Safety Regulation Group

Civil Aviation Authority

CAP 708

Guidance on the Design, Presentation and Use of Electronic Checklists

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Explanatory Note

1 Introduction

1.1 The CAA has made many of the documents that it publishes available electronically. Where practical, the opportunity has been taken to incorporate a clearer revised appearance to the document.

1.2 This is a living document and will be revised at intervals to take account of changes in regulations, feedback from industry, and recognised best practice. Contact addresses, should you have any comments concerning the content of this document or wish to obtain subsequent amendments, are given on the inside cover of this publication.

2 Revisions in this Edition

The material contained in this document, although different in appearance to the previous version, is unchanged.

Foreword

This guidance material has been developed for the Safety Regulation Group of the UK Civil Aviation Authority by RM Consultants Limited. Information on how the guidelines were developed can be found in CAA Paper 2000/09 (The Development of Guidance on the Design, Presentation and Use of Electronic Checklists)

The publication complements, and should be used in conjunction with, CAP 676 (Guidelines for the Design and Presentation of Emergency and Abnormal Checklists) which was published in 1997 and is primarily concerned with paper checklists.

Glossary

Checklist	The written instructions that describe the set of tasks to be carried out or confirmed
Drill	A set of tasks to be carried out
Electronic checklist (ECL)	Electronic checklist – written instructions which describe a drill displayed on an electronic system
ECL system	The technical system which delivers an electronic checklist (ECL), accepts input from the flight crew, and responds by changing the presentation of the ECL
Flight crew	Normally refers to two pilots, where either pilot may be interacting with the ECL system. In some cases there may be three membersof the flight crew (including the flight engineer) or only one pilot.
Flight Manual	The set of procedures provided by the manufacturer and approved by the appropriate regulatory authority. This forms the basis for the functional content of all checklists (both paper and electronic).
Paper checklist	Written instructions which describe a drill, provided on paper (or in other permanent form, for example printed on the central panel of the control column)
Quick Reference Handbook (QRH)	A handbook containing checklists which may need to be referenced quickly or frequently, including emergency and abnormal checklists.The checklists may be abbreviated, for ease of reference (although must reflect the procedures contained in the Flight Manual).

Abbreviations

CAA	Civil Aviation Authority
CRM	Crew Resource Management
ECAM	Electronic Centralised Aircraft Monitoring
ECL	Electronic Checklist
EFIS	Electronic Flight Information System
EICAS	Engine Indicating and Crew Alerting System
PF	Pilot Flying
PNF	Pilot Non-Flying
RMC	RM Consultants Ltd
SRG	Safety Regulation Group of the CAA

Chapter 1 Introduction

1 Objectives

1.1 This guidance is intended to promote best practice amongst UK aircraft operators with regard to electronic checklists (ECLs), maximising the potential safety benefits and minimising the potential disbenefits. The document complements CAP 676, which provides guidance on paper-based checklists. In some areas the guidance outlines the factors to take into account when deciding which approach is appropriate for the particular circumstances at the time, rather than providing a definitive answer.

1.2 Details of the process by which the guidance was derived, and discussion of aspects on which it is not possible to issue definitive guidance, are provided in CAA Paper 2000/09.

2 Scope of Guidance and Intended Audience

2.1 This guidance is written principally for aircraft operators, to assist them in:

- knowing what design and presentation features to consider when evaluating, specifying or selecting an ECL system; and
- installing ECL systems in the aircraft and writing or adapting the checklists as required, setting up effective training and education in the use of an ECL system, and developing procedures for operational use, obtaining pilot feedback and the managing modifications.

2.2 The guidance may also be of interest to manufacturers, although it should not be taken as superseding any existing regulatory requirements for hardware and software design.

2.3 These guidelines address the way in which checklists are presented and used, not their functional content. Operators are responsible for ensuring that any changes they intend making to ECL content do not conflict with the Flight Manual. This guidance is intended to promote best practice, but does not prescribe the only means of achieving this. Overall responsibility for providing a safe system and procedures remains with the operator. It is particularly important that the ECL system is evaluated prior to use, ideally by a representative user population.

