Advisory Circular

NCAA-AC-AWS003C

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APPLICATION OF HUMAN FACTORS PRINCIPLES IN THE DESIGN AND APPLICATION OF AIRCRAFT MAINTENANCE PROGRAMME, MAINTENANCE CONTROL MANUAL AND OTHER MANUALS

1.0 PURPOSE

This advisory circular is issued to provide guidance and information on the regulatory requirements that relate to the application of human factors principles in the development of AOC Aircraft Maintenance Program, AOC Maintenance Control Manual, and other relevant manuals. This AC presents one method, but not necessarily the only method, to address application of human factor principles in development of aircraft maintenance related manuals.

2.0 REFERENCE

2.1 Nig. CARs Part, 6.5.1.1, 9.4.1.4, 9.4.1.12

2.2 ICAO Doc 9824 AN/450 – Human Factors Guidelines for Aircraft Maintenance Manual

3.0 GUIDANCE AND PROCEDURE

3.1 General

3.1.1 Maintenance errors contribute to a significant proportion of worldwide commercial aircraft accidents and incidents and these occurrences are costly; yet until recently, little was known of the nature of maintenance errors and the factors that promote them. Human Factors as a term has to be clearly defined because when these words are used in the vernacular they are often applied to any factor related to humans. Human Factors is therefore about people in their living and working situations; about their relationships with machines, with procedures and with the environment around them; and also about their relationships with other people. In aviation, Human Factors involves a set of personal, medical and biological considerations for optimal aircraft, aircraft maintenance and air traffic control operations.

3.1.2 Procedures and Work Instructions - A work instruction is what you should do, whereas a procedure is how you should do it. Job cards are usually work instructions; procedures generally originate from the Maintenance Manual. Procedures fall into two categories: those produced by the manufacturer and those produced by, and within the control of, the maintenance organisation or aircraft operator. The former will be referred to as Maintenance Data; the latter will be referred to as procedures and work instructions.

Note.— In this AC "procedures" means all the documentation likely to be used in the control and/or recording of work on the aircraft or its components, e.g. company procedures, aircraft maintenance manuals, worksheets, and job or task cards.

3.2 Responsibilities

The responsibilities for human factors principles compliance as required by the regulations are assigned as follows:

3.2.1. The operator is responsible for developing the maintenance programme in order that it observes Human Factors principles;

3.2.2. The Authority is responsible for evaluating and, when satisfied that it meets the appropriate requirements, approving the maintenance programme submitted by the operator;

3.2.3 The operator is responsible for ensuring that the AMO apply the programme in such a way as to observe Human Factors (i.e. that the AMO facility, staff and procedures observe Human Factors principles);

3.2.4 The AMO is responsible for the standards of Human Factors training given to its staff; and

3.2.5 The Authority is responsible for evaluating the maintenance organization and, when satisfied, approving it as an AMO.

3.3 Human Factors Principles in the Design and Application of an Aircraft Maintenance Programme.

3.3.1 The Nig. CARs Part 9 requirement for the operator's maintenance programme addresses two aspects: first, the design of the programme and, second, the application of the programme. In practice, the operator designs the maintenance programme to be applied in the AMO and, hence, its facility, procedures and work instructions must observe Human Factors principles. Although the operator can have total control over the design of the maintenance programme, it has much less direct control over the maintenance organizations that perform maintenance work on its aircraft or its components. Whatever the balance of tasks and activities between the operator and the maintenance organization, it is the operator that remains responsible to ensure that its aircraft are maintained in an airworthy condition (Nig. CARs 9.4.1.2 refers). The operator must therefore be confident that the AMO observe Human Factors principles. The operator should consider this aspect, and if necessary, it should confirm this, perhaps by an audit, both before and during the maintenance contract.

3.3.2 Furthermore, the continuing airworthiness documents issued by the Type Certificate (TC) holder are not specifically required by Annex 8 to observe Human Factors principles. It may be, however, that industry standards, such as those issued by ATA, do result in satisfactory documents. The operator should therefore consider if it is necessary to perform detailed "Human Factors checks" on the following publications:

(a) The maintenance manual (i.e. the TC holder's recommendations on how to perform tasks);

(b) Information issued as a Service Bulletin or Service Letter (i.e. what changes or special inspections to make as a result of service experience); and
(c) The AMO maintenance control manual in respect of topics which define the procedures that control the application of the maintenance programme. When these Human Factors checks or internal company reporting systems (post-event) reveal a text that does not properly observe Human Factors principles, the operator should report this to the originator and consider the need to transcribe it so that it does observe Human Factors principles when it is applied by the AMO.

