis, a requirements capture exercise needs to be undertaken before the design of the Enrolment service which will include the following (some of which need data collated from Relying Parties under an SLA):

— Performance statistics from the Relying Party operating a service that is dependent on a successful enrolment of Applicants, with a breakdown to help identify the impact of any variations in quality of the enrolment service

— User satisfaction statistics, for example, extracted from analysis of questionnaires, numbers of complaints from enrolees or assessment from media reports. Identity proofing failure rates with a breakdown into rates where the Enrolment Authority detected suspicious (or proven) fraud, where it was unable to confirm identity to a sufficient (predetermined) level of confidence, and

where subsequent evidence of inaccuracy or fraud came to light. Failure to Enrol rates, analysed by demographic group, enrolment centre, time of day, the type of resolution procedure that was applied and the results of such actions

— Distributions of image and enrolment quality, analysed by demographic group, enrolment centre, time of day, etc

— Number of retries required and whether or not an operator override (e.g. of quality threshold) was used

— Statistical measures relating the duration of biometric enrolment (e.g. mean time from start of the process through to successful conclusion, maximum response times from a central database - if a check for duplicate enrolments is made) Note that terms need to be defined clearly, e.g. 'start time' may refer to the earliest recorded interaction between the biometric capture device and the Applicant, or it may be the instantiation by the Enrolment Officer of the process. Timings of the individual segments of the enrolment process may be recorded, for example, so that that the 'dead time' between individual transactions can be treated in accordance with a predetermined policy.

— Proportion of enrolments that fail the verification test (for services where these are implemented)

— Transaction logging of appropriate granularity

— Auditing support consistent with a set of established requirements.

6.2.13 Failure to Enrol and related failure rates

A classification of failures encountered in enrolment processes is provided as an aid to the design and development of the Enrolment Services. Based upon the definitions in ISO/IEC 2382-37, this classification (which is not part of the standard) will enable enrolment service designers to develop their own tabulation of failure types from Table 2 and Table 3 in preparation for definitions of their performance metrics. ('Notes' in the table refer to notes appended to the respective definition of a term in the standard)

Table 2 — Classification of failures encountered in enrolment processes

Class	Failure mode	Definition	Comment
1	An ineligible person is denied service and hence does not commence an enrolment process	Not considered as a failure to enrol	NOTE as part of the definition of Failure to Enrol. Such a person may become eligible for enrolment at a later time. Grounds for ineligibility should be determined prior to commencement of the enrolment service.
2	Excluded biometric enrolment transactions	Transactions that failed to complete for non-biometric reasons	NOTE 2 in definition of FTE
3	Failure to capture	Failure of the biometric capture process to produce a captured biometric sample	A blank or empty sample represents a failure to capture, even if the failure is not discovered until the biometric acquisition process. (NOTE 2)
			A captured biometric sample contains a signal from a biometric characteristic, but it might not be the biometric characteristic of interest. (NOTE 2)
			A captured biometric sample might not be suitable for future processing. (NOTE 1)

Table 2 *(continued)*

Class	Failure mode	Definition	Comment
4	Failure to acquire	Failure to accept for subsequent comparison the output of a data capture process	Failure to acquire occurs if the captured data does not meet system policy requirements for processing. Failure to acquire can only occur if there has been a successful data capture event. Otherwise the event is a failure to capture. (NOTE 1)
			Possible causes of failure to acquire include poor biometric sample quality, algorithmic deficiencies and biometric characteristics outside the range of the system.(NOTE 2)
5	Failure to enrol	Failure to create and store a biometric enrolment data record for an eligible Biometric Capture Subject, in accordance with a biometric enrolment policy	The failure to enrol rate (FTE) is defined as proportion of a specified set of biometric enrolment transactions that resulted in a failure to enrol. Excluded are those transactions that failed to complete for non-biometric reasons (NOTE 2 in FTE definition) Since the measure is based on the number of transactions, the FTE may result in a higher value than if it were based on the number of Biometric Capture Subjects.(NOTE 1 in FTE definition) Note the need to distinguish enrolment transactions (includes the checking of credentials, acceptance for biometric enrolment as well as the biometric enrolment transaction) from biometric enrolment transactions

In defining contractual terms with the Operator, the Enrolment Authority should take account of these definitions, referring to the Standard. If, after analysis of their requirements, the Authority decides that these definitions do not apply, the contract (and any SLA policies) should make explicit reference to this fact and provide new definitions, and amend accordingly any definitions in the requirements for testing.

The Authority should note that the Standard does not define the following terms:

— biometric enrolment policy;

— (biometric enrolment) transaction.

When reviewing the Failure to Enrol rates, the Enrolment Authority (and or Operator) should adopt a systematic approach, noting sources of data and common classes of failure.

6.2.14 Analysis of enrolment failures

The Authority may require a detailed analysis of failed enrolment transactions from the Operator, for example as part of a root cause analysis into changes in the FTE from certain enrolment locations. The capability to undertake such an analysis will depend on the availability of relevant data. Sources of data can be categorised as:

a) Data that is available from records of enrolment transactions, e.g. the proportion of applicants who have enrolled successfully.

b) Data that can be collected when the Authority or the Operator determines the need for an analysis of a representative set of enrolments but which would not be collected under normal circumstances. For example, the number of biometric enrolment transactions required for each enrolment may not be collected routinely, but a request can be made of attendants/Enrolment Officers to collect this data manually.

c) Data that cannot be collected (without change to the enrolment software) when the Authority or the Operator determines the need for an analysis of a representative set of enrolments, but which can be subsequently derived from data accessible to the authority. For example, few, if any, enrolment systems would be able to account for the reasons for NFIQ scoring of the quality of a fingerprint image. Assignment of an NFIQ score is the results of applying a software algorithm to various aspects of the image. A major contribution to the assignment of this quality score is the number of minutiae detected in the image, together with the numbers with specified levels of 'minutiae quality'. It might be that the total number of minutiae in an image is of possible relevance, in which case the Authority could request that an analysis be made of relevant stored images.

d) Data that cannot be collected (without change to the enrolment software) when the Authority or the Operator determines the need for an analysis of a representative set of enrolments, and that cannot be subsequently derived from data accessible to the authority. An example is the levels and direction of ambient illumination during the enrolment of facial images, if such enrolments are made in a relatively uncontrolled environment, such as a room with windows to the external environment. Although some estimate of the predominant direction of lighting could be inferred from analysis of the photos, the levels of illumination could not be determined absolutely if cameras were set to optimize collection automatically.

The following listing of possible causes of poor enrolment indicates the range of circumstances which could be considered.