3 Types of Aircraft Operation and ECL Covered by the Guidance

3.1 The term ECL is used here to include all forms of electronic reference by which flight crew are presented with a list of actions to be followed. It thus includes actions or instructions that may appear on the various types of electronic flight information displays (e.g. EFIS, EICAS or ECAM) as well as dedicated ECL systems.

3.2 Except where otherwise stated, these guidelines apply both to normal checklists and those for use in emergency and abnormal conditions.

3.3 An ECL system requires a method of presenting information and choices to the pilot (output) and a method of allowing the pilot to move between items, acknowledge completion of items and in some cases to input information. It is assumed that the ECL interface makes use of a physical input device (e.g. cursor control device or touch screen), and a display screen for output, possibly with aural alerting or voice

annunciation. Speech recognition systems for pilot input and the use of speech output for presenting options to pilots are not covered by these guidelines.

3.4 The guidelines cover both ECLs that receive inputs from the aircraft system or from the state of switches in the cockpit ('sensed' or closed-loop systems), and ECLs which are activated only by inputs from the flight crew (stand-alone or 'un-sensed' systems).

4 Structure and Use of Guidance

4.1 The extent to which operators are able to control or modify ECL features is variable. Some ECLs systems are entirely factory-fixed, such that the operator's influence on safety is principally by defining the ways in which pilots make use of the system. Other ECLs systems are more 'open', allowing the operator to customise the checklist by adding or adapting text. Hence it is not possible to make a clear distinction between what is fixed once the ECL has been acquired and what is subsequently within the control of the operator. Not all of the guidance will therefore be within the scope of every operator.

4.2 To assist readers with differing interests and types of ECL, the guidance is structured around the 'lifecycle' of an ECL, as relevant to an operator. The lifecycle shows the order in which operators may consider and use ECL systems. This lifecycle is shown in Figure 1.

