EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

Integrity of Aeronautical Information: Principles - Data and Quality Management

CHAIN

Controlled and Harmonised

Aeronautical Information Network

CHAIN/0028

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EUROPEAN AIR TRAFFIC MANAGEMENT

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Abstract

This document provides the high-level overview of a set of documents which provides guidance for organisations wishing to improve and enhance the integrity of their information.

Furthermore, the key statements of requirement which apply throughout the data processing chain are provided. These typically cover the management of the process, the data itself and its quality.

Although provided as guidance only, it is written in a style to allow States to use as regulatory material.

Keywords

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EXECUTIVE SUMMARY

The need for high-integrity data has never been greater and continues to increase, in particular, as new and improved navigation techniques are introduced.

This document presents the guidance on how the integrity of information may be improved and maintained. It applies to those organisations within States who operate within the data processing chain, from the point of origination, through to the publication by the AIS and distribution to the next intended user.

It is supported by four further documents, three of which address the specific areas of data origination, exchange and publication. The fourth supporting document provides the meanings and definitions of the abbreviations and terms used throughout the other documents.

Within this paper the key management activities covered are:

Organisational Management
The need for the organisation to establish adequate management of the processes by which the required integrity levels are ascertained and met.

Quality Management
Details the need for a Quality Management System to help ensure the compliance of day-to-day operations throughout the organisation.

Process Management
The integrity of data may only be assured through the provision of controlled processes.

Data Management
Data must be subjected to a management process, ensuring that it is adequately defined, processed and published.

Configuration Control
Data must be the subject of configuration management to ensure true traceability through each successive update.

Archive
Once data has been published, it must be archived for subsequent reuse at a later date or available for investigation.

Overall, it is hoped that through adoption of the guidance material provided, States can ensure that the information published meets both the requirements of ICAO and the needs of the end-user.

1. THE INTEGRITY OF AERONAUTICAL INFORMATION

1.1 Introduction

European Air Traffic Management (ATM) is faced with a significant and continuous increase in air traffic demand for the next fifteen years or so. In response to this demand, the EUROCONTROL 'ATM Strategy for the years 2000+' (ATM Strategy) has been developed to provide the strategic framework for change. The ATM Strategy describes the objectives, process and measures by which the forecast demand may be satisfied while improving aviation safety. It identifies the role of Aeronautical Information Services (AIS) as follows:

> *'Aeronautical Information Services will be improved and developed within the ECAC area to provide a harmonised, co-ordinated service delivering quality assured information for all phases of flight (as defined within the Strategy, see Figure 1). This will be achieved through the increased use of automation, the introduction of quality management and the evolution of aeronautical information provision to meet the interoperability requirements of system-wide information management.'*

The ATM Strategy also records the need for civil/military exchange of information. This is essential for civil-military co-operation and can only be achieved if the systems of each are mutually compatible, interoperable or integrated.

Figure 1: Phases of Flight

1.2 Harmonisation of the Aeronautical Data Process

The provision of Aeronautical Information of sufficient quality, accuracy, timeliness and granularity is a recognised key enabler of the present and future ATM systems. However, a number of EUROCONTROL studies have demonstrated that Aeronautical Information does not currently meet the integrity values required to serve specific applications. One key weakness, amongst others, is in the provision of flight critical data.

It was, therefore, considered necessary to introduce harmonisation through the development of guidance material documents to achieve the necessary aeronautical data accuracy and integrity performance, particularly covering the data chain from origination to publication, as required by ICAO.

1.3 Objective

The objective, therefore, of the guidance material is to ensure that aeronautical data of high quality and integrity are provided throughout the data chain, through the use of processes and procedures which eliminate manual data entry and/or transfer.

It has been prepared through the analysis, consolidation and presentation of requirements given within existing standards, combined with best practise.

Standards which have been assessed and from which requirements may have been derived include, ICAO, ISO, EUROCAE and EASA.

1.4 Scope and Applicability of Harmonisation

The Aeronautical Information data process extends from the original data sources (e.g. surveyors, procedure designers) through AIS and publication to the end-users of the data in aeronautical applications. That data process is not simple: it is a series of complex functions within a sequential flow, particularly from data origination through to the publication of the State Aeronautical Information Publication (AIP) and other media derived from the AIP for end-use.

The aeronautical applications and databases include, but are not limited to those used for navigation, flight planning, and terrain and obstacle avoidance calculations. The Aeronautical Information data process and those applications apply equally to bodies operating in either the civil and/or military aviation domain: consequently, the guidance material documents apply equally to both.

Figure 2: Aeronautical Data Chain, shows the overall data process chain from origination to end-use. The guidance material, however, only applies to those elements of the process shown in green, from origination through to publication. Thereafter, it is considered that the requirements published in ED-76 (Standards for Processing Aeronautical Data) apply. That said, the generic process described in section 3 does place the whole chain in context and much of the material provided would be equally applicable throughout the complete process, to data use.

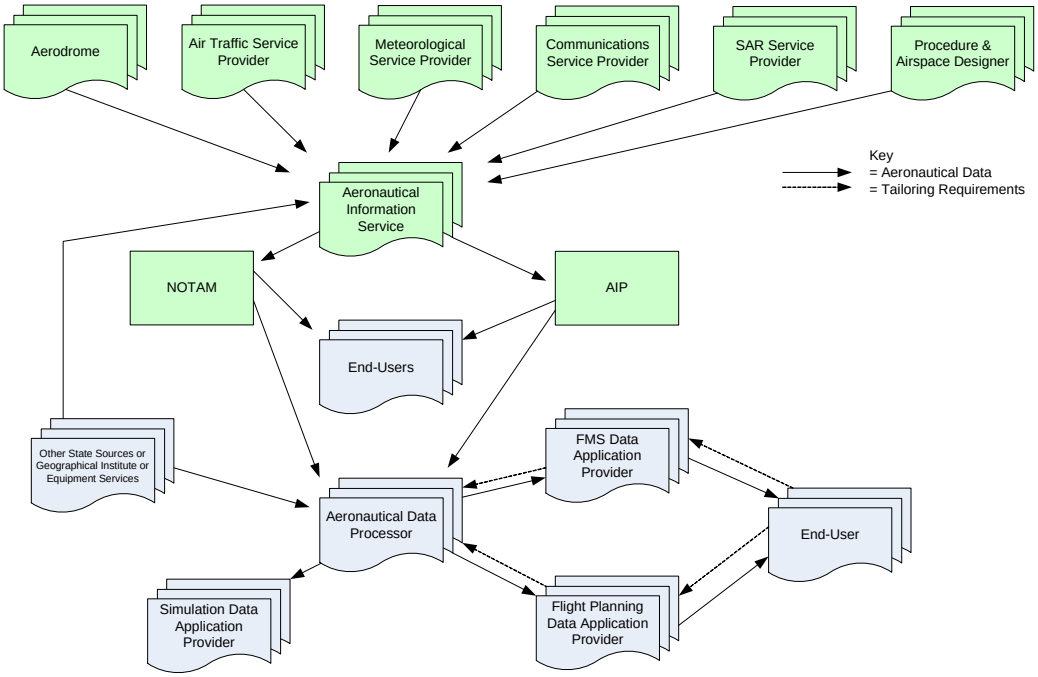

Figure 2: Aeronautical Data Chain ref. Industry Standards

1.5 Roles and Responsibilities

The actual structure and operating principles of the various organisations which contribute to the data processing chain vary greatly between States. This material has been prepared in a manner which does not require any specific structure to exist.

Rather, as part of implementation, it is expected that a State body or bodies involved in the rollout process, be it individual organisations or the State regulator, will

allocate responsibility for the various requirements within this guidance material to the physical roles existing within the State.

Table 1: Document Applicability provides a high-level mapping of the functions within the data processing chain and the guidance material provided to assist in this activity.

1.6 Harmonised Guidance Material

A set of guidance material documents has been produced to support the implementation of processes, procedures and systems throughout the Aeronautical Information data processing chain. These documents are written so that States can adopt them as national regulatory material.

This document 'Integrity of Aeronautical Information Principles – Data and Quality Management' provides a high level overview of both the processes and requirements which are applicable throughout the data chain.

It is supported by a separate Abbreviations and Definitions document and three documents which detail three specific functions of the generic data process from origination to publication:

a. Integrity of Aeronautical Information – Data Origination

   Sets out the minimum requirements for the origination of navigation-related data applying to all organisations involved in the data origination process. The requirements cover the surveying of radio navigation aids and points whose coordinates contribute to air navigation.

   Note: This document is prepared and issued by the EUROCONTROL Navigation (NAV) domain in collaboration with the Air Navigation Team. Use is made of this document within the CHAIN activities although its maintenance remains the responsibility of the NAV domain.

b. Integrity of Aeronautical Information - Data Exchange

   Provides the requirements necessary for the protection of data in transmission from one point to another, be it within an organisation or between organisations.

c. Integrity of Aeronautical Information - Data Publication

   Sets out the minimum requirements for the process involved in the provision of aeronautical data publication and applies to all organisations involved in the publication process for Aeronautical Information.

d. Integrity of Aeronautical Information – Abbreviations and Definitions

   Provides abbreviations and detailed definitions applicable to all documents and organisations.

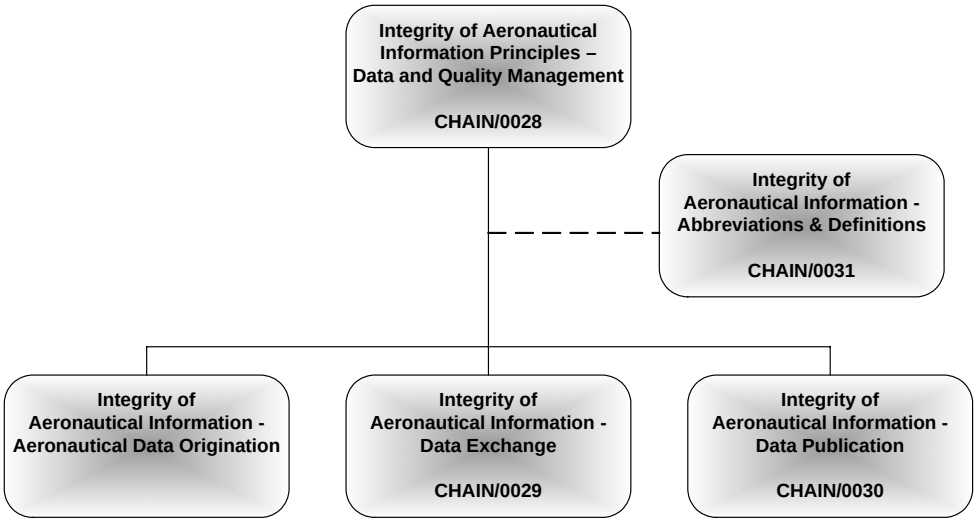

Figure 3: Document Relationship

1.7 Status of Guidance Material Documents

1.7.1 Responsible Body

These documents have been developed and shall be maintained by EUROCONTROL.