Table 3 — Causes of poor enrolment

	Failure Type	Notes, examples	Failure Class
1	An ineligible applicant is not allowed to complete the enrolment		1
2	An ineligible applicant completes the enrolment successfully		Exclude from analysis according to biometric enrolment failure class, but may still need to be recorded
3	An applicant refuses to complete the enrolment process		2
4	An applicant refuses to co-operate with the attendant in the capture of the biometric data in accordance with the Authority's biometric enrolment policy and any other instructions	Exclusions may be allowed for medical conditions, but Authority will need to offer guidance for people unwilling to touch surfaces as a result of obsessive-compulsive and similar conditions. This should be covered in the biometric enrolment policy.	2
5	Failures in power supply, air conditioning or telecommunications links, strikes by operating staff, etc result in abandonment of enrolments		2
6	Failure due to software or hardware malfunction		2
7	Absence of the body part	Missing iris (aniridia)	3
8	Body part is inaccessible due to medical condition	Bandaged finger or finger with psoriasis.	3

Table 3 *(continued)*

	Failure Type	Notes, examples	Failure Class
9	Body part is inaccessible on account of social, cultural or religious reasons	No female attendant present when a female applicant presents with a face covering required for cultural or religious reasons	3
10	System triggers collection of biometric sample before applicant is ready or before relevant body part is placed in contact/proximity to capture device		3
11	The applicant presents the wrong biometric modality		3
12	The applicant presents the correct modality but the feature is not presented in the correct order	Placing the wrong hand on the fingerprint or palm vein reader. This presumes that such cases are detectable automatically by software or through observation by the Enrolment Officer.	3
13	The applicant's medical condition prevents capture of the image through the required level of contact (or stability of position) not being made for sufficient time	Parkinson's disease, or conditions such as rheumatism preventing reqired area of contact with platen	3
14	Body adornment or treatment preventing the capture of a usable image	Henna	3
15	Body part out of range of the specification for the enrolment device	Fingers too broad to enrol in a single finger device with guides	4
16	Biometric sample is wrongly assessed as a spoof attempt	Anti-spoofing alert triggered by unexpected characteristics of the biometric feature	4
17	Biometric sample from a feature which is damaged	Fingerprint quality software alerts to excessive damage	4
18	Insufficient detail in the biometric sample	Number of minutiae in fingerprint falls below a threshold, or finger is too dry	4
19	Biometric features fall out of range of the specification of the proprietary algorithm to create a usable biometric reference		5

6.2.15 Analysis of poor quality enrolments

In addition to total failure of enrolment, the Enrolment Authority should develop metrics for measuring the incidence of poor quality enrolments. Users should refer to standards and technical reports in the ISO/IEC 29794- series.

This presupposes:

— The existence of a standard against which elements of quality can be assessed. In part, this may be supported by the series of standards in ISO/IEC 19794.

— Experimentally-validated software which defines quality metrics for one or more biometric comparison algorithms. For fingerprint systems using minutiae, NIST have developed NFIQ which has been tested on a number of comparison algorithms. NFIQ can be optimised for a specific commercial algorithm. A revised version of this algorithm is in development.

— Other specialist software, either from suppliers of comparison algorithms or from independent organisations, which often addresses specific elements of the 19794-x specification for the modality.

It is worth noting that certain demographic groups present particular challenges during enrolment. For example, experience shows that obtaining good quality fingerprint images from children and the very elderly can be difficult. Furthermore, certain activities, such as continued contact with abrasive materials, e.g. through working in the construction sector, can result in a greater proportion of poorer quality enrolments. This type of observation is often noted in standards such as ISO/IEC 19795-1.

6.2.16 Strategy for corrective actions

Analysis of the metrics relating to the enrolment service should highlight changes outside of the control parameters which have been determined for the service. Analysis of the metrics relating to the enrolment service may show changes outside of the control parameters. These should be investigated and remedial action agreed with the Operator. As part of the contract(s) with the system Designer(s) and Developer(s), the Enrolment Authority may wish to negotiate for the production of guidance documentation for such eventualities.

6.2.17 Use of data for research

There are at least two reasons for retaining data for research purposes:

— Proving that a system operates correctly may require the temporary storage of biometric data, e.g. in order that false match rates can be determined.

— Biometric data relating to operational systems is often very difficult to obtain, yet improvements in technology need access to extensive data sets in order to validate novel ideas. Hence. data collected in one system can be used to improve the performance of other, totally unrelated, systems

An Enrolment Authority should be aware of these opportunities and be prepared to develop security policies, privacy impact assessments, etc if these are shown to be of long term value to their organization. Note that in some cases, this will require co-operation with Relying Parties, in order to track an individual's encounter with a biometric system from enrolment to recognition. In some countries, proposals for research may need to be presented to an ethics committee.

6.2.18 End-of-contract or contract reassignment actions

Contracts with the Operator (which delivers the enrolment service on behalf of the Enrolment Authority) may be designated for a specific term, after the expiry of which, the Enrolment Authority may want re-tender the service. Arrangements for handover may include the production of documentation capturing the knowledge of the Operator and personnel about specific aspects relating to the successful delivery of the service at individual centres, and a detailed representation of the status of the biometric elements of the service. Note also that the Enrolment Authority may be engaged on a contract with the Relying Party (or Parties) in which case, preparations for orderly transitioning may need to be in place well in advance of the handover period.

6.2.19 Supporting the interests of the Operator of the enrolment service

For the Operator of the enrolment service (which in many cases will be the same organization as the Enrolment Authority), it is crucial that the procedures at enrolment fulfil the requirements set by the Enrolment Authority for a cost-effective, legal, quality and secure process, as expressed in a SLA (Service Level Agreement).

Considerations for the Operator include:

a) The Operator will need to consider how to collect the biometric features (optimising equipment, number of attempts, etc) that give the best available set of biometric references ('templates') so as to achieve targets for enrolment set by the Relying Party in its contract/agreement with the Enrolment Authority.

b) A good experience for the Applicant should contribute to a lower drop-out rate from the appointment system for enrolment; otherwise, poor user experiences shared with the mass media may deter other potential Applicants from keeping to their appointments.

c) Provide the operator with a standard method of collection to ensure the process is efficient and consistent.

d) A more efficient process will reduce operating costs.

6.2.20 Development and maintenance of training programmes for personnel

Enrolment officers and attendants at attended enrolment points should be trained with the aim of delivering a secure, efficient and effective service to the Enrolment Authority. Such trained personnel may receive a certificate to indicate their level of qualification, and a periodic re-certification may be offered as well.

Selection of the training method should make use of best practice with regard to the pacing of instruction, modality of delivery (written, face-to-face presentation, online learning, etc), frequency of refresher courses, etc. Some of the training material may be provided by suppliers of biometric components or systems. It is recommended that officers are tested on completion of the training.

Ongoing monitoring of enrolment quality, throughput rates and other relevant metrics may be used to indicate a need for refresher training, 'Mystery shopping' and observational studies may be used periodically to ensure that officers continue to maintain a high standard of practice.

A typical training programme may cover aspects such as

— an explanation of the biometric process, indicating why a high quality and secure process – and strict adherence to the procedures of enrolment, is necessary for the successful use of the system in future recognition activities (through more reliable comparison with data in the database of biometric references).

— practical enrolments under the supervision of a trainer covering all the relevant areas

— information about certain groups of Applicants that may have difficulties with enrolment (disabled, children or elderly people, etc), explaining how these groups may be assisted in providing a good quality biometric reference.

— processes that should be followed in exceptional cases, e.g. bandaged or missing fingers or more than 5 fingers in a hand.

— explanations that can be given to Applicants of the enrolment service regarding the purpose of the enrolment and subsequent recognition services, …

— interpretation of error and other messages from either the hardware units or computer screen, together with actions to be taken.

— regular maintenance activities (such as cleaning of fingerprint sensor units or checks to confirm that systems are operating within specified operating limits).

— security-related procedures, such as the examination of fingers for unexpected modifications and artefacts.

— instructions to the Officer or attendant regarding notes to be made relating to problems that were not resolved.

— procedures for closing down the enrolment session in a secure manner.

6.2.21 System performance monitoring and correction actions

The operation of enrolment service should be monitored in accordance with the requirements agreed with the Enrolment Authority or other governance body. If the Authority responsible for enrolment is not the same as the Relying Party (for the application of the biometric system for recognition of individuals), the testing of the end-to-end system (encompassing enrolment and recognition services) is strongly recommended.