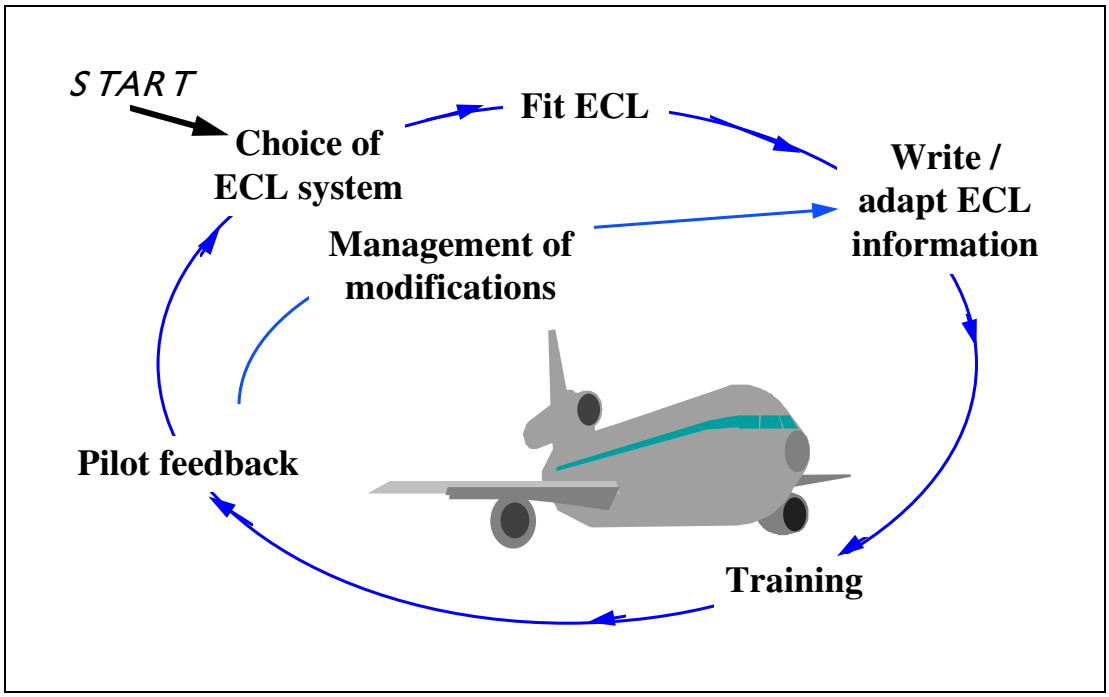

Figure 1 Lifecycle Model

4.3 Table 1 indicates the chapters in the guidance of most interest to different types of readers.

Table 1 Chapters of Particular Interest to Different Types of Readers

Roles of Expected Readership	Chapter and Content
All	1 Introduction
High level flight safety and management decisions about whether to acquire ECLs, and what type	2 Choices (fundamental decisions about ECL type and what checklists are provided electronically)
Specification/ evaluation/selection of ECL systems	2 Choices (fundamental decisions about ECL type and what checklists are provided electronically) 3 Positioning of ECL on the flight deck 4 Physical display issues 5 Interaction Issues
Fitting or retro-fitting of ECL systems	3 Positioning of ECL on the flight deck
Human Factors departments	4 Physical display issues 5 Interaction Issues 6 Language
Writing new or modified checklists	5 Interaction Issues 6 Language
Training departments	7 Education and Training
Provision of paper back-ups or the design of Standard Operating Procedures	8 Operational use
Line pilots and their representatives	9 Evaluation and feedback
Modification of checklists	9 Evaluation and feedback 10 Management of Modifications

Chapter 2 starts with some distinctions between types of ECL which operators should consider when specifying or acquiring an ECL system (Chapter 2 paragraph 1). Chapter 2 also includes consideration of which checklists to make available in an ECL system, as the choice of checklists may also influence the features required of the ECL system. The final part of Chapter 2 notes some additional features which an ECL system may have, and discusses the safety aspects to consider for each.

4.4 The choice of ECL system (Chapter 2 paragraph 1) largely determines what control the operator will have to amend or modify the ECL, and hence the extent to which the material in later chapters is relevant. A particularly important distinction is that between the guidance for sensed systems (or checklist items) and that for stand-alone ECL systems.

4.5 Chapter 3 concerns the physical location of the ECL on the flight deck.

4.6 Chapters 4 to 6 cover the design of the ECL system and its checklists, covering the physical display of information (Chapter 4), interaction issues (Chapter 5) and the issues to do with writing the checklists themselves (Chapter 6).

4.7 The subsequent Chapters cover the aspects that come into play once an ECL equipped aircraft enters the fleet. Chapters 7-10 cover, respectively, pilot training, operational use, feedback from pilots and the management of modifications.

5 Differences between Electronic and Paper Checklists

5.1 ECLs differ from traditional paper checklists in a number of ways.

5.2 The most obvious differences between paper checklists and ECLs is the way in which the user of the checklist interacts with the checklist. With a paper checklist, instructions are displayed in a fixed presentation (although in some cases it may be possible to effectively increase the display area, for example by looking at two pages of a checklist). With an ECL the display area is fixed, but the display can be altered easily to show different groupings of items (e.g. items 1 to 10, items 5 to 15, or all items not yet completed). With an ECL it is possible for the appearance of the item to change according to its status (e.g. to place a tick next to a checklist item and to change the colour of that item when it has been marked as checked by the flight crew). With a paper checklist the only way of achieving this would be to mark some indication on the paper (e.g. placing a tick in a box) when an item is completed. Such checklists would have to be replaced (or the marks erased) before being used again, which in most cases would be impractical.

5.3 A further difference is that whereas with paper checklists, the organisation of checklists into physical folders or subdivisions of a QRH ('normal', 'abnormal' and 'emergency') dictates the way in which the flight crew need to identify and select a drill. With ECLs such a distinction is not necessary, as a number of different methods can be provided for identifying a checklist. In some instances, the checklist may be triggered automatically by a fault. Alternatively, the pilot may be able to search for all procedures relevant to a particular key word. There may be a hierarchical menu structure from which to select a procedure.

5.4 ECL systems can reduce the workload of the flight crew through 'place-holding' i.e. remembering which items on a checklist have been completed and reminding the crew of items which have been deferred until later. For sensed or 'closed-loop' systems some items are checked automatically, reducing the number of items that need to be checked.