1.7.2 Technical Corrigenda and Amendments

These documents are kept under review to ascertain required amendments or technical corrigenda by EUROCONTROL.

1.7.3 Status of Document

These documents contain guidance material but are written in a style that States can adopt as regulatory.

1.7.4 Editorial Conventions

The following editorial practice has been followed in the writing of specifications:

- for prescriptive elements the operative verb '*shall*' is used;
- for recommended elements the operative verb '*should*' is used;
- for guidance elements, the operative verb '*may*' is used.

1.7.5 Relationship to Standards Documents

The guidance material contained in the documents is designed to help comply and measure compliance with the following ICAO SARPs:

- ICAO Annex 4 (Aeronautical Charts);
- ICAO Annex 11 (Air Traffic Services);
- ICAO Annex 14 (Aerodromes);
- ICAO Annex 15 (Aeronautical Information Services);
- ICAO Doc 9674 (World Geodetic System — 1984 (WGS-84) Manual);

- ICAO Doc 8168 (PANS OPS);

and other ICAO supporting material.

1.8 Applicability of Guidance Material Documents

This document, 'Data and Quality Management', the 'Data Exchange' document and the 'Abbreviations and Definitions' documents, apply to all organisations/functions in the data process chain.

The 'Data Publication' document is only applicable to the AIS function in each State.

It is the responsibility of all organisations/functions to determine the extent to which the supporting documents apply to them and Table 1 below should, therefore, be taken as a guide only.

Role / Function	*Data Origination*	*Data Exchange*	*Data Publication*
Surveyors	✓	✓	
Aerodrome/airport authorities	✓	✓	
State/National AIS		✓	✓
Civil Aviation Authorities (CAAs)	✓	✓	
Air Navigation Service Providers (ANSPs)	✓	✓	
Air Traffic Service Providers (ATSPs)	✓	✓	
Airspace planners	✓	✓	
Procedure designers	✓	✓	
External Data Originators*	✓	✓	
Suppliers of Equipment requiring survey data (e.g. TAWS)	✓	✓	

Table 1: Document Applicability

* These include, but are not limited to national mapping agencies, terrain/obstacle database providers, etc.

1.8.1 Applicability of This Guidance Material

All organisations *shall* determine the extent to which this document applies to their own responsibilities and functions.

[CHAIN-0028-1010]

Data and quality management *shall* be deemed to be necessary throughout the data process chain from origination to publication by the relevant National Administration responsible for Aeronautical Information Services (AIS).

[CHAIN-0028-1020]

Note: This document applies to all organisations in the data process chain, which may include (but is not limited to):

- Surveyors;
- Aerodrome/airport authorities;
- CAAs;
- State / National AIS;
- ANSPs;
- ATSPs;
- Airspace planners;
- Procedure designers;
- Suppliers of equipment requiring survey;
- Other data originators (e.g. national mapping agencies, terrain/obstacles database providers, etc).

If any aspect of the work associated with the origination, processing[1] or publication of data is delegated to another agency, the delegating body *shall* remain responsible for ensuring the application of this guidance material.

[CHAIN-0028-1040]

By adoption of this guidance material, States *shall* be considered to have met, with regard to data integrity, their obligations under the Single European Sky's common requirements for assuring safe and efficient provision of service.

[CHAIN-0028-1050]

States *may* wish to have independent verification of their compliance with the provisions of this guidance material.

[CHAIN-0028-1060]

The National Supervisory Authority (NSA) for a State *may* wish to verify compliance with the provisions of this guidance material.

[CHAIN-0028-1070]

Note: The NSA may delegate this verification to another body or organisation such as another approved service provider within the community.

1.9 Requirements References

Each statement of guidance, be it recorded using 'shall', 'should', or 'may', has been uniquely identified with a reference number which is enclosed in square brackets [ ].

These reference numbers will be used to allow requirements to be traced from the compendium of standards, through guidance and to assessment of actual performance by a State, through its auditing process.

[1] Processing is used to refer to any action performed throughout the data chain from the point of origination through to the point of issuing an AIS Publication.

2. THE REGULATORY SITUATION

2.1 ICAO Requirements for Data Integrity

ICAO Annex 15 (AIS), together with Annexes 4 (Aeronautical Charts), 11 (Air Traffic Services) and 14 (Aerodromes), ICAO Doc 9674 (World Geodetic System — 1984 (WGS-84) Manual), ICAO Doc 8168 (PANS OPS) and other supporting material, detail the data quality requirements (accuracy, resolution and integrity) each signatory State *shall* meet in regard to aeronautical data.

[CHAIN-0028-0010]

Annex 15 also specifies that the quality system employed by each State *shall* provide users with the necessary assurance and confidence that distributed aeronautical information/data satisfy their stated requirements.

[CHAIN-0028-0020]

In addition, ICAO requires that data be traceable from origination to publication, the use of appropriate procedures during each stage of data production or data modification processes being needed to achieve this.

2.2 Single European Sky

New regulations, mandates and implementing rules are being developed as part of the introduction of the European Commission's Single European Sky. At the time of writing these have not, as yet, been fully publicised and released.

One area of particular relevance to this guidance material is the issue of a mandate by the European Commission (EC) aimed at enforcing an improvement in the quality of aeronautical information; the so called "Aeronautical Data Integrity Mandate". This mandate has been issued under the Single European Sky (SES) Regulation aimed at the introduction of improved interoperability: The Interoperability Regulation.

It should be noted that this mandate, although specifically mentioning integrity in its title, is primarily aimed at data quality improvements, integrity being only one component. The four components from which quality is comprised being:

a. Accuracy;

b. Resolution;

c. Integrity;

d. Timeliness.

The development of this guidance material has been performed in such a way, and with sufficient reference to those responsible for developing the possible corresponding regulatory material, that the principles laid down fully support the desires and wishes of the Single European Sky.

3. A GENERIC AERONAUTICAL INFORMATION DATA PROCESS

3.1 Introduction

In order to ensure the end-to-end integrity of aeronautical data, it is essential that the data process is fully identified, mapped and understood. The establishment of this process is critical as it identifies the key participants, processes, inputs and outputs that must be addressed in any regularised process.

Any process is made up of three key elements; Inputs, Actions and Outputs. The end-to-end data integrity process is no exception. Data originators (e.g., surveyors, ATS Personnel, service organisations, etc.) will initiate inputs to the process. The activities that are then performed in order to turn the inputs into the outputs will form actions associated with the process.

The outputs of the process will be the products that meet the specific need of users for aeronautical data. These users may be human-based or system-based. A pilot operating in accordance with the Visual Flight Rules (VFR) using information derived from an AIP, or a Flight Management System (FMS) using its integrated geospatial data, are examples for each type.

3.2 Organisations

The generic Aeronautical Information data process identifies the following main functional groupings:

a. Surveyors;

b. Requesting Authorities – CAAs, ANSPs, ATSPs, aerodrome/airport authorities and, possibly, equipment suppliers (such as those developing terrain awareness warning systems – TAWS) that require surveys of, and survey information for, aeronautical facilities (Navaids, aerodromes, obstacles, etc.);

c. Originating Authorities - organisations responsible for creating facilities related to other ATM facilities. These organisations may perform procedure or airspace design, airspace planning etc. and create facilities such as ATS routes or instrument flight procedures;

d. Publishing Authorities - usually States' AIS that issue Aeronautical Information.

3.3 A Process

The generic data process may be best described by way of a diagram supported by explanatory text. It should be understood that although this process is designed to describe, at a high-level, those processes which have been found to exist within representative States, it may not immediately appear to fit the practices of all States. However, once its description is fully understood, readers should find that it provides a reasonable approximation to their individual process flow.

3.3.1 The Process Diagram

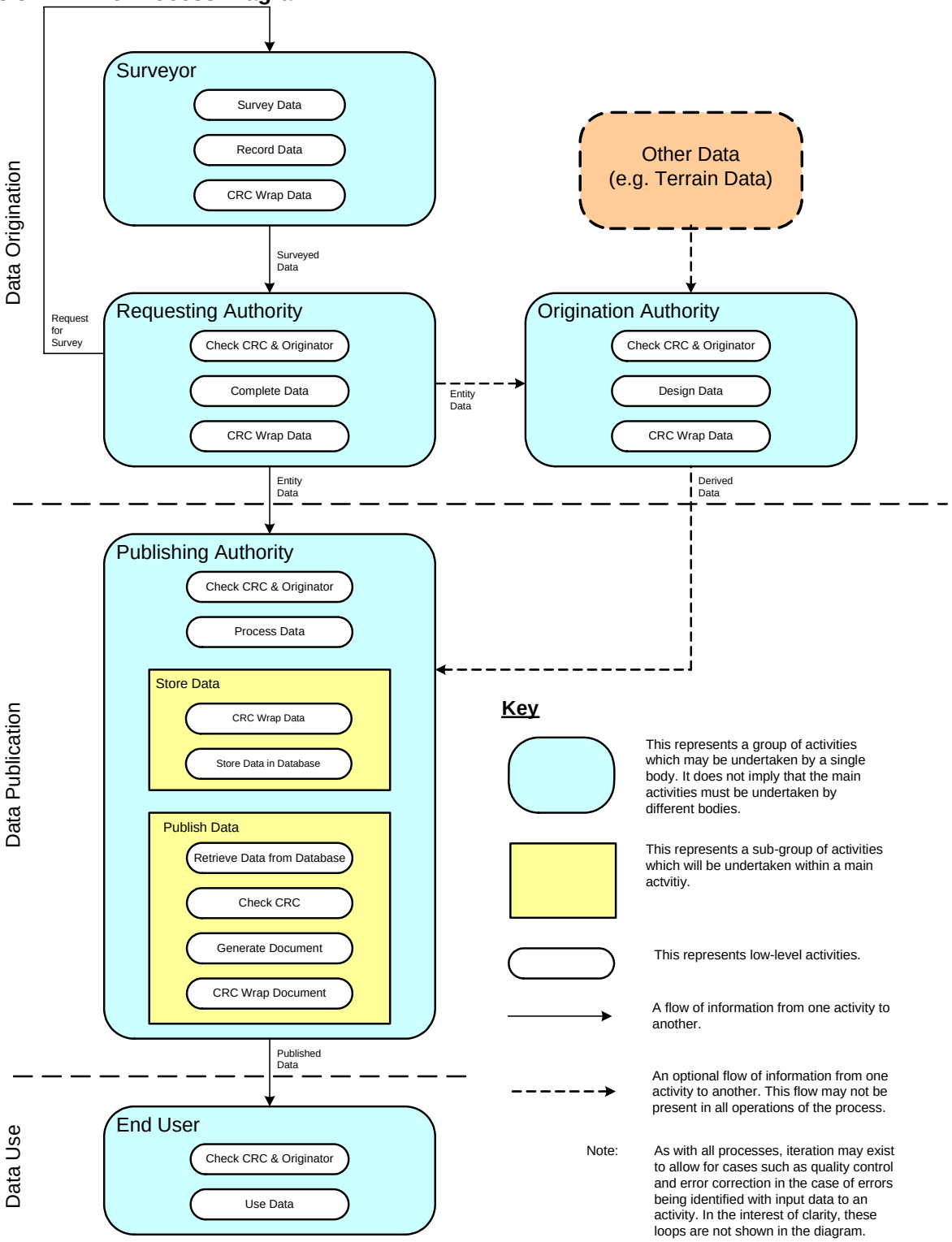

Figure 4: The Process Diagram

3.4 A Generic Process – A High-Level View

3.4.1 General

The following paragraphs outline the generic process. A detailed description can be found later in this document.