The operation of the enrolment service can be monitored at a number of levels of granularity, e.g. on a service-wide level, by geographical area or at the finest level of granularity. Among the data that can be collected is:

— the distribution of quality measures, average quality measures for different demographic groups

— time taken for enrolment transactions (mean, mode, and other statistically relevant measures)

— percentage of enrolment transactions that are not completed satisfactorily, e.g. measuring the FTE rate (6.2.13).

Automated alerts can be triggered when performance metrics exceed permitted bounds, calling for investigation of the causes and corrective action.

In any case, aggregated data should be reviewed periodically by an official of the Operator (optionally, with representatives of the Authority) to note patterns of change and investigate accordingly.

6.2.22 Service Improvement Actions

The operation of the enrolment service should be monitored at frequent intervals as part of a general system quality improvement scheme. Such a scheme may draw upon the results of research, either by the developers, the vendors of hardware and software, academia or by the Enrolment Authority itself. Operational data obtained from other deployments may give insights into ways of improving the Authority's processes. On the basis of these inputs, changes can be piloted on a certain group of enrolment stations, using existing performance data as the baseline against which to judge the impact of such changes

6.2.23 Periodic audit of the service

Periodic audits of the operation of the enrolment service may be held on behalf of the Authority, either to verify the secure operation of the processes, review the performance of the service or to confirm that the service is being delivered in accordance with a published mandate. Other types of audit may be undertaken on behalf of specific regulators, focusing on aspects such as compliance with legal requirements (e.g. in respect of privacy or personal data protection).

The outcomes of such audits should be in the form of actionable recommendations on the Operator or Enrolment Authority, with internal governance arrangements identifying a responsible owner of each recommendation. Although the service may have functions and components other than those relating to the collection of biometric data, this clause considers only audit actions relevant to biometric aspects of the service.

The Operator or Enrolment Authority should dispose of each recommendation by one of the following actions:

— agreeing to make changes in the enrolment service, determining what development work is required (if needed), contracting for its development and deployment, and testing the system in its new configuration to confirm that it still operates in accordance with the original mandate as amended by the recommendation

— deciding on the basis of an analysis of the impact of following the recommendation that the Service would be compromised operationally or financially, and reporting back to the auditor accordingly.

— by proposing alternative means by which the audit recommendations could be addressed.

6.2.24 Participation in end-of-service or contract reassignment activities

The Operator may have a license for an agreed period of time; or be contracted to deliver against a number of metrics in the Service Level Agreement with the Enrolment Authority. Consistent failure in meeting these metrics may result in recourse to remedies defined in the contract or even trigger contract reassignment processes. (Note that performance well above that expected may be rewarded in a graded manner). The Operator should work with the Enrolment Authority to develop processes for the orderly handover of assets and the management of the transition to a new Operator.

The existing Operator may have modified processes – and trained attendants accordingly, developed innovative solutions (for which they may have sought intellectual property protection) or modified quality assessment software, in order to improve the Enrolment Service. The Enrolment Authority should create an inventory of these changes, and establish transitioning procedures (which may entail support by the existing Operator) for transfer of these practices to the new Operator. After handover, the previous Operator may be required to support the service over a period to help resolve problems such as deterioration in the performance of the service.

6.2.25 Supporting the interests of Relying Parties

Relying Parties rely on the enrolment service to provide a reliable, repeatable, secure and consistent service. If the enrolment service delivers outputs of a lesser or variable quality than defined in an SLA, this may impact adversely on subsequent verification and identification processes. Such impacts will inconvenience Relying Parties and subjects of the enrolment as, for example, the exception handling options are exercised more frequently.

Two types of dependent parties can be identified:

a) The Identity Provider, the authority responsible for storage of the biometric references relating to individuals who have been enrolled successfully under the enrolment service

b) Relying Parties, that is Parties who rely on biometric recognition as part of an application or service

For the first type, the requirements include:

— Receipt of a file from the Enrolment Service formatted in accordance with the interface agreement with the Authority (see Clause 4), with ensured integrity and fitness for purpose.

— The biometric data in the file to be in a form that permits the Provider to make checks on biometric and data quality and if inadequate to seek further actions from the Enrolment Authority or Operator.

— Biometric data are usable in the proprietary processes for de-duplication (if required) and conversion into biometric references.

— When the Authority declares a Failure to Enrol, to ensure that the exception handling procedures are followed and relevant data are received by the Identity Provider in the appropriate format (6.2.37).

— Acceptance testing and periodic testing afterwards to ensure that an acceptable performance level is achieved and maintained.

— Testing carried out by the Identity Provider on its accumulated data may reveal opportunities for improvement in the enrolment service, necessitating discussions with the Enrolment Authority.

— New customers of this Identity Provider may have additional requirements on the enrolment service, again necessitating discussions with the Enrolment Authority.

For the second type of dependent party (the operator of an application or service), requirements on the service include

1) Assurance that the enrolment service has delivered enrolments (including exception handling) to a level of integrity consistent with its risk appetite and operational requirements.

2) Co-operation with the Enrolment Authority in the assessment of end-to-end performance of the application or service.

3) Capability to make adjustments to the enrolment service as and when the Relying Party changes its own requirements (e.g. adding new modalities, changing quality parameters, adding or subtracting biographic data, responding to amendments to standards).

4) Capability to make adjustments to the enrolment service as and when a new Relying Party is introduced.

A useful principle in the design of IT systems (as well as a requirement relating to personal data protection in some jurisdictions) is that data which is no longer required should be disposed of securely. For biometric systems, it is recommended that when the subject is no longer using any applications of a Relying Party, for example, because (s)he has left the organization and no longer needs access to its buildings, an exit process should be started by a Relying Party working in conjunction with the relevant Identity Provider. This process should define time limits for retention of biometric and other data on the live system and on any archive system, ideally referencing legal requirements or research that justifies the data retention periods. Removal of subject data and access rights is needed to protect the business as well as the subject.

6.2.26 System Design and Developer's perspective

Many individuals are involved in an enrolment process, each of whom will need training and support: the biometric Applicant – the subject of enrolment, an attendant to support the quality acquisition of the biometric feature, representatives of the Operator of the system (working on behalf of the Enrolment Authority), enrolment centre managers (who may not be employees of the Operator), and call centre personnel who may interact with Applicants before and after an enrolment. Design and development best practices should be employed to ensure that the system performs as required by the Enrolment Authority and regulators, and that the activities of these individuals are optimised to deliver a successful biometric enrolment service for all enrolees. Similar considerations relate to business processes.

6.2.27 Pre-enrolment and scheduling processes

Applicants for biometric enrolment will look to the operator to provide enough information ahead of time to understand what is required of them. If this information is part of a marketing campaign, the messages should be consistent with other information.

A pre-enrolment process can be used to collect data via a web application prior to appearing for capture of the biometrics as a way of reducing onsite enrolment time. (This can be done in conjunction with online appointment scheduling, providing directions to the enrolment centre, information on what documents to bring with the users, etc.)

A helpline (designed for inclusivity) may be offered to enable the Applicant to phone into the enrolment centre with any questions on the day of the session, e.g. whether the onset of a cold should postpone the enrolment into a voice verification system. This needs to be staffed with assistants with appropriate training.

Allocation of timeslots should take account of the time required for:

— pre-enrolment formalities (e.g. checking of the identity credentials supplied by the Applicant),

— mean time for biometric enrolment, as well as the allowable maximum time for such enrolment,

— allowing time for any cleaning and/or maintenance of any devices

— allowing time in between the enrolments of Applicants and providing for rest periods for attendants to ensure that they remain vigilant throughout an enrolment session.