5.5 However, one of the potential hazards that has been raised in connection with ECLs concerns the compelling nature of the display. It is possible that in some situations the flight crew could become over focused on the ECL display, and their awareness of other important events in the cockpit might be reduced. This possibility needs to be considered in the design of ECLs and in training flight crew to use them.

6 Principles to be Used in Applying this Guidance

6.1 On a number of occasions throughout the guidance it has not been possible to provide definitive guidance, as the answer will depend on the context of use (pilot expectation, flight deck design philosophy, type of checklists, technical capability of the ECL system etc). However, for all decisions, some common human factors principles can be applied.

6.2 At the highest level, a checklist is a device to reduce the potential for flight crew error in configuring the aircraft safely for the phase of flight, and for any failures that may have occurred. A number of more specific principles can be considered to achieve this purpose.

6.3 For both normal and abnormal/ emergency checklists, the potential for error is reduced principally by:

- reducing reliance on long term memory.

Normal checklists do this by providing the flight crew with a means of checking that all necessary routine actions have been carried out for each phase of flight. Emergency and abnormal checklists inform flight crew of the required actions (which are infrequently practised, and therefore tend not to be memorised).

6.4 The checklist (especially where it has a degree of sensing or internal intelligence) can also assist by:

- trapping errors.

i.e. by detecting and alerting the flight crew to certain slips, lapses and mistakes or by preventing them occurring. For example, an ECL system with internal intelligence can prevent the pilot from removing a checklist before all the items have been completed.

6.5 Abnormal and emergency checklists have additional high level principles:

- reducing workload, by presenting the required actions in a readily accessible, concise and efficient form;
- improving situational awareness, by showing the crew where they are in a sequence of actions, and what they are trying to achieve.

6.6 Sensed ECL systems for abnormal and emergency cases have further high level principles:

- assisting in rule-based and knowledge-based decision-making, by presenting the most likely option(s);
- reducing reliance on short term memory. For example, to avoid the need for crew to recall which engine is on fire, a sensed ECL can present this information both in the Engine Fire checklist title and by 'personalising' the action items. For example, it can show the item:

  Fire bottle right..... Discharge

  rather than:

  Fire bottle (right or left)..... Discharge

  as might appear in a paper checklist.

7 High Level Requirements Based on Principles

7.1 The human factors principles noted above can be embodied in requirements which can be more directly implemented in the design, presentation and use of checklists. As in CAP 676, these requirements can be expressed as:

- accuracy;
- lack of ambiguity;

- clarity;
- succinctness (suppressing information not relevant to the task);
- consistency with other checklists, pilot expectations and airline culture and (for electronic checklists) other flight displays and the paper back-up.

7.2 Additional requirements can be stated for reducing mental workload. These are especially important for abnormal and emergency checklists:

a) Provide unambiguous information and suppress information (or detail) that is not task relevant.

b) Avoid reliance on long-term memory.

c) Reinforcing task goals.

d) Provide meaningful cues to the type of response expected.

e) Avoid forcing absolute judgements by providing a reference where possible so relative judgements can be made instead.

f) Present information at appropriate rates, to avoid overloading short-term memory.

g) Minimise noise and redundancy.

h) Avoid the need for mental transformation and conversion.

i) Maximise compatibility with user expectations and conceptual models.

j) Maximise discriminability by reducing noise and redundancy.

7.3 Examples of how to meet some of these requirements are provided in Appendix 1 paragraph 1.

Chapter 2 Choices

1 Which Type of ECL should we Use?

1.1 In this chapter we look at some of the different features of ECL systems currently available. The advantages and disadvantages are outlined in order to help the operator make decisions on the mix of capabilities they require.

1.2 A fundamental distinction is between sensed and stand-alone (or 'unsensed') ECL systems.

1.3 Sensed ECLs take input from aircraft systems or switch positions in order to determine which checklist should be presented to the pilots, or to test whether items or checklists declared complete by the pilot have actually been completed. Stand-alone systems have no connection to the aircraft; they are controlled entirely by the pilot and thus are more directly analogous to paper checklists. However, both sensed and stand-alone systems may have some internal logic, for example, to prevent a checklist being removed from the display until all the items within it have been completed, or to present only one branch of a checklist (equivalent to an 'if.. then.. else' structure) dependent on the pilot's response to a previous checklist item.