A high level generic process for all Aeronautical Information/data is as follows:

a. Data/information is provided by defined/approved/certified, ISO9001 : 2000 (series as appropriate), ISO TC211[2] accredited companies in accordance with legal and regulatory requirements;

b. Data/information is held in electronic media, preferably through use of standard worksheets which are used throughout the process;

c. In order to ensure that data/information being transferred electronically is received at the next activity without having suffered any change, be it accidental or malicious, it is necessary that a Cyclic Redundancy Check (CRC) value be calculated. This activity is usually referred to as CRC wrapping (see Appendix A);

d. Data/information being transferred electronically is encrypted to provide further protection to its integrity;

e. Data/information is checked/verified by the Responsible Organisation (Aerodrome Authority, ANSP, CAA etc) if provided by a subcontractor (e.g. surveyor);

f. Data/information is transferred electronically to AIS;

g. AIS verifies completeness and integrity of data;

h. AIS processes the data to publication using electronic media.

3.4.2 Data Origination

Data Origination addresses the functions performed by Requesting Authorities, Originating Authorities, Surveyors and any other third party organisations supplying aeronautical data to such authorities.

Those functions are:

3.4.2.1 Surveyed Data:

a. Geodetic datum specification and use;

b. Establishment of Aerodrome survey control networks;

c. Recommended procedures for achieving minimum data requirements;

d. Monumentation of survey control stations;

e. Production of survey reports;

f. Ongoing maintenance of data;

g. Data management and quality assurance;

h. Document configuration management.

[2] TC211 is the International Standards Organisation group specialising in the standardisation of digital geographic information. The relevant ISO standards are currently in the process of being adopted by ICAO.

3.4.2.2 Calculated and Derived Data (Originating Authority activities):

a. Geodetic datum specification and use;

b. Airspace design;

c. Instrument flight procedure design;

d. Audit;

e. Data management and quality assurance;

f. Document configuration management.

3.4.3 Data Publication

Data publication addresses the functions undertaken by, usually, State AIS authorities, or their delegated agent(s), receiving surveyed, calculated and derived data from their receipt to publication. These apply to both electronic and paper publication. Data publication includes:

a. Document management:

- Quality assurance;
- Data management;
- Document processing requirements;
- Document modification;
- Document configuration management.

b. Document publication tool;

c. Guidance for specific publication types.

4. PROCESS MANAGEMENT

4.1 Introduction

The integrity of the information is not only dependent on the use of check values such as Cyclic Redundancy Checks (CRC) but also upon the process used to originate, manipulate and publish the information. Indeed, the integrity of the information at the end of the data process will only be as good as the weakest point of the chain.

It is therefore essential that the process applied in originating, processing and publishing data is clearly defined, achieves the necessary requirements and is executed accordingly. Where possible, automated processes should be adopted and manual processes kept to a minimum.

4.2 Quality Process

Each organisation involved in the data chain from the point of origination through to publication to the next intended user *shall* have a defined quality process.

[CHAIN-0028-2010]

The quality process *shall* ensure that the integrity of information, as defined within the ICAO Annexes, is achieved and maintained.

[CHAIN-0028-2020]

Recommendation: It is recommended that the International Organisation for Standardisation (ISO) 9000 series of standards for Quality Management Systems be adopted.

[CHAIN-0028-2030]

Senior management within each organisation *shall* ensure the effective and efficient operation of service provision, the support processes and the associated process network, such that the organisation has the capability of satisfying its interested parties.

[CHAIN-0028-2040]

The quality processes established *shall* pay particular attention to validation of processes:

a. for high value and safety critical products;

[CHAIN-0028-2050]

b. where deficiency in a product will only be apparent in use;

[CHAIN-0028-2060]

c. where verification of a product is not possible; and

[CHAIN-0028-2070]

d. which cannot be repeated after the event (e.g. distribution of a product).

[CHAIN-0028-2080]

Changes to the quality process *shall* be identified, recorded, evaluated, reviewed and controlled in order to understand the effect on other processes and the needs and expectations of customers and other interested parties.

[CHAIN-0028-2090]

Note: The quality process should not be considered a static manual. It should evolve over time as the processes are improved, demands change and best practise is established and implemented.

4.3 Interface Management

4.3.1 Customers

The organisation *shall* determine:

a. Any requirements specified by the customer, including the requirements for delivery and post-delivery activities;

[CHAIN-0028-2100]

b. Requirements not stated by the customer but necessary for specified or intended use, where known;

[CHAIN-0028-2110]

c. Statutory and regulatory requirements related to the product; and

[CHAIN-0028-2120]

d. Any additional requirements determined by the organisation.

[CHAIN-0028-2130]

4.3.2 Suppliers

Where a State is provided services or information by another organisation, including another Service Provider, this arrangement *shall* be formalised.

[CHAIN-0028-2140]

Arrangements for the provision of information *should* encompass all data originators such as Airports, Air Traffic Service Providers and other States AIS.

[CHAIN-0028-2150]

States *should* consider the use of Service Level Agreements to formalise arrangements between organisations.

[CHAIN-0028-2160]

The formal arrangements made with organisations for the provision of service *shall* include details of data quality (accuracy, resolution, integrity and timeliness) and format of provision.

[CHAIN-0028-2170]

Suppliers *shall* be involved in the definition of the processes by which information is supplied, such that a mutually agreed interface is specified.

[CHAIN-0028-2180]

States *shall*, where practicable, ensure the direct transfer of information between the organisations to facilitate a controlled exchange during which the integrity of the information is maintained.

[CHAIN-0028-2190]

Recommendation: When able to, data providers *should* be encouraged to provide information as early as possible and not to wait until the end of the delivery schedule.

[CHAIN-0028-2200]

The units of measurement used for information *shall* be standardised throughout the data processing chain based on ICAO SARPS or, in their absence, based on standards selected within the State.

[CHAIN-0028-2210]

4.4 Introduction of Systems

The Single European Sky's requirements for interoperability *shall* be taken into account when designing systems.

[CHAIN-0028-2220]

States *should* ensure that any systems introduced within the data chain, from the point of origination to the point of distribution of publications to the next intended user, are compliant with this guidance material.

[CHAIN-0028-2230]

Before introduction, States *should* verify the compliance of the system with this guidance material.

[CHAIN-0028-2240]

5. AERONAUTICAL DATA MANAGEMENT

5.1 General

This section specifies requirements and recommended methods/practices for:

a. Data management processes and practices that apply to all organisations involved in aeronautical data origination including Data Surveyors;

b. The management of the processes and functions undertaken in the execution of data management.

The methods and tools to be used in order to comply with these requirements are not specified, unless deemed absolutely necessary.

This data management standard is required in order to:

a. Ensure compliance of the data quality reported to National Administrations, as specified in this document;

b. Ensure that the data management processes are carried out such that the integrity of the data is not jeopardised at any point in the process;

c. Design the data collection and handling processes such that due regard is paid to the risk of error;

d. Operate multi-layer data integrity management tools that enable the detection of discrepancies against known and tested logic and the appropriate rules;

e. Ensure that data management tools are developed and managed in a controlled manner to ensure the integrity of the overall process;

f. Provide for the development of appropriate metadata to ensure that complete audit trails are available at all times.

Note: For information purposes, this section is based primarily upon material found in the following related standards:

a. ICAO Annex 4, Aeronautical Charts;

b. ICAO Annex 15, AIS;

c. EUROCAE ED-76, 'Industry Standards for Processing Aeronautical Data';

d. EUROCAE ED-77, 'Industry Standards for Aeronautical Information';

e. EN ISO 9001:2000, 'Quality Management Systems – Requirements';

f. EUROCAE ED-98A, 'User Requirements for Terrain and Obstacle Data';

g. EUROCAE ED-99A, 'User Requirements for Airport Mapping'.

For more complete guidance, readers are advised to consider EUROCAE ED-76 which describes the activities in the Aeronautical Data Chain from a data centric[3] perspective with data transferring from party to party along the chain until it reaches its end-use[4]. In reality, a series of complex flows exist, with the first flow from data origination being data centric through to the publication of the State AIP where, in

[3] The term 'data centric' is used to describe those instances where the data is itself of primary importance rather than any document or end product that *may* be created.

[4] ED-76 scope extends beyond that of CHAIN to the end-use of data. Whilst the scope of CHAIN is limited to the upstream operations, much of the guidance provided is equally applicable for downstream operations.

many cases, the flow becomes document centric[5] – as a result of the requirement to produce the data in the form of a document. From this point onwards to the end-user:

a. A conversion from document centric to data centric is carried out by agencies such as the data suppliers, and then

b. The transmission of the data and the requirement for the protection of its integrity.

Figure 5: Aeronautical Data Chain presents the concept of the Aeronautical Data Chain.

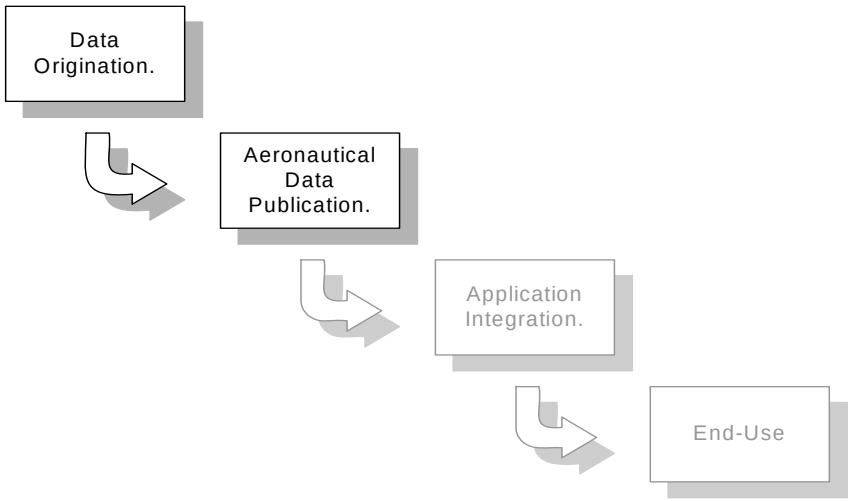

Figure 5: Aeronautical Data Chain

The introduction of complex flows within any of these elements of the Aeronautical Data Chain, such as the transition from data to document or from data import to data export, creates barriers to the maintenance of the integrity of the aeronautical data.