6.2.28 Confirmation of the biographic identity of the Applicant

A key purpose of most enrolment processes is to establish an individual's identity by linking one or more biometric characteristics with their biographical data In these cases, it is important that the identity is verified prior to this binding. This is typically done by performing "identity proofing" by inspection (and sometimes capture) of identity documents, sometimes referred to as "breeder documents". Examples of such documents include birth certificates, driver's licenses, passports, etc. For some Applicants, e.g. minors lacking relevant identity documents, special processes may be required.

Where the security policy mandates this, the authenticity of these identification documents should be confirmed with the relevant issuing agency(ies), as well as using equipment and procedures to verify the documents as not being forgeries or altered. Acquiring high quality digital colour copies of these identity documents may be a requirement for audit processes, assuring the integrity of the enrolment process against human error and collusion

This may also be the opportunity for persons with medical conditions that limit the quality of the biometric to show evidence.

6.2.29 Requirements of the verification system(s) which will depend on this enrolment

Multiple modalities could be used; fallback systems and requirements from inclusive design may need to be developed.

6.2.30 Selection of enrolment system

Equipment and software may be available that differs from that used in verification systems, e.g. in being more robust against repeated mechanical impact, having additional functionality and feedback information to the Applicant to optimize the positioning of the biometric feature or characteristic, etc. Assessment tools may be available and could help in determining whether the enrolment system has captured and processed an image or signal of sufficient quality to allow for subsequent comparison with the features of other enrolees (if it is important that no duplicate identities are recorded), or for use later in a verification system.

6.2.31 Physical design of the enrolment environment

The sensing equipment should be positioned in ways that optimize the collection and processing of high quality images. Where enrolment takes place at a large numbers of sites, the hardware should be designed to be as independent of the environment as is possible. Environments should only be modified where the enrolment solution cannot be adapted to the existing environment. Each modality will also have associated recommendations in respect of the ambient environment, e.g. acceptable background noise levels for enrolment in a voice verification system, and requirements of uniform illumination for facial image collection.

The importance of good ergonomic design cannot be overstated, for example, taking account of naturally occurring variations (e.g. height, size, left/right handedness), and where necessary the needs of disabled Applicants and attendants, and Applicants who are not native speakers. Further information relating to ergonomics and inclusivity issues is to be found in ISO/IEC/TR 24714-1:2008. In designing the hardware for enrolment, attention should be paid to user friendliness, ease of keeping it clean, etc.

Provision for accompanying persons may be required, e.g. a translator or personal assistant with measures to reduce the chance of any interference in the biometric capture process, e.g. by collection of an additional face – or even the attendant's face only – in a facial enrolment system.

6.2.32 Interfacing with the Applicant

— Since the enrolment session may be the first time that enrolees have been in contact with biometric equipment, the business may need to develop an interaction protocol with the enrolee. This may include elements of direct face-to-face support

— written material (provided in an inclusive and comprehensible manner) in the form of posters, information leaflets, etc, and/or

— video clips of an idealised enrolment session in action.

Even simple issues can cause additional problems which could be avoided by planning ahead, e.g. if a subject and attendant sit facing each other, they should have a mutually agreed view of "left" and "right" if this is significant in the comparison process.[2)]

6.2.33 Appropriate training of the Enrolment Officer and Attendants

Enrolment Officers and Attendants should be able to support the Applicants in achieving the most effective enrolment through answering their questions and addressing any difficulties. Operators will need to recognize that training is needed that acknowledges the range of both cultural expectations and specific requirements of individual subjects. This should reduce the chance of litigation and bad publicity.

Since they are in continual contact with enrolees, there should be provision for officers and attendants to note any problems and opportunities for process improvement, with a procedure for reviewing these insights and thereby improving the training (and re-training) of other attendants. Such provision could be made through additional fields in the forms or screens detailing information captured during the enrolment.

As early in the process as possible, the operator (or the Enrolment Authority) should take steps to identify and resolve issues such as health and safety considerations and negotiations with trade unions.

6.2.34 Support Staff Training

Provision for the training of maintenance and other personnel should be made. The content of the training material and its delivery should be prepared recognizing that personnel may not be familiar with biometric systems. Further general guidance about training of Enrolment Officers is to be found in 6.2.20, with specific recommendations directed to the Operator of a service described in 6.2.3.

6.2.35 Security

In designing the enrolment processes, specifying the equipment, software and user interfaces, operating environment, etc. the designer of the system will take into account known security threats and vulnerabilities relating to the biometric modality. For example, it may be prudent to confirm that the fingertips of subjects enrolling on a fingerprint sensor are examined visually by the attendant to note whether there is anything untoward, such as damage, concealment or artefacts that partially or totally obscure the Applicant's own fingerprints.

Similarly, any replacement hardware may be required to be have tamper evident features, and also to be validated as genuine - for example by digital certificate verification of software. Some knowledgeable Applicants may require reassurance that the equipment is genuine, untampered with, accredited and certified to ensure that their biometric features cannot be reused for unlawful purposes.

Other security threats are common to all forms of registration process, e.g. collusion of the attendant with the Applicant in proofing of the identity of the person. Attendants and Enrolment Officers should be trained accordingly. The security of data both at enrolment centres and over transmission networks to centralised storage or monitoring centres (one of the Relying Parties) needs to be considered, as well as the delivery and installation of software updates.

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2) In a test of 300 adults, NIST demonstrated that in presentation of enrolment information for optical tenprint collection, verbal and video methods of communicating the process were approximately equivalent. In contrast, a poster representation of the same information led to significantly more errors, as well as taking substantially longer. Subjects who were informed verbally of the process tended to anticipate continued support through the enrolment.

In the special case where applicants for biometric service supply their own biometric samples (e.g. submitting facial photographs when applying for a passport), the designer of the system should be aware of the significant risks that the biometric sample may not reflect accurately the biometric characteristics of the individual.

For facial photographs, the applicant or photographer may have made alterations for e.g. vanity or cultural reasons, or for subversive purposes. Such changes may not be detected by human examiners or automated systems (indeed such changes may impact on ease of human comparison). These changes could include digital alterations such as:

— removal of blemishes and scars,

— the whitening or darkening of skin pigmentation,

— changes to eye colour,

— the manipulation of image dimensions to make the subject look thinner or fatter

If the aim is to subvert the enrolment system, the applicant could enrol under multiple identities or avoid detection through biometric watchlist checks.

In addition, conversion of printed photographs to digital formats can cause degradation of the image or addition of artefacts.

6.2.36 Number of attempts at collection of a biometric feature or maximum duration of collection time before timeout

Many enrolment processes have been used that require a specific number of presentations (e.g. three separate placements of a finger on a sensor within a set period), from which the highest quality image(s) is/are obtained for subsequent processing. In order to improve the quality of the image between successive presentations, position sensing software may give an indication to the Applicant of any adjustments to the presentation of the biometric feature (e.g. to press down harder on the platen, or move the finger), or group of presentations. Alternatively, the sensor can collect samples of a biometric feature for a fixed time duration taking facial images in quick succession for 20-30 s) followed by an image quality assessment that selects the best representation(s); or declares that an image of sufficient quality has not been obtained. Such differences will impact upon the process of enrolment and equipment suppliers should be consulted as to the appropriate measures to be taken.