3.3.3 The design of a maintenance programme has two aspects: first, the definition of actual work tasks and, second, the design and presentation of the programme document itself.

(a) The actual maintenance work tasks and activities defined in the maintenance programme should take into account the following factors:

i. The type of operation: short or long sectors which require different scheduling of tasks, e.g. a short sector operation may break down the tasks into "packages" which can be performed overnight, whereas the long-sector operation requires a minimum of scheduled tasks over the operating days or weeks followed by a much larger maintenance work "package";
ii. The geographical area of operation: e.g. operation in a high or low latitude with very short or long winter daylight hours where the high latitude will necessitate scheduling all tasks into a hangar to protect personnel from cold and to provide good lighting;
iii. The operator's or AMO's experience in operating or maintaining the aircraft type: e.g. personnel who are new to a particular type of aircraft are likely to require more time to perform tasks than those with considerable experience;
iv. The standards of aircraft type training provided to operating and maintenance personnel: e.g. personnel who have received a minimum level of training on the aircraft type are likely to require more time to perform tasks than those with more comprehensive training;
v. The standard of competency of the AMO, its associated procedures and quality system: e.g. manpower planning should suit not only the actual tasks during a particular shift but also the actual available manpower; and
vi. The standard of competency of the operator's organization and its associated procedures for the operation of the reliability programme (if applied to the aircraft type): e.g. an operator with a good standard of data collection, analysis and organization structure is likely to be able to take faster and better corrective action. As a result, the airworthiness of individual aircraft is likely to be higher.

(b) The design of the operator's aircraft maintenance programme document should observe Human Factors principles as describe in this AC.

3.3.4 An aircraft maintenance programme design that observes Human Factors principles (and also follows the recommendations for Type Certificate (TC) holders) should have the following features:

(a) Task or job sequences which are likely to reduce the probability or effect of error in its application (for example, performing engine maintenance with different work teams or between different flights);
(b) Work packages which suit an operator's specific operation (for example, overnight packages); and

(c) Task or job cards or sheets which meet a standard for good document design specified in paragraph 3.5.

3.3.5 In order to apply an aircraft maintenance programme so as to observe Human Factors principles, the AMO should have the following features, as appropriate to its scope and size:

(a) Satisfactory environment and ergonomics;
(b) Procedure documentation which meets a standard for good document design specified in paragraph 3.5;
(c) Management that has satisfactory processes to achieve improvements in communication, effectiveness and safety in its operations (for example, these processes could include MRM and a quality system);
(d) Error management systems for reporting, investigating, analysing, measuring and taking corrective action; and
(e) Aircraft maintenance manuals (or equivalent documentation) which has been assessed to a standard for good document design specified in paragraph 3.5.

3.3.6 The long-standing and widely accepted industry standards for aircraft maintenance technical manuals are those published by the Air Transport Association of America. (Until 1999, these standards were in ATA Specification 100 and ATA Specification 2100. In 2000, these two documents were incorporated into ATA Specification 2200.) These standards are, perhaps, best known for the aircraft zone or system numerical identifiers that are instantly recognized by maintenance personnel. Except as outlined below, the ATA recommendations are generally consistent with Human Factors principles:

(a) The maximum number of levels of paragraph breakdown exceeds the maximum of three which is recommended as best Human Factors practice;
(b) (b)Capital letters are recommended for “caution” or “warning” text rather than lower case letters which are proven to be easier to read;
(c) (c)The policy recommendation to assume users are unfamiliar with the aircraft can result in too much detail being provided for experienced users; and
(d) The only policy recommendation for writing is: “It should be written in clear, logical, easy-to-read style. …” As a policy objective, this is ideal. The FAA “Documentation Design Aid” includes more detailed information as to how this can be achieved.