Although, to an increasing extent, source data is being produced, distributed and stored electronically, transformation from one environment to another provides the greatest challenge to the protection of data integrity through the process.

5.2 Aeronautical Data Integrity

ICAO Annexes 4, 11 and 15 state that, '*the Contracting States shall ensure that the integrity of aeronautical data is maintained throughout the data process from survey/origination to the next intended user*'.

Aeronautical data integrity requirements are based upon the potential risk resulting from the corruption of data and upon the use to which the data element is put by the end-user. Consequently, the following classification and data integrity levels apply:

- **Critical Data, integrity level $1x10^{-8}$:** there is a high probability when using corrupted critical data that the continued flight and landing of an aircraft would be severely at risk with the potential for catastrophe;

[5] The term 'document centric' is used to describe those instances where the end product (in this case a paper or electronic document – e.g. an AIP) is of primary importance.

- **Essential Data, integrity level $1x10^{-5}$:** there is a low probability when using corrupted essential data that the continued flight and landing of an aircraft would be severely at risk with the potential for catastrophe; and
- **Routine Data, integrity level $1x\ 10^{-3}$:** there is a very low probability when using corrupted routine data that the continued flight and landing of an aircraft would be severely at risk with the potential for catastrophe.

Full details of the aeronautical data quality requirements related to classification and data integrity are provided in ICAO Annex 15 which also specifies the need for the protection of the integrity of this aeronautical data whilst stored or in transit to another system.

Furthermore, EUROCAE presents Figure 6: Data Processing Model which provides a more detailed view of the Data Publication element of the process shown earlier in Figure 4.

This process relies heavily on the validation, verification and conformance confirmation at each of the major steps of the process, against the established criteria for the stages of Receive, Assemble, Translate, Select, Format and Distribute. It may be seen that there are many points at which the integrity of data must be assured.

The model also relies heavily on the establishment of the appropriate acceptance criteria at each phase. These criteria must include validation and conformance with the requirements of the next phase in the process flow. For example, data integrity requirements, completeness of the data set or sub-set and other structural considerations.

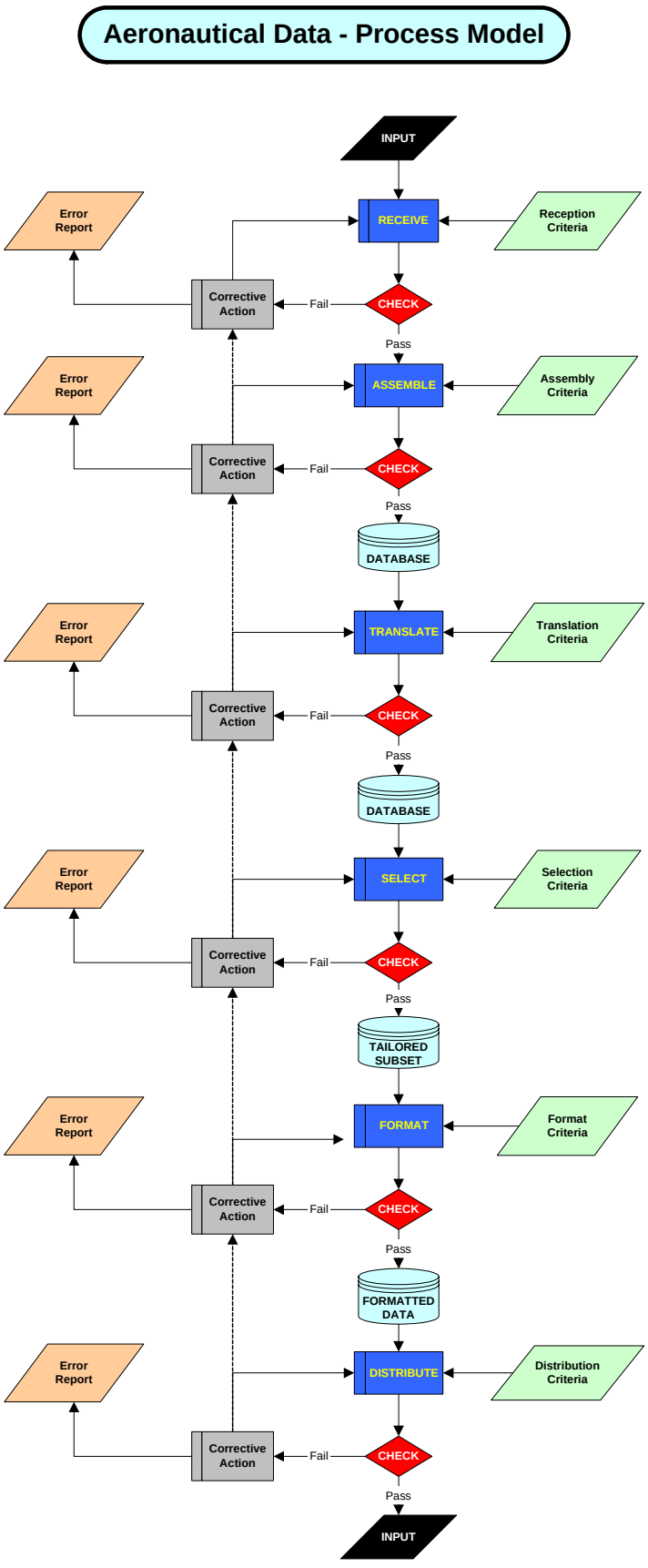

Figure 6: Data Processing Model

All data *shall* be classified according to these categories, as laid down in the ICAO Annexes. Where a data item has not been specifically categorised by ICAO, a hazard analysis *shall* be performed to ascertain its allocation to one of these three categories.

[CHAIN-0028-3010]

The ICAO prescribed monitoring methodology is the Cyclic Redundancy Check (CRC) and, in order to provide the required level of integrity for critical and essential aeronautical data, a 32- or 24-bit CRC algorithm *shall* apply respectively.

[CHAIN-0028-3020]

Routine data *shall* be protected through the use of, as a minimum, a 16-bit CRC.

[CHAIN-0028-3030]

EUROCAE ED-77 also sets industry requirements for maintaining data integrity when preparing databases for use, for example, in FMS.

To ensure interoperability, it is essential that a common CRC algorithm be used. ICAO Annex 15 does not specify an algorithm, but an algorithm applicable to Microwave Landing System (MLS) data is specified in ICAO Annex 10 and has been incorporated into the European AIS Database (EAD) and Data Quality Tool Set (DQTS).

For conformance, a single CRC Algorithm for general use in aviation *shall* be used.

[CHAIN-0028-3040]

Recommendation: The use of a common CRC algorithm is beneficial and States *should* consider the use of the CRC-32Q algorithm for all data protection.

[CHAIN-0028-3050]

From a practical standpoint, the diverse treatment of data due to differing classifications of data is not possible. It is, therefore, necessary to ensure that the whole data processing system is designed to facilitate the protection of the highest classification of data present within that system at any one time.

The verification of CRC on retrieval, receipt and distribution *shall* be functions of these processes, as discussed later.

[CHAIN-0028-3060]

However, it is important to note at this stage that, since the CRC will accompany the data throughout the whole process and through the whole data chain, it is vital that the CRC value be correct at the first possible point within the managed process.

In order to best maintain the integrity of information throughout the data chain, States *should* aim to implement systems in which the information is maintained electronically.

[CHAIN-0028-3070]

5.3 Data Requirements

5.3.1 General

In order for States to correctly process their data, it is essential that the requirements with which the data must be associated are fully understood. In order to establish these requirements, States must consider the use of the data, which may be ascertained through the application of assessments such as Safety or Hazard Analyses, as well as the regulatory situation.

States *should* establish the intended use of all data and the associated criticality level through the application of safety analysis techniques.

[CHAIN-0028-3075]

5.3.2 Defining Requirements

All organisations *shall* ensure that data quality characteristics are correctly established for the data's intended usage.

[CHAIN-0028-3080]

All organisations *shall* ensure that the data quality requirements are clearly documented.

[CHAIN-0028-3090]

The data *shall* have the agreed and documented data quality, characterised by:

a. The accuracy of the data (expressed in the same units as the data itself);

[CHAIN-0028-3100]

b. The resolution of the data;

[CHAIN-0028-3110]

c. The confidence (termed 'assurance level') that the data is not corrupted while stored or in transit;

[CHAIN-0028-3120]

d. The ability to determine the origin of the data (termed 'traceability');

[CHAIN-0028-3130]

e. The level of confidence that the data is applicable to the period of intended use (termed 'timeliness');

[CHAIN-0028-3140]

f. The confidence that all of the data needed to support the function is provided (termed 'completeness');

[CHAIN-0028-3150]

g. The format of the data meets the requirements stated in this document plus any other standards imposed by National Administrations or Regulatory Authorities, as appropriate.

[CHAIN-0028-3160]

5.3.3 Ensuring Compliance

Each organisation in the aeronautical data chain *shall* have a system for recording and handling problems reported during data management and those reported by the subsequent user in the aeronautical data chain after delivery of the data.

[CHAIN-0028-3170]

All problems reported with the data *shall* be analysed.

[CHAIN-0028-3180]

Any errors or anomalies *shall* be resolved and documented.

[CHAIN-0028-3190]

All errors or anomalies detected in the data *shall* be resolved prior to delivery.

[CHAIN-0028-3200]

Information concerning any errors or anomalies found in the data after it has been delivered, *shall* be made available to all affected users.

[CHAIN-0028-3210]

The means by which errors or anomalies have been resolved *shall* be reported immediately to all affected users.

[CHAIN-0028-3220]

5.3.4 Data Validation and Verification

All data received from sources other than another State's AIS *shall*, if possible, be validated and/or verified before entering the processing chain.

[CHAIN-0028-3230]

Note: The techniques available are wide ranging and the most appropriate should be selected based upon the data item in question.

Note: Sufficient resources should be provided to permit each point within the data chain to undertake adequate validation and verification.

All data processed *shall* be verified to ensure its correctness before transmission to the next actor in the data chain.

[CHAIN-0028-3240]

Suitable verification may take one, or more, of three approaches:

a. Feedback

   Feedback testing is the comparison of a data set between its output and input state. A common method of feedback is manual confirmation, whereby data is copied to a new location and confirmed to be correct.

b. Independent Redundancy

   Independent redundancy testing involves processing the same data through two (or more) independent processors and comparing the data output of each process.

c. Update Comparison

   Updated data can be compared to its previous version. This comparison can identify all data elements that have changed. The list of changed elements can then be compared to a similar list generated by the supplier. A problem can be detected if an element is identified as changed on one list and not on the other. This method can also be used to reduce the amount of data that is subjected to other forms of verification, concentrating on only those elements that have changed.

5.3.5 Data Formats

5.3.5.1 Data Conversion

Whenever a conversion is necessary from one unit of measurement to another, the conversion value provided in ICAO Annex 5 *shall* be used.