6.2.37 Exception handling: enrolment and/or registration procedure for secure and effective fallback

Even after inclusive design, a certain proportion of the population may still have difficulties in enrolment. Such Applicants will have to be offered an alternative procedure. This may be

— another instance of the same modality (e.g. further attempt at enrolment of a thumb if one or other of the index fingers is inadequate),

— an alternative modality (such as collecting an iris image), or

— an entirely separate, non-biometric process that meets the same requirements of security and usability.

Enrolling multiple modalities should also be considered to allow for more choices during verification. An individual may find one biometric modality easier to use or prefer it for other reasons. This also provides the ability to use the “alternate biometric modality” when the preferred one is not available or working well due to a temporary injury, for example.

Wherever practicable, these alternatives should not disadvantage the Applicant, for example, by offering an inferior level of service or functionality.

Designers of systems should be aware that exception handling or fallback processes are potential sources of security weaknesses, and appropriate measures and training for any specialist staff are required.

6.2.38 Post enrolment verification session

In many systems, once the enrolment has been completed satisfactorily, the enrolee may have an opportunity to experience the verification process. There is an assumption that this will help a knowledgeable user to understand why (s)he should follow the recommended verification process and be able to try again if the verification was unsatisfactory in any way. A full or partial re-enrolment may be needed if repeated failures in such verifications are noted.

In some cases, the enrolment encounter is also an opportunity to train the subject on the use of the associated verification system. (For example, if the enrolment is for a physical access system, it is useful to have one of the door reader units available at the enrolment site for instructional and habituation purposes.) The environment of this check could reflect the operational use, e.g. through having similar signage.

This can also confirm that the biometric sample has been correctly associated with the biographic and other data in the database or token, that the transmitted file has been processed correctly by the Identity Provider, converted into references, and stored in a manner accessible for applications.

6.2.39 System maintenance procedures

At specified intervals, attendants should be required to verify the correct operation of the hardware and/or software which may involve cleaning of surfaces and initiating self-calibration procedures, checking that tamper-resistant seals are intact, etc. It is recommended that the date and time of such routine activities be recorded. On occasion, enrolment Applicants may request that any systems that require physical contact with equipment be cleaned; it is good practice to provide suitable wipes for this purpose. Other specialist measures based upon recommendations of the system supplier and on testing and piloting of the system, will also be followed, for example, in fingerprint systems where the software advises that fingers are too dry or too moist. Only materials approved for use by the operator should be used, and the system designer should provide advice on such materials.

In some environments (e.g. a hospital setting) hygienic requirements may require frequent use of disinfectants. Equipment may need to be selected or modified (e.g. sealed) to allow for such cleaning without damaging the electronics.

A programme of secure replacement of hardware at appropriate intervals can be developed.

6.2.40 Token production and secure delivery

In many cases, the enrolment system could also start the process of issuing a token containing either the biometric reference model or template, or a unique alphanumeric identifier pointing to the entry in the database that stores this reference element. In the use of the token the security and privacy of the biometric data should be protected (e.g. through access controls, cryptographic mechanisms, etc.). The delivery of the token must be secure and this could offer a further opportunity for biometric verification of the identity of the subject. Policies for this should be developed by the designer, whether using biometric procedures or not.

6.2.41 System performance monitoring

At periodic intervals, the operator of the biometric enrolment service should review the Key Performance Indicators (KPIs) to ensure that the quality of the service is being maintained. This requires that such a list of indicators is constructed during the system design, procurement testing and piloting phases. Such a list should also reflect the experience of people with impairments.

As a minimum, operators, through their Performance Manager, may wish to confirm that the proportion of failed enrolments is stable (or decreasing) over time, and that the mean time for enrolment is not increasing. User satisfaction with the process could also be assessed, since a poor perception of a

service (as reported in mass media or through direct contact with previous enrolees) is likely to impact adversely on the confidence with which enrolees embark on their own session.

For larger scale deployments, where there are several offices, comparison of the KPIs can reveal opportunities for improvement to the enrolment process, particularly if, for example, this data are associated with the maintenance logs

If the enrolment service is associated with one or more verification services, the performance characteristics of the latter can be examined in relation to the KPIs of associated enrolment offices and periods of time. Any degradation in verification performance should be investigated as it may be an early pointer to problems with the design of the enrolment procedures and/or unexpected ageing of the biometric features. Such investigation is amenable to more detailed analysis by age group, ethnicity, disability, gender, specific attendants, enrolment office, etc. (Note that gathering this data will need approval by the Applicant to secure handling procedures, especially if the original biometric samples are to be retained. Other legal checks may be necessary to ensure that there is no suspicion of this data being used in a discriminatory manner).

6.2.42 Effective system level performance through testing and piloting

Biometric enrolment is only one of a set of processes that taken together provide a benefit to an organization. The Relying Party may want to satisfy itself that the initial performance of the enrolment subsystem satisfies the requirements of the end-to-end system(s) of which it forms a part, and that, subsequently, the effectiveness of the subsystem does not drop to a point where it places the operation of the end-to-end system(s) at risk. Modelling of such system(s) can help identify the key metrics of the enrolment subsystem and justify investment in monitoring and testing of enrolment. Appropriate testing procedures should be followed using a demographically representative group of test subjects, and procedures that are described in the ISO standards in the ISO/IEC 19795- series.

Piloting is best carried out in a location and environment that is representative of the application.

6.3 Regulator's perspective

6.3.1 Regulation

The operation of a biometric enrolment service may be subject to national and state laws relating to data protection, privacy, discrimination and disability. Regulators for respective aspects may have in place codes of practice or regulations which may specify how to implement and manage their requirements.

6.3.2 Completeness of the governance processes

A regulatory authority may have best practice recommendations or legally mandated provisions for the governance of some aspects of the operation of the service, e.g. the nomination of an official responsible for the personal data protection aspects of the service. There may be other provisions of codes relating to health and safety, disability discrimination, etc. with separate requirements. A complete governance structure will ensure that these are woven into a wider framework that ensures that the Authority's interests are fully protected.

6.3.3 Integrity of the logging and audit processes

Logging of activities relating to significant actions in the operation of the enrolment service (e.g. setting of parameters for biometric quality software or to identify the Enrolment Officer on duty in a specific session) should be secured to an appropriate security level. Auditing requirements may surface after the system has been delivered, and provision for collection of such data may need to be added to the management information (MI) system after the MI system has already been completed. This has implications for an initial design of a secure system architecture that is extensible through change control, as well as affordable. Further information on auditing requirements is discussed in 6.2.7.

6.4 Auditor's perspective

Measures should be in place to ensure that terms of reference are appropriate, that these conform to local laws and regulations, codes of practice, etc, that the data and information is available in sufficient (but not excessive) detail and presentation mode, that reports and recommendations are made to the correct functions in organisations and that follow up on these recommendations is in place.

7 Process for the development of biometric enrolment capability

7.1 General

Since a successful biometric enrolment is key to the operation of applications and services that provide benefit to organisations, it behoves authorities that are responsible for the delivery of enrolment systems to design, deploy and operate these in a quality way. The Enrolment Authority should consider the following phases (noting that agile project approaches to delivery may be used as well):

— System definition – requirements capture from stakeholders;

— Procurement – the acquisition of the enrolment system;

— System design – the process of defining the architecture, components, modules, interfaces, and data for the enrolment system to satisfy specified requirements;

— Development – creation of a service (hardware, software, business processes, training of staff, etc.);

— Testing – an investigation conducted to provide stakeholders with information about the quality of the enrolment system;

— Piloting – a small scale deployment of the enrolment system that is representative of the full scale system (some piloting can be done during the procurement stages);

— Deployment – the transformation of the enrolment system from the development environment to the operational environment;

— Operation – the day-to-day use of the enrolment system;

— Maintenance – the modification of the enrolment system for preventive and corrective actions;

— Governance – monitoring and process improvement, together with audit;

— Cessation or Withdrawal of service;

Enrolment processes will, in general, include proofing of identity – measures to ensure that the Applicants are indeed who they claim to be (e.g. before binding the identity to the enroled biometrics).