In cases where the aircraft maintenance manual has been developed in conformity with the ATA Specifications, operators will need to consider the above points when ensuring that the application of their maintenance programme by the AMO observes Human Factors principles. It should be noted that Annex 8 does not require that the continuing airworthiness publications observe Human Factors principles.
The application of a maintenance programme is required by Nig. CARs Part 9.4.1.12(e) to observe Human Factors principles. Planning the process, location, personnel and tasks can have a significant effect on the likelihood of human error. Some of the issues that should be taken into account during the planning process are summarized in paragraph 3.4 to this AC.

3.4 Aircraft Maintenance Programme Maintenance Planning

3.4.1 Planning is vital to the successful application of a maintenance programme not only from a Human Factors viewpoint but also to ensure operational and economic efficiency. The primary aim should be to ensure that there are adequate appropriately qualified and alert personnel, tools, equipment, material, maintenance data and facilities at the right place and at the right time for the scheduled (and, as far as is possible, the unscheduled) tasks.

3.4.2 The purpose of this paragraph is to highlight some (but not necessarily all) of the Human Factors issues which should be taken into account in the planning process, such as human performance limitations when working shifts and long hours. The U.K. CAA document entitled *Aviation Maintenance Human Factors* (CAP 716) has been used as a reference.

3.4.3. Depending on the amount and complexity of work generally performed by the maintenance organization, the planning system may range from a very simple procedure to a complex organization including a dedicated planning department in support of the production function. Planning has two aspects: first, logistics planning for availability of parts and materials and, second, production planning which has the following two complementary elements:

(a) scheduling the maintenance work ahead to ensure that it will not adversely interfere with other maintenance work as regards the availability of all necessary personnel, tools, equipment, material, maintenance data and facilities; and
(b) organizing the maintenance teams and shifts during maintenance work and providing all necessary support to ensure the completion of maintenance without undue time pressure.

3.4.4. The planning system and procedures should consider, as a minimum, the following:

(a) logistics and inventory control;
(b) coordination with internal and external suppliers, etc.;
(c) square meters of workshop and/or hangar accommodation;
(d) hangar and/or workshop availability;
(e) estimation of man-hours;
(f) availability of man-hours;
(g) preparation of work; and
(h) scheduling of safety-critical tasks during periods when staff are likely to be most alert, and avoiding periods when alertness is likely to be very low, such as early mornings on night shifts.

3.4.5. It is considered best practice for the maintenance organization to have a maintenance man-hour plan showing that there are sufficient staff to plan, perform, supervise, inspect and quality monitor the organization. In addition, the organization must have a procedure to reassess work intended to be carried out when actual staff availability is less than the planned number for any particular work shift or period.

3.4.6. It is important that planners have Human Factors training in order to better appreciate how good or bad planning can potentially affect human performance and, ultimately, safety and airworthiness.

3.5 Document Design for Aircraft Maintenance

3.5.1. Considerable research shows that significant improvements in error rates can be achieved by the application of Human Factors principles to the design of documents used in the aircraft maintenance activity. Written communication is at the very heart of AME work. Therefore, ensuring that documents are both usable and are actually used are keys to a successful maintenance error reduction programme.

3.5.2 Investigation of maintenance-related incidents has shown that many procedures are poorly written or presented. While it is important that the manufacturers' data are incorporated accurately within the procedures, this information can be presented well or poorly, depending upon the skill of the procedure writer and the extent to which the procedure is revised based on experience and practice.

3.5.3 The following guidelines, based on the U.K. CAA document *Aviation Maintenance Human Factors* (CAP 716), are intended to assist operators and maintenance organizations in the production and amendment of procedures:

a. Ensure procedure design and changes involve maintenance personnel who have a good working knowledge of the tasks;