[CHAIN-0028-3250]

Note: Conversions *shall* include:

a. map projection, which is a method using mathematical functions to convert ellipsoidal co-ordinates (excluding height) to two-dimensional Cartesian co-ordinates, or vice-versa;

b. coordinate conversion of ellipsoidal co-ordinates (including ellipsoidal height) to three-dimensional Cartesian co-ordinates, or vice-versa;

c. unit change by application of a multiplication factor (for example, metres to feet) or an algorithm (for example, radians to degrees, minutes and seconds).

5.3.5.2 Co-ordinates

All coordinate data *shall* be collected or computed using the WGS-84 co-ordinate reference system.

[CHAIN-0028-3260]

Note: Co-ordinates collected using other reference systems should be transformed into the WGS-84 coordinate system.

If a transformation is performed, the original data *shall* have met the quality requirements laid down within this guidance material.

[CHAIN-0028-3270]

If the co-ordinate has been transformed from another co-ordinate system to WGS-84, it *shall* be clearly indicated as such.

[CHAIN-0028-3280]

The data structure used for storage of the coordinate *shall* allow for the clear indication of any co-ordinate transformation.

[CHAIN-0028-3290]

5.3.5.3 GEOID

The Earth Gravitational Model — 1996 (EGM-96), containing long wavelength gravity field data to degree and order 360, *shall* be used by international air navigation as the global gravity model.

[CHAIN-0028-3300]

At those geographical positions where the accuracy of EGM-96 does not meet the accuracy requirements for elevation and geoid undulation specified in Annex 14, Volumes I and II, on the basis of EGM-96 data, regional, national or local geoid models containing high resolution (short wavelength) gravity field data, *shall* be developed and used.

[CHAIN-0028-3302]

When a geoid model other than the EGM-96 model is used, a description of the model used, including the parameters required for height transformation between the model and EGM-96, *shall* be provided in the Aeronautical Information Publication (AIP).

[CHAIN-0028-3304]

5.3.5.4 Dates

Any date *shall* use the Gregorian calendar.

[CHAIN-0028-3310]

A date using a local calendar system *may* be published.

[CHAIN-0028-3320]

If dates use a local calendar, this *shall* be clearly indicated.

[CHAIN-0028-3330]

5.3.5.5 Time

Any time *shall* use Co-ordinated Universal Time (UTC).

[CHAIN-0028-3340]

A time using a local time system *may* be published.

[CHAIN-0028-3350]

If times use a local time frame, this *shall* be clearly indicated.

[CHAIN-0028-3360]

5.4 Data Processing Requirements

5.4.1 General

Previously we have looked at the data processes and what is needed. This section takes a further step and details some of the necessary considerations which support the higher level requirements.

5.4.2 Timeliness

The processing chain defined *shall* take into account the necessity for the on-time provision of information.

[CHAIN-0028-3370]

Aeronautical Information of an operationally significant nature *shall* be promulgated in accordance with the AIRAC cycle.

[CHAIN-0028-3380]

5.4.3 System and Process Design

5.4.3.1 System Integrity

The required system integrity is determined using Functional Hazard Assessment (FHA). This process identifies failure modes and associated hazards for the system. The assessment identifies the mitigation required to retain the required system integrity.

The system design *shall* mitigate failure modes including those associated with database errors.

[CHAIN-0028-3390]

Typical techniques used to mitigate system failure modes include:

a. Architectural techniques such as system redundancy, perhaps using dissimilar implementations. In general, redundancy allows comparison of system outputs and allows detection of system failure. Use of dissimilar implementations ensures that one implementation does not have a systemic flaw/error that could adversely affect integrity;

b. The addition of monitoring and built-in test equipment (BITE) functions allows detection of system failures. The effect of monitoring or using BITE is to lower the probability of undetected failures or errors.

The intent is to highlight that aeronautical databases may contain undetectable errors.

Mitigations for these types of errors *shall* be incorporated in the design of the system that uses an aeronautical database and in the allowed operational uses of the system.

[CHAIN-0028-3400]

5.4.3.2 Sources of Error

It is essential that a holistic view of the total data processing system be taken in its design, including the sources of possible error. This is necessary to establish the total capability of the system to provide protection of the integrity of the data being handled.

Note: The classical theory considers errors as being of three types, namely: Random Errors, Systematic Errors and Blunders.

With respect to data origination, statistical methods *shall* be applied in order to assess the random errors.

[CHAIN-0028-3410]

Digital filters, based on statistical principles, *shall* be used in order to locate and eliminate blunders.

[CHAIN-0028-3420]

Deterministic procedures *shall* be adopted to correct systematic errors, or

[CHAIN-0028-3430]

The systematic errors *shall* be taken into consideration in the derived statistics.

[CHAIN-0028-3440]

Each data acquisition method introduces its own systematic effect or bias. To eliminate this effect or bias there are two recommended approaches:

- The use of an appropriate mathematical model that describes the systematic effect (e.g. earth curvature, refraction, etc.);
- The use of extended models to account for a combination of systematic effects of known sources and quasi-random effects. A typical example is the auto-calibration used in photogrammetric aero-triangulation.

Confidence level: Point estimation is the estimation of the mean, variance, and covariance of a random variable from sample data. It is only possible to estimate a probability that the true value of the parameter in question is within a certain interval around the estimate. This probability is referred to as the Confidence Level. The confidence level of a database is directly related to the lowest confidence level for any existing random variable in the database.

Any type of error may affect the confidence level of the database, but systematic and blunder errors will have a larger impact.

Therefore, to achieve high confidence levels, it is critical to locate and eliminate these systematic and blunder-type errors.

Accuracy and Precision: The main difference between precision and accuracy lies in the possible presence of bias or systematic error. Although precision includes only random error, accuracy comprises both random and systematic errors. Both terms are often used with the same meaning.

In surveying practice, for the majority of cases, the true value is not known and only a most probable value is estimated via random sample measurement procedures.

All observed (random variables) or derived statistics *shall* be qualified through their corresponding accuracy parameters such as mean, variance, standard deviation and covariance.

[CHAIN-0028-3450]

Resolution: Errors may be introduced as a result of using multiple databases where differences exist in any of the following: spatial resolution, spectral resolution, radiometric resolution and temporal resolution. This issue is further described in ED-98A, Appendix D.

Timeliness Effects and Currency Errors: An attribute of a database is its currency, which informs the user of the date of its latest update or the effective date of the data.

This information *shall* be made available to the user.

[CHAIN-0028-3460]

In the absence of databases which are continuously updated, changes that occur between periodic updates (e.g. between AIRAC cycles) will not be available as part of the database. During this interim period, these changes *should* be provided to users via a Notice to Airmen (NOTAM).

[CHAIN-0028-3470]

For some applications, aerodrome, terrain, obstacle and other databases will be integrated. This integration of data is typically accomplished by layering the various information sources into an information hierarchy that supports the application and associated display processing. The data that contribute to these layers are subject to varying levels of change which, in turn, suggests that the data will be updated at different times or in cycles of differing length. This inconsistency may result in database errors that can be difficult to detect by the system or the end-user.

Semantic Errors: These are generally considered blunder errors. Examples include errors due to the mis-identification of an object (e.g. a tower for a mast, a tree for a pole, a road for a railway); errors due to misclassification of a theme (e.g. sand for clay); and errors due to incorrect attachment of attributes (e.g. length for width). These blunder errors will affect the consistency and the reliability of the whole database. Consistency checks are recommended when the initial database is produced and again on each update (see 5.4.14).

5.4.4 Data Processing Procedures

Organisations *shall* have a set of operational data processing procedures that ensure the effective planning, operation and control of its processes.

[CHAIN-0028-3480]

These procedures *shall* take account of:

a. The size and type of the activities being undertaken;

[CHAIN-0028-3490]

b. The complexity of the processes and their interactions;

[CHAIN-0028-3500]

c. Competence of the personnel performing the procedure(s).

[CHAIN-0028-3510]

The data processing procedures *shall* define:

a. The method of origination for all data that is originated locally;

[CHAIN-0028-3520]

b. The means by which data is assembled;

[CHAIN-0028-3530]

c. The means used to confirm that data that is originated locally has not been corrupted prior to being stored;

[CHAIN-0028-3540]

d. The means by which validation of any data element is to be performed (see below);

[CHAIN-0028-3550]

e. The method to be used to evaluate degradation of accuracy when the resolution of a data element is reduced or the data is translated into a different co-ordinate system or unit of measurement;

[CHAIN-0028-3560]

f. The means used to confirm that the data has been received without corruption;

[CHAIN-0028-3570]

g. The method to be used to provide the user with the ability to verify that the data received by the user has not been corrupted;

[CHAIN-0028-3580]

h. The method to be used to verify received data;

[CHAIN-0028-3590]

i. The action to be taken when data fails a verification or validation check;

[CHAIN-0028-3600]

j. The method by which data quality is preserved;

[CHAIN-0028-3610]

k. The means used to ensure that stored data is protected from corruption;

[CHAIN-0028-3620]

l. The method by which the user is assured that, whenever the resolution of a data element is changed or the data value is translated, the accuracy and resolution of the new value meets the data quality requirements;

[CHAIN-0028-3630]

m. The requisite skills and competencies necessary to perform each procedure;

[CHAIN-0028-3640]

n. The tools required for the procedure.

[CHAIN-0028-3650]

The means by which validation of any data element is to be performed *shall* include:

a. When the source of a data element cannot be trusted, how an appropriate validation can be performed;

[CHAIN-0028-3660]

b. When multiple suppliers are available for a data element, how differences between them are determined and resolved;

[CHAIN-0028-3670]

c. When separate data elements have a defined relationship, how this relationship is confirmed and any anomalies are resolved.

[CHAIN-0028-3680]

5.4.5 Data Alteration

Organisations *shall* not alter data received from another organisation without informing the originating organisation of the change, the reason for the change and endeavouring to receive concurrence in a timely manner.

[CHAIN-0028-3690]

If the originator rejects the alteration, the altered data *shall* not be transmitted to the subsequent data user.

[CHAIN-0028-3700]

Records *shall* be kept of all alterations.

[CHAIN-0028-3710]

Records *shall* be made available to all subsequent users upon request.

[CHAIN-0028-3720]

Note: This requirement only applies to the alteration of the data and does not apply to:

a. Assembling;

b. Translating;

c. Selecting;

d. Formatting of the data.

5.4.6 Data Entry and Management

The general management of data has three basic stages:

a. To ensure that the data entered into the system is correct;

b. To ensure that whilst the data resides in the system its integrity and that of the whole set, is protected;

c. To ensure that the data transmitted from the system to the next user is complete, has the requisite level of integrity and meets the requirements of the next user.

Several data entry strategies are available including:

a. Single point data entry with validation of selected key data attributes on entry only;

b. Single point data entry with monitoring of the whole data set only;

c. Single point data entry with validation of selected key data attributes on entry plus whole data set integrity monitoring;

d. Multiple point data entry with comparison of resulting data sets (match =OK/no match = likely error).