7.2 Architectural considerations in enrolment station design

In designing a biometric enrolment capability, the architecture is an important consideration for many of the stakeholders. The architecture not only affects the initial procurement and deployment, it also affects decisions made downstream with regard to system maintenance, upgrade, etc. Some considerations for enrolment station architecture are given below.

— Form factor. Enrolment stations may take the form of a desktop workstation, an "across the counter" setup, a kiosk, or a mobile enrolment kit. Selection of the configuration will depend on the facility, space considerations, cost, and the enrolment process.

— Ergonomics and Accessibility. The configuration must take into consideration how the users and operators will interact with the equipment (and the operator) in terms of both comfort (physical and psychological) and facilitation of the best quality biometric capture.

— Connectivity. The enrolment station may operate in a stand-alone fashion, but is most often connected to a back-end system – either continuously or periodically. In either event, the station should be able to work in both an online and offline mode. The latter may need to support a batch upload capability (e.g. after collection in a remote area) or a "store and forward" capability. When the station includes a storage requirement, both the storage capacity and data security must be considered. The enrolment station/application should be able to be integrated within a services oriented architecture (e.g. provide a Web services interface).

— Security. The enrolment station must incorporate security mechanisms to protect the confidentiality and integrity of the biometric data, as well as provide for auditing for incident investigation and non-repudiation purposes. Operator access controls are needed to protect access to functionality and data.

— Standards based. Enrolment stations should collect biometric data in a format that allows it to be interchanged (e.g. using ISO/IEC 19794). Interface and messaging standards may also be applicable

— Flexibility. The architecture of the enrolment application should be flexible so that it can be easily modified in the future as requirements and environments evolve over time. For example, it should provide configurable workflow, user interface, and policies/rules; support multi-modality (even if not implemented initially), and be vendor/device neutral to the extent possible.

7.3 System definition

A robust system to deliver an enrolment service should be designed in line with best practice in systems engineering. For a biometric system, the system definition may entail some or all of the following

— developing a system that meet the needs of the Relying Party in a legal, secure and cost-effective way

— taking into account at an early stage in the design and development process, non-functional requirements such as privacy-compliance, Inclusivity (for the disabled, Biometric Applicants who are not native speakers of the language(s) used in the country where enrolment sessions are held), user acceptance and usability, etc

— interoperating with systems of other organisations in the same sector, to allow for future sharing of resources

— allowing for substitution of biometric hardware and software from other vendors, in case the suppliers retire their current components from the market, or the Authority requires to re-compete the system at a future date

8 Guidance relating to specific modalities

8.1 General

Information about best practices for successful enrolment of Biometric Applicants (hereafter termed Applicants) is available from various sources. For example, experience gained in practical applications is distilled in data format standards in the ISO/IEC 19794- series, in particular in the informative appendices.

There is a scarcity of publicly-available information about enrolment where more than one modality is used. An exception is the UK Passport Service enrolment trial for face, fingerprint and iris (May 2005), but the information in this report needs to be treated with some caution, since the trial predates much of the ISO standardization activity and experience with large scale enrolments for biometric visas and passports.

There is growing interest in enrolling Biometric Capture Subjects (hereafter termed subjects) on mobile systems, and these require specialist design. In general, the quality of biometric data obtained from enrolments using mobile systems is likely to be inferior to that obtained in fixed systems where the environment can be controlled more consistently, computer systems with more processing power can be deployed, etc. However, the use of a mobile enrolment terminal may be the only practical way

of collecting biometric data when Applicants are unable or unwilling to travel to a dedicated facility. Further information is provided in Clause 9.

8.2 Facial Biometrics

This section discusses recommendations for co-operative enrolment in a dedicated facility. It uses the results of studies that were undertaken for the introduction of ePassports and summarized in ISO/IEC 19794-5:2011. Some of the advice is applicable to other situations, where the Applicant is not necessarily co-operating or when the Relying Party is unable to control environmental conditions and/or the behaviour of the Applicant

Further detailed information about enrolment of facial biometric images can be found in 9.3.

For Applicants to be recognized using a facial biometric system in an application in which the environment is controlled and the subject co-operates in being recognized, images captured at enrolment and recognition should be as similar as is possible. More specifically, this means that

— the pose of the face should be similar in terms of roll, pitch and yaw angles. Conventionally, enrolment images are taken with a 'full-frontal pose' and the standard for passport photographs quotes a maximum rotation of no more than ± 8 degrees from frontal in roll. Research has shown that collecting a three-dimensional image may be beneficial if appropriate software is used. Alternatively, a number of images taken at different angles may assist in successful comparison if suitable software is available.

a) the illumination of the face should be similar, in terms of angle, diffusion, etc. In typical enrolment scenarios, the recommendation is for an even illumination with no visible shadows across the face.

b) eyes should be open and visible in both cases, since most algorithms use the centres of the eyes in photographs to reference the face.

c) the expression in each image should be similar (e.g. if the expression in the enrolment image is neutral, it will be more difficult to compare it successfully using biometric software to a smiling facial image).

Although the emphasis has been on attaining similarity between enrolment and recognition conditions, many applications require that high quality images be captured with the subject posed in a standardised mode (facing the camera directly, with a neutral expression, evenly illuminated, etc.) In addition

— the face should be uncovered with the Applicant not wearing headgear such as caps,

— hair should not obscure the main part of the face,

— if the Applicant normally wears glasses, there should be no reflections of flash or lamps visible on the glasses,

— a high resolution image should be captured – with the resolution often expressed in terms of the numbers of pixels between the eyes with a figure of 90 pixels offering good matching performance in studies supporting this requirement within ISO/IEC 19794-5. Guidelines for best practice from the Facial Identification Scientific Working Group (FISWG) recommend that cameras should be four megapixels or above of effective resolution, with the camera mounted for portrait mode capture,

— the camera height should be positioned at the same height as the subject's eyes and positioned about two meters (6,5 ft) from the subject,

— the depth of field in the image should allow all visible parts of the face to be in focus,

— the background of the enrolment image should be such that the face and hair is easily distinguishable from it. Ideally there should be no shadows on the background surface and a uniform 18 % grey with a plain smooth surface is recommended for certain applications,

— the camera settings for the images to be captured should be an industry acceptable format such as JPEG, and the highest possible quality setting should be used to minimize image quality loss and distorting factors such as image artefacts. The camera's digital zoom should not be used,

— colour-balanced techniques should be used to avoid unnatural colours.

Towards the end of the enrolment session, it is recommended that the Applicant is offered the opportunity to be recognized in a simulation of the application that the Relying Party intends to use. This familiarises the Applicant with the context of application and provides a measure of confidence that the enrolment has been carried out successfully. It allows for an on-the-spot re-enrolment should the simulation indicate problems with collection and/or encoding of the facial image. Ideally, the simulation should be carried out in a different environment, and not directly after the enrolment.