b. Validate all procedures and changes to those procedures before use, where practicable;
c. Ensure procedures are accurate, appropriate and usable, and that they reflect best practice;
d. Take into account the level of expertise and experience of the user; where appropriate, provide an abbreviated version of the procedure for use by experienced AMEs;
e. Take into account the environment in which the procedures are to be used;
f. Ensure that all key information is included without the procedure being unnecessarily complex;
g. Where appropriate, explain the reason for the procedure;
h. Ensure that the order of tasks and steps reflect best practice, with the procedure clearly stating where the order of steps is critical and where the order is optional;
i. If the order of steps is not already dictated, consider ordering the steps according to logic or space (e.g. working around the aircraft sequentially, as with a pilot's checklist), as opposed to alphabetical or ATA chapter order;
j. Group steps into "chunks" and plan for interruptions. Train staff to complete a "chunk" of steps before allowing themselves to be interrupted, and design the procedure in such a way that it can be marked when and where an interruption occurs;
k. Ensure consistency in the design of procedures and use of terminology, abbreviations, references, etc.;
l. Where possible, try to ensure that a complete procedure or chunk of information is on one page. Where a procedure runs to more than one page, make this clear;
m. Include clear titles at the top of each page and section of the procedure. Where the procedure has been changed, highlight this change where appropriate (with a line or the letter "R" at the side of the page), and note the revision date at the bottom of the page;
n. Avoid cross-referencing where possible. This may require steps to be repeated in several places (note: the drawback of this is that any changes have to be made in several places also);
o. Logical flow should be clear, using a flow chart if necessary. If procedures include options and branches, care should be taken that the path through the procedure is clear, especially if the user is required to return to an earlier point in the procedure after having actioned a set of steps. This can be particularly important in troubleshooting;
p. Group associated steps on the page; separate non-associated steps on the page. Use blank lines or spaces appropriately;
q. Use emphasis (e.g. italics and bold) consistently. Avoid overuse of upper case for emphasis; lower case is easier to read. Avoid overuse of italics, reserving this for single words or short phrases only, or for notes. Boxing is useful to distinguish very important steps or chunks from less important steps or chunks;
r. A diagram or photograph can be very useful and can communicate large amounts of information efficiently. However, care must be taken with their use, ensuring:
    i. it is correct (a diagram of a similar piece of equipment which is not exactly the same can cause more confusion than help);
    ii. it photocopies well (if photocopying is likely to take place);
    iii. the fine detail can be read in the lighting conditions under which it will be used;
    iv. it is orientated and labeled appropriately; and
    v. the diagram/photograph is clearly linked with a procedure/step;

s. Insert warnings and notes into the procedure wherever necessary, without unduly detracting from clarity, to ensure safe and accurate performance;
t. Consider the use of warnings, cautions or notes to highlight important points and steps where errors are likely (information from the internal error management scheme should identify error-prone procedures and steps);
u. Distinguish between directive information, reference information, warnings, cautions, notes, procedures and methods;
v. Use cautions and warnings directly above the text to which they refer or, where this is inappropriate, clearly link the text and the warning or note. Use notes after the related text;
w. Cautions, warnings and notes must be on the same page as the text to which they refer;
x. Where practical, build in check boxes into the procedure to enable and encourage the user to check off steps as they are completed;
y. Clearly link the check box with the associated step, e.g. using dotted lines;
z. Allow enough space if information needs to be entered;
aa. Stress the importance of clear handwriting if written information needs to be handed over to another person;
bb. Ensure that printing/copy quality is good, and that there are enough printers, copiers, etc.; and
cc. Provide training on the use of technology to access and print procedures and maintenance data.

3.5.4. Information Readability

The following guidelines on readability are based on the FAA/AAM *Human Factors in Aviation Maintenance and Inspection*, 1997 Phase VII Progress Report, Chapter 4, Appendix B, entitled "The Documentation Design Aid (DDA) Development" by C. G. Drury, A. Sarac and D. M. Driscoll. The PC version of the complete DDA is included on the FAA Human Factors CD-ROM (1998) and Web site: www.hfskyway.com.

(a) Typographic layout

Page size

• Use a standard paper size. In Canada and the United States, use 8-1/2 x 11 inches. In the rest of the world, use A4.

Page layout

• Use a single column layout as this is easier for lower-level readers and does not affect more experienced readers.
• For 8-1/2 x 11 inch paper, use a left margin of 1.5 inches and allow at least 1.0 inch for all other margins. The ideal line length is 10 to 12 words, or about 6 to 7 inches.
• Label each page with a subject heading at the top.
• Number each page sequentially placing the numbers at the lower right corner, 0.5 inches above the bottom edge of the page and not extending into the right margin.
• There is no need to end every page at the same point, i.e. the baseline can vary from page to page.

Justification

• Use left justification, i.e. typing lines up at left edge only. Centre and right justification is distracting and can slow reading speed.

Paragraphs and indentation

• Use modified block style with two space indentation for subdivisions.
• Label each heading and sub-heading sequentially, i.e. 1., 1.1, 1.1.1, etc.