Empirical evidence exists to support the selection of a multi-path approach as follows:

Data Management Phase	Recommended Action
Provide for data validation on entry	Test the entered data against specific syntax and range values
Monitor the integrity of each record set	Test each complete record set against logic/value/syntax/temporal rules
Monitor the integrity of the whole record set	Test the whole data set against a similar set of rules

Table 2: Multi-path Data Entry Strategy

Since, at the end of the process, the data set extracted for the next user in the data chain may not be the complete data set (i.e. the entire contents of the core database), it is important to ensure that the data set released complies with the requirements of the target system and has its own internal integrity. Accordingly, the resulting process flow is presented in Figure 7: Data Management Process Flow.

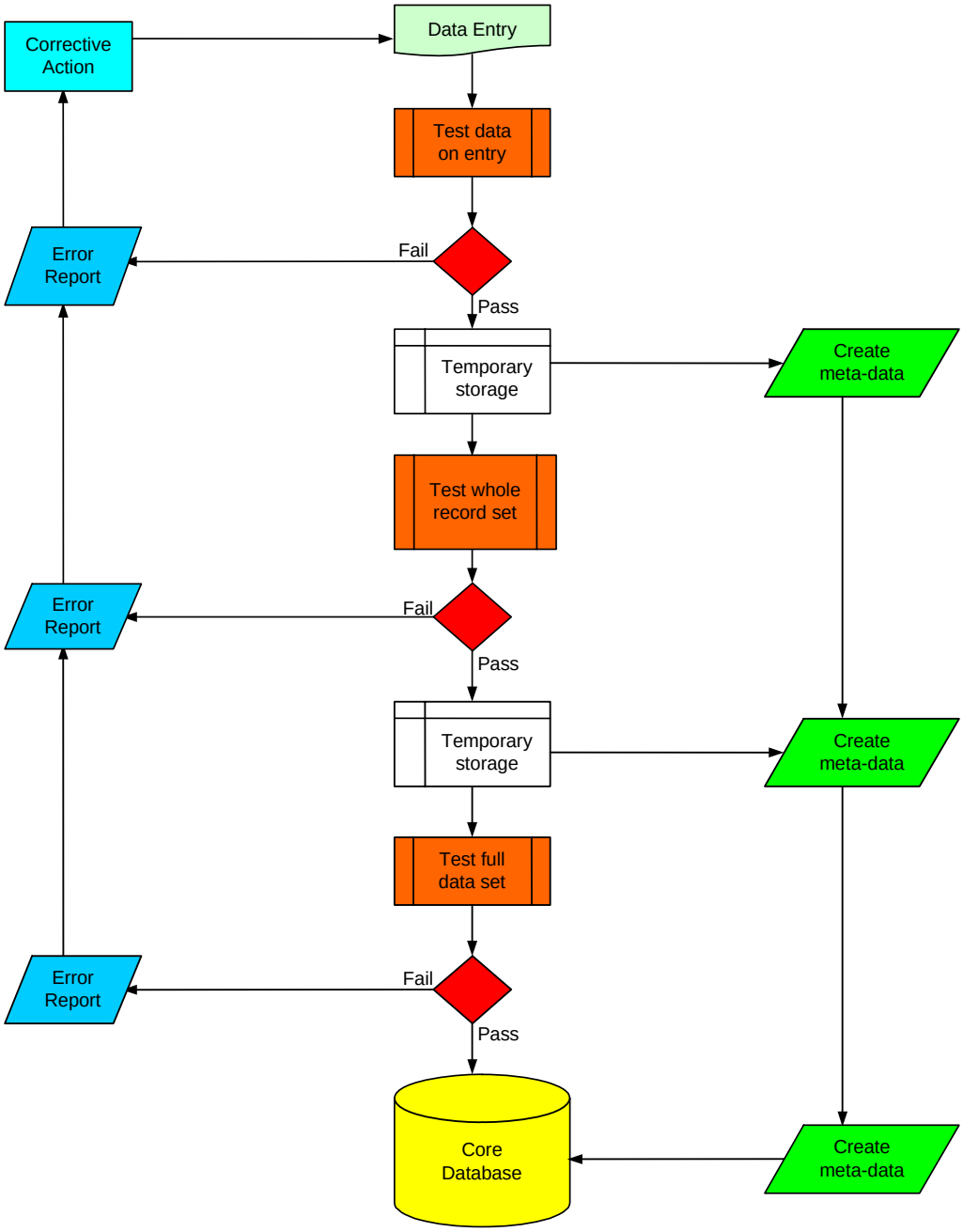

Figure 7: Data Management Process Flow

5.4.7 Data Configuration Management

In order to meet the traceability requirements of ICAO, it is essential that a correct configuration management of data is maintained. Such controls on the update of data and the records which it is necessary to keep will also contribute to meeting some of the needs of any legal recording requirements which may exist.

Organisations *shall* adhere to the general data delivery requirements specified in section 6.4.2.

[CHAIN-0028-3730]

Each distinct version of a data element *shall* be assigned a unique identification.

[CHAIN-0028-3740]

The data element identification *shall* be contained within the data element.

[CHAIN-0028-3750]

The data element identification *shall* also be used as a physical label attached to any portable storage medium used to hold the data elements.

[CHAIN-0028-3760]

The configuration management procedures *shall* ensure that a data element cannot be changed without the data element identification also being changed.

[CHAIN-0028-3770]

Note: A version number or date of applicability of a data element forms one element of its data identification.

Records *shall* be maintained that identify the data content of all data elements in order to support traceability.

[CHAIN-0028-3780]

These records *shall* ensure that:

a. A data value has not been separated from its correct label;

[CHAIN-0028-3790]

b. Start and end dates of the period of validity of the data element are precisely specified;

[CHAIN-0028-3800]

c. The date of production of the data element is specified;

[CHAIN-0028-3810]

d. The supplier of each data value is contained within the data element;

[CHAIN-0028-3820]

e. Procedures used to produce the element are fully documented.

[CHAIN-0028-3830]

A copy of each element *shall* be retained for a period determined in the Configuration Management Plan (see section 6.3).

[CHAIN-0028-3840]

The method of storage, and the numbers of copies held *shall* be such that:

a. The integrity of each element can be assured for the entire period that it is to be retained;

[CHAIN-0028-3850]

b. Due attention is given to protection against physical damage and deterioration.

[CHAIN-0028-3860]

5.4.8 Data Integrity Modelling

The integrity testing of either the data elements or a complete database can be carried out using three alternative strategies or a combination of all three. The three strategies are:

1. Logical and rule tests;
2. Graphical analysis;
3. Data comparison.

In any event, the value in the validation and modelling arises from a matching of the validation means or process with the intended application or use of the data. For example, data or a data set that describes a flight path command should be modelled using a simulation of the flight path direction from the target systems for which the data set has been developed. Since, at this level, the results of these tests can be accumulative, it is recommended that the combination approach be taken where at all possible.

During data origination some form of flight testing of data sets *may* be required in specific cases.

[CHAIN-0028-3870]

Such circumstances include the post design flight testing of instrument approach procedures. These tests are carried out in addition to the data integrity modelling activities as outlined above and form the final step in validation prior to the formal approval of the specific aeronautical data set.

Logical and Rule Tests: These tests are a comparison of data values entered with single or multiple rules such as relative position, values within an appropriate and specific range, syntax tests and data family test. Such logic may include, as examples:

a. The proposition that a runway cannot exist at an airport that is not present in the database;

b. That an ILS Glide Path antenna is unlikely to exist without an associated runway and is unlikely to be a significant distance from its edge, and so on.

Using this approach, for each type of data and data element, a series of logical and relational tests can be built up and the failure of any data to satisfy the test would indicate a failure of that data element or attribute to meet the acceptance criteria.

Much of the material for these logical and rule tests can be found in ICAO Annex 15 and ED-77.

Graphical Analysis: Using high-level Computer Aided Design (CAD) systems or Geographical Information Systems (GIS) data it is possible to construct synthetic images of families of data records or elements or, in extreme cases, complete databases. The resulting images can either be viewed as a validation test in their own right – obvious data deviations will show as major departures from expected results – or, using data overlay techniques, be used to compare results with other sources of information. For example, a satellite image, presented at the right scale, could be used to confirm the data representing the layout of an airport or to confirm a terrain model against actual terrain.

For flight path validation, flight director or flight management simulators in which the logic of the specific airborne system[6] is used will, alone, provide the validation of the data set.

Data Comparison: The comparison of three or more data sets that should be the same is a valid means of determining gross error. However, the availability of more than two additional data sets is always a challenge unless a multiple point of entry strategy is employed.

[6] It should be noted that each airborne system may have different operational characteristics which will produce a different flight path compared with a similar application on other aircraft types.

5.4.9 Traceability

Traceability is the ability to track the history, application or location of an entity by means of recorded identifications. More specifically, it is the degree to which a system or data product can provide a record of the changes made to that system or product and, thereby, enable an audit trail to be followed from the end-user to the data originator.

Specific requirements with regard to data traceability are presented in Section 6.4.2 of this document.

5.4.10 Data Quality Assurance

When organisations are unable to demonstrate compliance with the requirements of this document, the related data requires testing by using validation, logical consistency, or other means to be agreed upon by the organisation that approves the application.

When multiple databases are employed for validation, the available metadata *shall* be used to demonstrate the independence of each data set.

[CHAIN-0028-3880]

Two sets of measurements provided by the same company, using the same data collection technology, may induce a bias, either in the initial collection, or in the post-processing techniques used for acquisition and sampling.

Differences between the data *shall* be identified and compared to the quality characteristic requirements specified for the data.

[CHAIN-0028-3890]

Note: For example, two independently prepared survey results may be compared. They are highly likely to have slightly different values which, provided they are within the accuracy requirements determined for the data, are acceptable. If the differences are outside this acceptable range an investigation is required.

5.4.11 Archiving

The regular archiving of the quality assured aeronautical data, together with the appropriate metadata, is essential to the maintenance of systems, data and service continuity and integrity.

Many tools, technical solutions and media options exist for archiving activities but consideration must be given to the ability to successfully retrieve the archived data as part of either the disaster recovery strategy, system re-establishment or investigation, and audit of past activities.

This *should* involve the close tracking of technology and operating system changes as a system archive made at one point in time may not be readable at a later stage, as a result of system changes.

[CHAIN-0028-3900]

5.4.12 Metadata

Industry requirements exist for the metadata which should be available with aeronautical information. These needs are supplemented by best practise and international standards, such as the ISO 19100 series of documents. As these

needs may be considered as customer requirements, the following requirements outline these needs.

Metadata *shall* be collected at each stage of the process and for each action undertaken.

[CHAIN-0028-3910]

Metadata *may* also include any additional information needed by a particular organisation.

[CHAIN-0028-3920]

Note: If additional metadata attributes are required by an organisation, they should be specified for such entities. If they are not applicable, this should be specified within the attribute.