Usability studies can offer insight into improvements that can improve the performance of a facial biometric enrolment, improvements that can be made without imposing additional tasks on attendants or making changes in the environment. A NIST study on improvements in the collection of images at the US-VISIT primary line showed that all participants would be imaged correctly if five interventions were introduced:

a) The cameras were changed from a webcam (unfamiliar to some travellers at immigration) to appear as a traditional camera

b) The camera should click as the picture was taken to provide feedback that the process had been completed

c) The camera should be positioned in portrait mode

d) The attendant should face towards the traveller (and the monitor) when adjusting the camera position

e) Indicate to the traveller where to stand (e.g. by placing images of footprints on the floor in front of the camera)

8.3 Fingerprint biometric systems

8.3.1 General

Four tiers of fingerprint enrolment have been discussed

a) A full tenprint set of rolled and plain (alternatively known as flat or slap) prints from both hands – generally used only in law enforcement applications

b) A set of plain tenprints – for other government and public sector applications

c) Capture of images from a smaller number of fingerprints, with one or (preferably two, for resilience) flatprints – in general for commercial applications or where small closed user group identification is required

d) Self-enrolment, e.g. by using a swipe sensor on a laptop or Smartphone.

The requirements for a successful enrolment in each of these use cases will depend to a great extent on the dependent application. There will be tradeoffs, such as those between high accuracy, low cost, and high speed throughput, so that an optimization of all three parameters for the specific context of operation will require careful planning.

Self-enrolment in an unattended environment is not recommended at present, except for situations where the security aspect of an implementation is secondary to convenience in operation. Anti-spoofing technologies are still under development and once fully commercialised are unlikely to be implemented for some time in these systems (characterized by low cost devices and software).

Further detailed information about enrolment of fingerprint biometric images can be found in 9.1 which relates to their enrolment in mobile systems.

8.3.2 Fingerprint image optimization

High quality fingerprint systems generally enrol on optical scanners, for which there seems to be an optimum moisture of the finger. Experience shows that overly moist fingers should be wiped with a cloth or paper towel. A number of strategies have been suggested for fingers that are too dry; asking the Applicant to breathe on the finger(s), sliding it across the forehead (or the side of the nose) to pick up traces of oil, or applying a surface dab of a skin-moisture lotion have all been used.

Further detailed information about enrolment of fingerprint images can be found in 9.2 which relates to their use in mobile systems.

8.3.3 Single finger systems

Based upon experience gained from tests on 1 100 people in the Autumn of 2006, and using 3 different sensors, Bausinger and Seidel developed the enrolment procedures for fingerprints in German e-Passports. This example of a procedure which may be implemented differently in other countries consisted of the following:

— The standard process is the enrolment of two fingers, one from the right and one from the left hand.

— Fingers that are not available (e.g. due to injuries or disability) are not part of the standard process. It is up to the official to decide if a finger is suited for enrolment or not

— Attempts at enrolment follow a pre-defined order, starting with the index finger, then thumb, middle finger, and finally the ring finger (*designations are conventional*). In the study, 89 % of both right and left index fingers were enrolled, with the right thumb enrolled for 2,5 % and the left thumb enrolled for 2,8 % of subjects.

— A process is mandated, requiring the applicant to try two fingers of one hand before the option to switch to the other hand is offered.

— From each hand, the best finger is selected for storage (according to the quality scoring method)

— From each fingerprint, three separate images are captured (by placing the finger three times on the scanner).

— For each image, the quality score is calculated.

— The systems matches the three images against each other to avoid substitutions.

— The best image, according to match score, is selected for storage.

QA software is used in the following way:

a) The software has to model the control flow so that the fingers are taken in the correct order

b) Pre-qualification of single fingerprints by NIST Fingerprint Image Quality (NFIQ) algorithm

c) There is always a series of 3 enrolled images per finger

d) The image with the best Bozorth3 reference match score average is chosen, rather than relying on NFIQ, since experience shows that the NFIQ values of fingers taken in succession are very similar. The first image was used for 21 % of fingerprint captures, whereas nearly 48 % of stored images came from the final of the three images for a single finger.

In order to reduce the Applicant's fears about the transmission of diseases and to improve the experience, fingerprint sensors should be regularly cleaned and disinfected. The image capture quality should also improve with regular cleaning. Enquiries should be made of the suppliers with regard to any religious connotations of using alcohol based cleaning solutions and whether any components contain materials known or suspected of causing allergies

Although it is generally recommended that full size optical and semiconductor sensors are deployed, there are applications for which 'swipe sensors' such as those found on certain laptop computers can be specified. Initial guidance on specification of these devices is to be found in the NIST biometric specification for Personal Identity Verification.

8.3.4 Tenprint systems

Tenprint systems are mostly designed for large scale identification applications, often with de-duplication functionality at the Identity Provider's data centre to ensure that a database of single identities is maintained. (Note that several sets of tenprints may be retained against a single individual's identity for operational reasons). In such cases, it is important to reduce the failure to enrol rate (FTE) to a minimum through:

— Optimised fingerprint capture hardware and environment (e.g. positioning of devices as mentioned above, cleaning contact surfaces in accordance with the suppliers schedule)

— Autocapturing software which collects images of the fingerprints on an automated cycle, performing quality checks at each capture, and retaining the best images (either singly, if segmentation and sequencing software is reliable – or otherwise as a single image)

— Use of trained attendants who can address problems as they arise, share their experience in quality improvement circles and are motivated to obtain the best images.

— Upgrades to the system as improved quality analysis software, hardware, etc are introduced.

The FTE rate (and associated operating parameters, such as total biometric collection time, NFIQ quality measures for each finger and an aggregated metric summarizing the general quality of the images from 10 fingers) should be monitored at a number of levels of granularity, from the global statistics for all enrolment stations, to a specific enrolment unit operated during a specific shift of an attendant. It is important that these parameters are tracked over time, taking corrective actions in accordance with a pre-defined policy once critical parameters drift out of permitted bands.

The root cause analysis of problem areas is helped immeasurably if more detailed data are available relating distributions of NFIQ scores to specific age and ethnic groupings, analysed by gender and NFIQ scores from previous enrolments (if available). Data from proprietary quality software may be of assistance, since often this consists of specific aspects of image quality which are aggregated into a single number for NFIQ. Attendants may be encouraged to note any untoward circumstances in a freetext file which can be collected as part of the metadata for the enrolment session.

In these systems, alternative biometric modalities may be collected, and tracking the KPIs related to these modalities (e.g. FTE, throughput time, quality scores) may support the root cause analysis of problems with tenprint collection.

8.3.4.1 Example process

A complete enrolment process for tenprint capture is described in the specification for the Personal Identity Verification (PIV) for US Federal Employees and contractor staff Among the specific elements it mandates in a conformant enrolment are:

— The attendant should inspect the fingers, checking that there is no dirt, coatings, gels, and other foreign materials (Step 1). Note that it may be useful for the attendant to be familiar with various types of skin irregularities associated with common medical conditions.

— The attendant should ensure that the imaging surface with which the finger is to be in contact is clean (Step 2).

— After acquisition of the images, these should be segmented into single finger images (preferably automatically) with the attendant making any fine adjustments (Steps 3 and 4).

— NFIQ quality scores are computed for each of the single finger images, and if not all are of value 1, 2 or 3, then image collection and segmentation is repeated up to three extra times (Steps 5 and 6).

— If a set of fingerprints has been acquired with all of the scores being 1, 2 or 3, then the images are digitally encoded in accordance with the US version of ISO/IEC 19794-4, Information technology – Biometric data interchange formats – Part 4: Finger image data (Step 8).