• Within a heading, keep paragraphs below half a page in length, to help the reader's concentration.
• Leave one blank line between paragraphs.
• Do not indent the start of each paragraph.

Spacing

• Use 1:2 space ratio between sentence spacing and paragraph spacing.
• Use one blank line to separate all paragraphs and headings.
• Use one space after commas, colons and semicolons.
• Use two spaces after periods, question marks and exclamation marks.

Typeface (font)

• Use the typefaces (fonts) which have a relatively large height, are moderately expanded, solid rather than delicate looking, and have fairly uniform type colour, for example, Times Roman, Century Series, New Gothic, or Helvetica. Times Roman is the most common font style and the least fatiguing to proofreaders due to its easy readability.
• Keep the font consistent throughout the document and between documents.

Type size (font size)

• Use sizes between 9 and 12 points for ease of reading. The best size for most uses is 11 or 12 points.

Emphasis

• Keep a consistent use of emphasis throughout the document and between documents.
• To emphasize a single word, use bold (most preferred), underlining, italics or all capitals (least preferred).
• To emphasize a lengthy passage, use bold or underlining. Avoid CAPITALS or italics as they slow reading and reduce comprehension.
• Use only one or two emphasis techniques within a document to increase comprehension. Bold and underlining are good choices.
• Do not overuse emphasis techniques as it causes confusion and reduces comprehension.

Responses

• If you are using a check box following the related instruction, do not use a large gap between the check box and the instruction.
• Avoid the use of a sign box with "Not Required" or "XXXXX" if the user of the document is not responsible for the instruction accomplishment.
• Use a consistent check box design throughout the document if it is possible.
• Give enough space if you are expecting any answer from the user.

Colour

• Avoid regular use of colour in illustrations. Use distinctive shading patterns within black line images instead of colour.
• Coloured paper does not photocopy well.
• Black ink on white paper is recommended.

(b) Pagination

• Avoid use of any reference back to previous text.
• Avoid references to other sections of the document as far as possible. Unavoidable cross references must be precise and unmistakable.
• The page should act as a naturally occurring information module, i.e. it should contain an appropriate number of tasks and avoid carryover of task across pages.
• Each task that begins on a page should also end on that page.
• Minimize the routing; in other words, do not route the user from page to page since it can cause serious defects.

(c) Letters, numbers and words

Letters and numbers

• Use lower case letters instead of upper case in the text since lower case letters are much easier to read because they have more distinguishable shapes (ascenders and descenders). Note that upper case letters occupy more space (40 to 45 per cent more than lower case letters) and reduce the reading speed by 13 to 20 per cent.
• Use mixed-case headings and sub-headings instead of all capitals to improve readability.
• Avoid hyphens which merely indicate word division at the end of a line.
• In series of words or statements which present mutually exclusive choices, making the "or" explicit throughout the series enhances comprehension.
• Avoid using Roman numerals since they are not easy to read and can cause confusion.
• Use Arabic numbers followed by a period for each item in your list if you should use numbers. If not, you can use a bullet or dash to get the attention of the user.
• Do not enclose the number in parentheses.
• Use a conventional (ATA style) dash-number breakdown such as chapter-section-subject-page (e.g. 26-09-01-02).

Words

• Avoid using different terms for the same object.
• Use precise, unambiguous and common words, with which the user of the document is familiar, throughout the document for consistency. (AECMA Simplified English is a suitable guide.)
• Do not use many prepositions; they cause the user to read slowly.

Abbreviations

• Use only known acronyms and proper nouns.
• Avoid abbreviations. If you have to use abbreviations, then:
— Use them consistently; and
— Use the first few letters to remind the reader of the word.
• Provide a glossary if the users need one.

(d) Writing well

General considerations on writing

• Try to achieve a balance between brevity, elaboration and redundancy of information.
• Complement verbal material by appropriate pictorial representation.
• Adapt the format of instruction to the characteristics of the respective task.
• Write clear, simple, precise and self-explanatory instructions.
• Minimize the writing requirement for the users of the documents.
• Summarize the main ideas of lengthy prose passages in a section before the text since it aids in learning the context.
• Use adequate information in the instruction steps.
• Text should be written in a consistent and standardized syntax.
• Text should be as brief and concise as practicable.
• Use a logical structure of sentences and paragraphs since they are easier to understand and remember.