As a minimum, the following metadata *shall* be collected:

a. Who performed the operation;

[CHAIN-0028-3930]

b. When (date and time) the operation was performed;

[CHAIN-0028-3940]

c. The role of the person performing the action;

[CHAIN-0028-3950]

d. What operation was performed;

[CHAIN-0028-3960]

e. If information has changed, what the value was before the change;

[CHAIN-0028-3970]

f. If information has changed, what the value is after the change;

[CHAIN-0028-3980]

g. If information has been deleted, the value of the deleted information;

[CHAIN-0028-3990]

h. If information has been added, what has been added;

[CHAIN-0028-4000]

i. The method(s) used for data acquisition and the standards applied in its acquisition;

[CHAIN-0028-4010]

j. The quality attributes of the information;

[CHAIN-0028-4020]

k. The confidence level[7] for the information (as a percentage);

[CHAIN-0028-4030]

l. The quality scope attributes of the information.

[CHAIN-0028-4040]

Note: The following attributes may be used to describe a data quality scope:

a. the level (a dataset series to which a dataset belongs, the dataset or a smaller grouping of data located physically within the dataset sharing common characteristics);

[7] A confidence level is expressed as the probability that any single location in the data set is in error of the true position by less than the stated horizontal accuracy.

b. the types of items (lists of feature types, feature attributes and feature relationships) or specific items (lists of feature instances, attribute values and instances of feature relationships);

c. the geographic extent;

d. the temporal extent (the reference time frame and accuracy of the time frame).

5.4.13 Data Product Specifications

A data product specification defines the requirements for a data product. It forms the basis for producing or acquiring data. It may also help potential users to evaluate the data product to determine its fitness for use. The information contained in a data product specification is different from that contained in metadata, which provides information about a particular physical dataset. Information from the data product specification may be used in the creation of metadata for a particular dataset that is created in conformance with that data product specification. Thus metadata describes the actual state of a dataset whilst a data product specification describes what the expected state is. The requirements for metadata are described in ISO 19115. The relationship between a data product specification and metadata is described more fully in Annex B of ISO 19115.

Increasingly, aeronautical information is being provided in a digital form and it is, therefore, essential that the users are aware of the details of the product that they receive. A Data Product Specification provides a means of informing customers of the status and content of the products which they are using. As a consequence, such specifications are considered essential to ensure the correct usage of aeronautical information products by their customers.

A data product specification *shall* contain major sections covering the following aspects of the data product:

a. Overview;

[CHAIN-0028-4050]

b. Specification scopes;

[CHAIN-0028-4060]

c. Data product identification;

[CHAIN-0028-4070]

d. Data content and structure;

[CHAIN-0028-4080]

e. Reference systems;

[CHAIN-0028-4090]

f. Data quality;

[CHAIN-0028-4100]

g. Data product delivery;

[CHAIN-0028-4110]

h. Metadata.

[CHAIN-0028-4120]

A data product specification *may* also contain sections covering the following aspects of the data product:

a. Data capture;

[CHAIN-0028-4130]

b. Data maintenance;

[CHAIN-0028-4140]

c. Portrayal;

[CHAIN-0028-4150]

d. Additional information.

[CHAIN-0028-4160]

For more information on Data Product Specifications, see ISO 19131.

5.4.14 Consistency Checks

It is intended that, at all stages of the process, the data is checked for plausibility through the application of consistency checks. There checks take two forms:

5.4.14.1 Logical Consistency

Logical consistency *shall* be applied to validate the data by comparing the relationship between different data sets.

[CHAIN-0028-4170]

For example, published headings can be compared to the computed heading between two fixes, or contour lines of adjacent cells can be compared. This method cannot completely validate the data as there is the possibility that the different data sets include the same error. Independence of the data sets substantially improves the effectiveness of this type of validation.

Examples of logical consistency include:

a. comparison of duplicate information; or,

b. contextual relationships between data elements (related record, field and character checks, co-linearity checks).

5.4.14.2 Semantic Consistency

Semantic consistency *shall* be applied to validate the data by comparing data to an expected value or range of values for the data characteristics.

[CHAIN-0028-4180]

This method cannot completely validate the data as there is the possibility that the data has an error that lies within the expected range. Examples of semantic consistency include:

a. presence versus absence of data;

b. field and character context;

c. range limit checks;

d. geographic vicinity checks;

e. use in the declared time period of validity;

f. field sizes.

6. QUALITY MANAGEMENT, SYSTEMS AND CONTROL

6.1 Introduction

6.1.1 General

In order for a provider of a service to maintain the integrity of its products, quality must be maintained. However, much confusion exists over what is meant by the term quality and how this may be achieved.

Within the aeronautical data community, ICAO Annex 15 provides a set of definitions that assist in the understanding of the terms and, therefore, the implication on the data process chain.

Within this guidance, the need for processes is clear. These may be established through the implementation of a QMS.

6.1.2 Implementation

In order for the required quality of service / data to be provided, a quality management system is required for all organisations operating within the total aeronautical data chain.

ICAO mandates this for AIS organisations through Annex 15 (chapter 3.2 Quality System) which states:

> "*Each contracting State shall take all necessary measures to introduce a properly organised quality system containing procedures, processes and resources necessary to implement quality management at each function stage as outlined in 3.1.7 above. The execution of such quality management shall be made demonstrable for each function stage, when required.*"

Furthermore, a recommendation is then made as to the preferred quality assurance standard:

> *"The quality system established in accordance with 3.2.1 [text above] should be in conformity with the International Organisation for Standardisation (ISO) 9000 series of quality management assurance standards, and certified by an approved organisation."*

6.1.3 Quality Procedure Design

The processes and procedures developed as part of quality procedures *shall* take into account the recommendations offered within this guidance material.

[CHAIN-0028-5010]

6.1.4 AIS Data Process and Static Data Procedures

Of direct relevance to the quality management of aeronautical data is the AIS Data Process (ADP) and its associated Static Data Procedures (SDP), prepared by EUROCONTROL.

These documents provide a generic process and supporting procedures covering the activities of a State AIS. Whilst they are not designed for immediate implementation within a State, they provide a description of best practice which is easily tailored to meet the needs of the State.

The AIS Data Process covers all activities from the receipt of data within the AIS to its publication. The activities associated with the AIS Data Process may be represented by Figure 8: AIS Data Process below.

Figure 8: AIS Data Process

6.2 Quality Management, Systems and Control

6.2.1 Applicability

The requirements stated in this section apply to all organisations involved in the origination, processing and publication of data including:

a. Surveyor;

b. Procedure designer;

c. Requesting Authority;

d. Origination Authority;

e. Aeronautical Information Services;

f. All third parties contracted to the aforesaid organisations for the purpose of undertaking data origination.

6.2.2 Quality Management System

All organisations involved in the origination of navigation related data *shall* implement a Quality Management System (QMS).

[CHAIN-0028-5020]

The QMS *shall* ensure the quality of all processes and deliverables undertaken by each organisation.

[CHAIN-0028-5030]

Recommendation**:** Organisations *should* comply with ISO 9001:2000, 'Quality Management Systems – Requirements' (hereafter referred to as ISO 9001).

[CHAIN-0028-5040]

6.3 Quality Management Documentation

6.3.1 General Requirements

All organisations *shall* produce the following documents as part of their QMS:

a. Quality Policy – a documented statement of quality policy and associated quality objectives;

[CHAIN-0028-5050]

b. Quality Manual – defining the scope of the QMS and how the different processes within the QMS interact;

[CHAIN-0028-5060]

c. Control of Documents – defining the controls and personnel needed to:

◊ Approve documents prior to issue;

[CHAIN-0028-5070]

◊ Review documents at planned intervals and update as required;

[CHAIN-0028-5080]

◊ Ensure currency of documents;

[CHAIN-0028-5090]

◊ Ensure current documents are readily available;

[CHAIN-0028-5100]

◊ Ensure documents from other sources are identified and controlled;

[CHAIN-0028-5110]

◊ Prevent unintentional use of obsolete documents.

[CHAIN-0028-5120]

d. Data Configuration Management Plan

[CHAIN-0028-5130]

◊ the plan *shall* identify all data to be placed under configuration management (see Section 6.4.2);

[CHAIN-0028-5140]

e. Corrective and Preventive Action – required to eliminate the cause of any non-conformities to prevent recurrence (see Section 6.5). These *shall* be commensurate with the impact of the non-conformities foreseen or present;

[CHAIN-0028-5150]

f. Control of Non-Conforming Product – ensures that a product that does not conform to its requirements is identified and controlled to prevent its use (see Section 6.4.5);

[CHAIN-0028-5160]

g. Control of Non-Conforming Product – also assists the organisation in learning where problems are introduced and hence provides data for analysis and subsequent process improvement activities;

[CHAIN-0028-5170]

h. Instructions for Internal Audit – defines the responsibilities and requirements for audits and reporting results (see Section 6.5);

[CHAIN-0028-5180]

i. Quality Process Assessment and Improvement – the activities associated with the continuous improvement of the processes applied.

[CHAIN-0028-5190]

Recommendation**:** Quality Management Documentation *should* comply with the specific requirements of ISO 9001:2000, 'Quality Management Systems – Requirements'.

[CHAIN-0028-5200]

6.3.2 Survey Specific Quality Records

All co-ordinates *shall* be traceable to their source of production by an unbroken audit trail (see section 6.4.2).

[CHAIN-0028-5210]

Information on the source of production *shall* include:

a. Name of Surveyor;

[CHAIN-0028-5220]

b. Surveying organisation;

[CHAIN-0028-5230]

c. Date of survey;

[CHAIN-0028-5240]

d. Method of survey;

[CHAIN-0028-5250]

e. Equipment used.

[CHAIN-0028-5260]

Records *shall* be maintained for at least ten years for all designated co-ordinates that are published in each national Aeronautical Information Publication (AIP).

[CHAIN-0028-5270]

6.4 Quality Management

6.4.1 Quality Management Procedures

As part of their QMS, organisations *shall* establish Quality Management Procedures that:

a. Define criteria used for review of plans and procedures;

[CHAIN-0028-5280]

b. Define criteria used for review of personnel skill records;

[CHAIN-0028-5290]

c. Define criteria used for review of qualified tools;

[CHAIN-0028-5300]

d. Identify the personnel with authority to approve plans and procedures;

[CHAIN-0028-5310]

e. Identify the personnel with authority to certify competence of personnel and competence requirements;

[CHAIN-0028-5320]

f. Identify the personnel with authority to authorise (qualify) tools for use;

[CHAIN-0028-5330]

g. Define maximum intervals between reviews, as specified in the requirements above.

[CHAIN-0028-5340]

6.4.2 Data Delivery

Organisations *shall* ensure that data controls have been implemented to provide assurance that data values in delivered products are applicable to the declared period of validity.

[CHAIN-0028-5350]

Organisations *shall* support the requirement for traceability of each data element to each organisation involved in each stage of the data origination process.

[CHAIN-0028-5360]

Organisations *shall* take steps to reduce the vulnerability of the data origination process to loss or corruption of stored data, regardless of the media or system used to store the data.