— If multiple sets of fingerprints have been collected with none of them scoring 1, 2 or 3 for all fingers, then compute a 'mean NFIQ' figure for each set collected, adding the values of NFIQ for the two thumbs and two index fingers, and select the set for which the mean is a minimum for encoding as above. (Step 7).

— Should there be no thumbs or index fingers, then the image set from the initial acquisition should be encoded.(Step 7).

Additional requirements for this process are:

a) The presence of the attendant at the time when the fingerprints are acquired.

b) A requirement on the Authority to follow measures to ensure the quality of acquisition of the fingerprints, and that the applicant does not present their fingers in a faulty way, either intentionally or unintentionally.

c) In particular, the attendant should pay attention so that the applicant cannot swap fingers or hands, cover any fingers or misalign or wrongly place them.

d) If the fingers extend beyond the edge of the platen, then they should be replaced at an angle to ensure capture of the complete finger.

8.3.4.2 Usability studies

Usability studies of the impact of positioning the hardware at different heights and angles have been reported by NIST. Two different scanners were used, and the quality of images captured had a different dependency on the height for each of the two devices. User satisfaction was a complex function of the height and angle at which the device was placed, as well as being dependent upon the height of the subject.

In US-VISIT, tests were undertaken to compare the user convenience of collecting fingers first from each hand, followed by the two thumbs (with the shorthand of 4-4-2) with collection of all fingers and thumb from a hand before starting on the other hand (4-1-4-1). The latter had the advantage of being able to complete one hand, then switch to the other, aiding those who were holding children, purses, etc. Researchers assessed throughput and quality. A disadvantage of the approach is that if the receiving system will only accept 4-4-2 sequences, then the thumb images had to be stitched together prior to submission.

8.3.4.3 Example of development of an enrolment process

An approach the development of an enrolment process by a national authority – collection of tenprint images for the European Visa information system – has been described in a presentation by the German Federal Office of Administration. The enrolments from the first stage of piloting were unacceptable with a very high failure to enrol rate of 75 %. Introducing a number of changes, such as new hardware, improving the training of personnel, making changes to the workflow, revisiting the requirements for quality (using additional metrics to NFIQ) and providing feedback to the enrolees resulted in significantly improved performance (with the failure to enrol rate reduced to 3 %).

8.3.4.4 Example of tenprint enrolment operation as part of a multimodal sequence

One of the largest deployments of a biometric system is the UIDAI implementation in India. As of 31 December 2011, more than 150 million enrolments of facial images, 10 slap fingerprints and both irises had been completed in over 36,000 stations operated through 83 agencies.

A recent report noted that 2,9 % of enrolees had poor quality fingerprints (with NFIQ scores of 4 or 5). Collection of the supplementary biometric – using the iris modality – led to the conclusion that 'the majority of people who have poor quality fingerprints actually have good quality irises', with only

0,23 % exhibiting both poor quality fingerprints and iris images The report further stated that, with the use of the supplementary modality, 99,86 % of the enrolled population had biometric data that was 'usable for de-duplication purpose'.

Prior to deployment, in the first half of 2010, the UID Authority of India carried out a proof of concept trial of the enrolment process using 75,000 subjects from three predominantly rural areas as well as well as schoolchildren around a larger city. This enabled different types of equipment and process to be examined and assessed the likely rates of incidence of absent and poor quality finger images and irises, as well as throughput times for the entire biometric process. A subsequent re-enrolment after three weeks provided additional data to cross-check the initial engagement with the subjects.

8.4 Vascular (Vein) authentication systems

8.4.1 General

Vascular authentication uses the blood vessel patterns of the vein in the subcutaneous tissue of the human body to discriminate between individuals. Vein patterns are read using near-infrared light. When a hypodermic vein is illuminated with near-infrared light, the reduced hemoglobin contained in the vein absorbs near-infrared light and the hypodermic vein creates a shadow on an image. Using image processing technology, the shadow pattern of the venous blood is processed from the captured image. The resulting patterns are used in biometric comparison, referencing features such as flow directions and bifurcations, or using the patterns themselves. In practice, veins in the hand, such as that those in a palm, the back of a hand, or a finger, are used for authentication because such these are easy to capture by a sensor.

8.4.2 Palm vein technology

Palm vein authentication systems generally use optical palm vein sensors for capture of the image pattern.

8.4.2.1 Capture device

Palm vein authentication is used normally without a cradle for hand. However, especially for those who are not familiar with this modality, a cradle for hand may be offered.

If a cradle for hand is used in enrolment, the cradle should be appropriately positioned so that it does not obstruct the imaging of the palm by the sensor.

Guidance from the GUI or audio prompts is the most effective way to provide support for users in placing their hands correctly .

8.4.2.2 Enrolment considerations

If there is only one hand available, then only the palm vein image or pattern from this hand will be enrolled.

Quality check algorithms and/or a verification test after enrolment should be used in the enrolment process.

8.4.2.3 Important considerations regarding hand placement

— Open the fingers lightly and position the hand over the sensor.

— Keep the hand horizontal over the sensor in the same way that you would when resting your hand on the surface of a desk.

— When viewing your hand from directly above, position it over the sensor such that the middle finger is aligned with the central axis of the sensor and the hand is straight.

— Try to keep the distance between palm and the sensor surface at an appropriate distance. Be careful not to bring the palm too close to the sensor surface.

— The recognition accuracy of the system is affected considerably by the quality of the enrolled palm vein pattern data. If the quality of enrolled data are not sufficiently high, there may be repeated false rejections even if the hand is positioned correctly for verification.

— The pattern of veins in the palm may not be enrolled correctly, and the recognition accuracy of the system may be impaired if:

  — an adhesive or other type of bandage is applied to, or wrapped around, the palm;

  — the palm is soiled, wet or injured.

— If problems are encountered when using the device on cold mornings, performance can be improved by warming the hands by for example, rubbing them together.

— Applicants should take care that their sleeves do not obscure any part of the palm.

8.4.3 Finger Vein technology

8.4.3.1 Capture device

Enrolment devices should be installed at a height between one's chest and waist, so as to improve their usability.

8.4.3.2 Enrolment considerations

Finger vein patterns of the frontal side (fingerprint side) of a finger are enrolled.

Biometric references from the veins of two or more fingers are enrolled to make at least one finger available for authentication should one be are unavailable due to physical injury

At enrolment, applicants can select fingers from both hands for enrolment.

Index fingers, middle fingers and ring fingers are recommended for enrolment because these fingers can be positioned on the device in a steady position during enrolment or recognition

8.4.3.3 Quality of the biometric reference

Attended enrolment is essential to optimize the capture process and to enrol high quality references. Some users may place a finger tip on the image capture sensor in the belief that the device is a fingerprint sensor

For each finger, more than three finger vein images are captured, with a quality assessment performed for each image, and repeating the transaction if the quality threshold has not been reached. Features are extracted from the images as candidates for inclusion in a biometric reference with features of the highest quality being selected.

A verification is recommended after enrolment to confirm that the reference is of an adequate and repeatable quality

9 Guidance relating to enrolment for mobile biometric applications

9.1 Best practice guidelines

In 2009, NIST published best practice recommendations for the use of biometric mobile Identification devices using fingerprint, face and iris modalities. Such devices could be used for a number of government or private sector applications, but the report focused on the needs of government organisations in the law enforcement, defence and homeland security sectors. Mobile systems are more challenging both for the device supplier as well as attendants, since the units must be portable and robust, the environment of operation is less controlled and the design of hardware, software and enrolment processes has to