Logically place:
— General before specific provisions;
— Important before lesser provisions;
— Frequent provisions first; and
— Permanent before temporary provisions.

Sentences

• Use simplified language (e.g. AECMA Simplified English) as much as possible.
• Use short sentences instead of long ones since short sentences are easier to read and understand.
• Use definite and affirmative sentences in the active tense instead of using negative forms and passive tenses since the active voice increases comprehension.

• Use sentences with personal pronouns since they increase comprehension and the reader's motivation.
• Sentences with many subordinate clauses are difficult to comprehend.
• Use action verbs because they are easier to read and understand.
• Do not use sentences with a long noun string, since they are hard to understand.
• Use sentences complete with the necessary "who" and "which" words to clarify the relative clauses. This should avoid ambiguity and ease reading.
• Use third person for definitions as follows:
"The torsion link assembly transmits torsional loads from the axle to the shock strut."
• Use second person imperative only for operational procedures as follows:
"Check the oil level."
• Ideas expressed in positive terms are easier to understand.
• State directly what you want to say without excess or unnecessary words since the sentences with unnecessary words are harder to understand and take longer to read.

Lists and tables
• Data and information presented in the tables facilitate understanding and comparison.
• In lists and tables, do not leave blanks within a line greater than half an inch or five spaces.
• Group the lines in lists and tables according to content.
• Do not group more than five lines together.
• Separate the groups in the list and table by spacing.
• Write the list of items in parallel construction since that way is easier to read and remember.
• List a series of items, conditions, etc. rather than displaying them in a series separated by commas.
• Avoid using compound questions and statements.
• Minimize the logically related question as much as possible.
• Construct the questions in a way which requires minimum memory use from the user of the document.
Graphic information
• Place the visual item in the text of a document near the discussion to which it relates. If it is not possible, place the visual item in an appendix, label the item and refer to it.
• Use a clear title with a figure or a table number on the line directly below all illustrations.
• Use the same title for illustrations as corresponding text subject title.
• Use either a horizontal-landscape format with the top of the illustration at the binding edge or vertical layout to present graphic information for ease of reading and cross-reference consistently.
• Adequate text must be supplied to support illustrations, not vice versa.
• Draw illustrations in a size and line weight such that they can be used without any rework for the production of material for screen projection in a training environment.
• Illustrations should have limited information in order to avoid a cluttered appearance. The presentation should be self-explanatory.
• Use illustrations as the primary source of information transfer.
• Present all spatial information in graphical format instead of in textual format.
• Label each table and figure with an Arabic numeral, such as Table 1 and Figure 1.
• Use simple line drawings, which are superior in most cases.
• Use a consistent format for figure layout and numbering.
• Use illustrations whenever they will simplify, shorten or make the text easier to understand.
• Do not use complicated reference numbers for figures, e.g. T07-40423-001.
• Avoid use of perspective part drawings as figures.
• The figure views should be as the user sees it.
• Use standard and correct technical drawing terminology, e.g. avoid use of terms "section" and "view" interchangeably.

• Reference all tables and figures in the text by the numbers.
• Use bar charts to make accurate comparison of numerical data whenever possible.
• Line charts (or graphs) help to understand trends and allow accurate comparison between two or more numerical values.

(e) Printing and copying quality

• Check the toner box regularly to have consistent copy quality.
• Make sure that no major image degradation occurs with reproductions of originals.
• Use paper which has a reflectance of at least 70 per cent.
• Use low visual acuity and large type size if user is going to use the document under low illumination levels.
• Readers prefer matt paper to medium or glossy paper.
• High opacity paper is preferable.
• Use black ink on white paper since it is more effective than white ink on black paper.
• Develop and implement standards for changing printer ribbons, toner boxes, etc. to ensure a consistent print quality at all times.

3.5.5 Organizational Issues

• Allow the prospective users of work cards to participate in the design of the document.
• Check every individual instruction by testing it in the field situation.
• If your document is going to include multiple copies, colour can be a useful processing aid.
• Have a feedback system so that users are aware of how to correct an erroneous entry.

The content of this AC shall be used by NCAA Inspectors in the evaluation of Aircraft Maintenance Programme and Maintenance Control Manual submitted by operators to ensure that human factors principles are used in the design and development of the manuals.

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Nigerian Civil Aviation Authority

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