[CHAIN-0028-5370]

6.4.3 Skills and Competencies

All personnel performing work affecting data quality *shall* be competent on the basis of appropriate education, training, skills and experience.

[CHAIN-0028-5380]

Organisations *shall*:

a. Determine the necessary competence for personnel performing work affecting data quality and provide necessary training or take actions to satisfy these needs;

[CHAIN-0028-5390]

b. Evaluate the effectiveness of all actions taken;

[CHAIN-0028-5400]

c. Ensure personnel are aware of the relevance and importance of their activities and how they contribute to the achievement of the quality objectives;

[CHAIN-0028-5410]

d. Maintain appropriate records of education, training, skill and experience.

[CHAIN-0028-5420]

Note: The objectives of skills management are to:

a. Establish the skills required for each function or process;

b. Ensure that personnel assigned to perform data origination have the necessary skills, competencies and knowledge of procedures.

All people within the organisation *shall* be empowered, and trained, with the authority and responsibility to report nonconformities at any stage of a process in order to ensure timely detection and disposition of nonconformities.

[CHAIN-0028-5430]

6.4.4 Management of Third Parties

Organisations *shall* take all necessary steps to ensure the quality of products delivered by third parties and that the products are in accordance with the requirements of this guidance material.

[CHAIN-0028-5440]

In particular, organisations *shall* establish Quality Management Procedures, which specify:

a. Deliverables or products to be provided by each third party;

[CHAIN-0028-5450]

b. Acceptance criteria to be applied to each product;

[CHAIN-0028-5460]

c. Procedures for defect detection and subsequent resolution;

[CHAIN-0028-5470]

d. Methods for ensuring compliance against Quality Assurance requirements.

[CHAIN-0028-5480]

Note$_{(1)}$: These documented procedures should take into account the requirements for interface management included in section 4.3.

Note$_{(2)}$: This requirement is particularly important to Requesting Authorities who elect to subcontract data survey services to a third party and must adhere to the requirements.

6.4.5 Quality Control

Organisations *shall* monitor and, where applicable, measure the QMS processes.

[CHAIN-0028-5490]

Note$_{(1)}$: Monitoring and measurement should be used on a daily basis for ongoing assurance of product quality, as well as for use within periodic audits.

Note$_{(2)}$: Measurements of process performance should cover the needs and expectations of interested parties in a balanced manner. Examples include:

a. Capability;

b. Reaction time;

c. Cycle time or throughput;

d. Measurable aspects of dependability;

e. Yield;

f. The effectiveness and efficiency of the organisation's people;

g. Utilisation of technologies;

h. Waste reduction; and

i. Cost allocation and reduction.

If deviations are noted and results not achieved, then corrective action *shall* be taken.

[CHAIN-0028-5500]

All tools, including updated versions of tools, *shall* be reviewed and approved prior to application.

[CHAIN-0028-5510]

Records of procedures, personnel and tools *shall* be maintained to allow identification of the procedures, personnel and tools employed in the production of each delivery of data to a client.

[CHAIN-0028-5520]

6.5 Audit and Compliance

6.5.1 Demonstration of Compliance

Organisations *shall* conduct internal audits at planned intervals to determine whether the QMS:

a. Conforms to the planned arrangements and to the QMS requirements established by the organisation;

[CHAIN-0028-5530]

b. Is implemented effectively and maintained.

[CHAIN-0028-5540]

An audit programme *shall* be planned

[CHAIN-0028-5550]

and a documented procedure *shall* include:

a. Due consideration of the status of the activities under audit;

[CHAIN-0028-5560]

b. Previous audits;

[CHAIN-0028-5570]

c. Responsibilities and requirements for planning and conducting audits;

[CHAIN-0028-5580]

d. Responsibilities and requirements for reporting results and maintaining records.

[CHAIN-0028-5590]

Where a non-conformity is identified, the organisation *shall* identify the root-cause of the non-conformity and collect information to define the necessary corrective actions.

[CHAIN-0028-5600]

Note: The establishment of the root-cause will allow for a more permanent and substantial corrective action to be taken.

The root-cause analysis results *shall* be verified by testing, prior to defining and initiating corrective action.

[CHAIN-0028-5610]

6.5.2 Audit Objectives

Audits *shall* confirm that:

a. Controls, such as plans, documents and procedures, exist and are applied, which are specifically associated with data quality assurance;

[CHAIN-0028-5620]

b. Only authorised versions of all plans, documents and procedures associated with data quality assurance are used;

[CHAIN-0028-5630]

c. The QMS meets all requirements in this guidance material and any deviations or exclusions have been documented, tracked and/or justified;

[CHAIN-0028-5640]

d. A system is in place to manage change, as well as to ensure that any changes meet stated quality requirements.

[CHAIN-0028-5650]

6.5.3 Control of Devices for Monitoring and Measuring of Compliance

Organisations *shall* determine the level of monitoring and measurement required and the devices needed to provide evidence of conformity to this guidance material.

[CHAIN-0028-5660]

Note$_{(1)}$: The use of measurement should provide a useful baseline from which the organisation can make product and process improvements. Care should be taken that the measurements adopted are effective and useable.

Note$_{(2)}$: Examples of measurement of performance of the organisation's processes include:

a. measurement and evaluation of its products;

b. capability of processes;

c. achievement of project objectives; and

d. satisfaction of customer and other interested parties.

Any status of any item being measured or monitored *shall* be recorded.

[CHAIN-0028-5670]

All monitoring and measurement *shall* be carried out to a consistent level of performance.

[CHAIN-0028-5680]

All measuring and monitoring equipment *shall* be:

a. Calibrated or verified (prior to use, at specified intervals or after any adjustment or repair) against measurement standards traceable to international or national standards;

[CHAIN-0028-5690]

◊ If no such standard exists, the standard *shall* be determined and recorded;

[CHAIN-0028-5700]

b. Adjusted or re-adjusted as required;

[CHAIN-0028-5710]

c. Identified to enable calibration status to be determined;

[CHAIN-0028-5720]

d. Protected from interference that would invalidate results;

[CHAIN-0028-5730]

e. Protected from damage and deterioration during handling, maintenance and storage.

[CHAIN-0028-5740]

Any computer software used in the monitoring and measurement process *shall* first be confirmed as suitable for the purpose.

[CHAIN-0028-5750]

7. CALIBRATION / QUALIFICATION OF EQUIPMENT AND TOOLS

7.1 Introduction

Procedures and processes are the foundation of data and quality management. It is vital, however, that any equipment or tools used in the origination of data and its management throughout the data process chain are the subject of calibration or qualification, as appropriate, to provide assurance of data accuracy and that errors are not being introduced.

7.2 Tool Qualification

7.2.1 General

Tools (software or otherwise) used during the activities associated with procedure design (e.g. PANS Ops tools), aeronautical data management (e.g. database internal integrity checks) and aeronautical data publication (e.g. Configuration Management Tools) *shall* undergo a process of qualification.

[CHAIN-0028-6010]

Tool qualification is required when data processes are eliminated, reduced or automated by the use of a tool without the output being verified.

Qualification is the process by which assurance is achieved that the tools employed will neither introduce errors into the data nor degrade its integrity.

Note: The objectives of tool qualification are to:

a. Demonstrate that the tool complies with the user's intended requirements;

b. Ensure the tool provides equivalence to any activities it automates, and that the tool qualification is commensurate with its intended use, or the data management process.

7.2.2 Tool Qualification Requirements

The following requirements apply equally to tools obtained 'off-the-shelf' or developed by the data processor, either as a stand-alone product or as a module within an existing product.

Organisations *shall* develop a Tool Qualification Plan that describes the tool qualification process.

[CHAIN-0028-6020]

This Tool Qualification Plan *shall* identify:

a. Tool requirements and qualification procedures;

[CHAIN-0028-6030]

b. Tool configuration management procedures;

[CHAIN-0028-6040]

c. Tool qualification documentation requirements and quality management procedures;

[CHAIN-0028-6050]

d. Personnel responsible for the process and the authority vested in them.

[CHAIN-0028-6060]

Each proposal for a new tool or modification of an existing tool *shall* be reviewed to determine whether the tool is required to undergo qualification.

[CHAIN-0028-6070]

If qualification is not required, justification for that decision *shall* be documented.

[CHAIN-0028-6080]

Records *shall* be maintained in accordance with the general quality assurance requirements specified in this document.

[CHAIN-0028-6090]

Tool requirements *shall* be defined that include:

a. Functionality and performance;

[CHAIN-0028-6100]

b. Operational environment;

[CHAIN-0028-6110]

c. User information, such as installation guides and user manuals.

[CHAIN-0028-6120]

Tool qualification procedures *shall* be specified to include:

a. The means by which it is ensured that the output from the tool has the required quality;

[CHAIN-0028-6130]

b. The means by which it is ensured that the output from the tool has the required integrity;

[CHAIN-0028-6140]

c. The means by which it is ensured that the tool satisfies the Tool Requirements.

[CHAIN-0028-6150]

Organisations *shall* develop a tool configuration management process that provides:

a. Unique identification for each distinct version of a tool;

[CHAIN-0028-6160]

b. Means for convenient availability/visibility of tool version;

[CHAIN-0028-6170]

c. Ability to consistently replicate or regenerate a particular version of the tool;

[CHAIN-0028-6180]

d. Change control processes which establish recording, evaluation, resolution and approval for changes throughout the tool development and the tool's life;

[CHAIN-0028-6190]

e. Secure environment for physical archiving, recovery and control for configured items.

[CHAIN-0028-6200]

APPENDIX A CYCLIC REDUNDANCY CHECKS

A.1 General Introductions

This guidance has been provided on the basis that use is made of Cyclic Redundancy Check values to prove, to a mathematically proven degree of certainty, that data has not been amended or corrupted from that for which the original CRC Value (CRCV) was calculated.

The use of CRC is widespread and is the most common form of check used to ensure that the information contained within a dataset has not been changed. It forms the basis of the methodology employed within internet communications to ensure that the information received has not been corrupted. Many international organisations have adopted the use of CRC within their standards, such as the International Organisation for Standardisation (ISO), the Institute of Electrical and Electronics Engineers (IEEE) and, most importantly in our domain, ICAO.

CRC also form an inherent part of many other technologies used for data security and CRCs are utilised within most digital signature and encryption technologies in use today.

A.2 Recommendation

The use of CRC technology for all storage and exchange of data has been recommended for a number of reasons:

a. It is the ICAO mandated technology;

b. It is the most widely used and accepted technology;

c. Interoperability is aided if all actors and systems involved make use of the same technology;

d. Through the use of supporting tools (which are widely available) its use is relatively simple.

A.3 Alternatives

Whilst the use of alternatives would be discouraged, should a State wish to implement alternative methods which may also demonstrate the assurance of integrity, both in storage and distribution, then this may be permitted. Such a decision should not be taken lightly, however, as interoperability may be lost (and hence, result in a loss of integrity) and a non-compliance with ICAO SARPs and the Single European Sky Common Requirements result.

End of Document