1.4 The terms sensed and stand-alone encompass a range of possibilities, as shown in Table 1.

Table 1 Factors to Consider when Assessing Options for ECL System Features

Feature	Options	Factors to Consider
What is sensed?	One or more of the following: 1. Aircraft system state 2. Switch positions 3. Pilot inputs to the ECL (Stand-alone is 3. only)	Aircraft system state sensing (1) gives the most accurate feedback of the three options – it determines whether the required change has actually taken place. However, for some checklist items, the response time of the aircraft system may be slow, such that a pilot may look at a checklist at a point in time, when a particular action has been taken but has not yet registered on the checklist. This could cause the pilot to attempt to take the action again, in some cases reversing the previous result. For such items, the checklist will be more up-to-date if it senses the switch positions (2) rather than the aircraft system state (1).

Table 1 Factors to Consider when Assessing Options for ECL System Features

Feature	Options	Factors to Consider
		Some aircraft designers take the view that the checklist system should not duplicate or supersede other warning systems. Like a paper checklist, it is regarded as an aid to the pilots, not a system monitoring device. Taking this view implies that if the aircraft systems do not respond as desired to switch position this should be revealed by the warning system, not via the checklist. Other designs integrate the checklist and warning systems more closely. Decisions on what should be sensed must therefore be taken in the context of the overall flight deck design philosophy. Some items may only respond to the input the pilot makes to the ECL (3), i.e. in selecting an item. This may be because the whole system is stand-alone, or because it is necessary to keep the pilot in control for certain items to maintain situational awareness even where the ECL system could sense the item.
Completeness of sensing	One only of the following: Fully sensed (all checklists and items – although probably not practical) Mixed system (only some items are sensed) Stand-alone (none of the items are sensed)	Full sensing would provide the greatest degree of automated assistance and checking. However it is not possible to sense all items – some items, such as whether the approach briefing has been carried out, cannot be checked automatically. There is also an issue of maintaining situational awareness: if the crew know that all items are sensed, there may be a reduction in the awareness which is built up by having to scan the various controls. A mixed system, where some items are sensed and others entered by the flight crew, is the recommended option. The decision on the appropriate mix of sensed items will need to take account of the aircraft design philosophy with regard to automation, and the expectations and training of crew.

Table 1 Factors to Consider when Assessing Options for ECL System Features

Feature	Options	Factors to Consider
Function of sensing	None, or: One or more of the following: 1. Select and present an appropriate checklist (or a queue of appropriate checklists) according to the phase of flight or any failure detected in the aircraft system. 2. Remove items already completed (sensed from aircraft or switch state). 3. Change the presentation of items already completed (by flight crew). 4. Check the completion or status of items cleared by the pilot against what has actually been done.	Presentation of the correct checklist (1) can reduce the chance of selecting the wrong checklist, and reduce crew workload, but may lead to some loss of situational awareness, since it takes the crew out of the decision-making loop. Removing items from the list which have been sensed as complete (2) reduces workload and improves clarity, by reducing display clutter, but at the same time will reduce situational awareness. Automatically changing the presentation of items that have already been completed (3) can reduce workload, without loss of situational awareness, but does not reduce clutter. Checking the status of items against what has actually been done (4) can be a useful way of catching errors of omission, providing that the notification of an error is given in an appropriate manner and at the appropriate time. As with the completeness of sensing, decisions on the function of sensing need to take account of the aircraft design philosophy with regard to automation, and the expectations and training of crew.
Treatment of multiple failures	None, or one or more of the following: 1. Presents list of appropriate checklists and flight crew determines order of completion. 2. Presents list of appropriate checklists, ordered according to priority assessed by ECL 3. Automatically sorts out conflicting information, and presents only the checklist considered most urgent as assessed by ECL. A list of inhibited checklists may also be presented.	Where a large number of faults occur, it can be difficult to determine which is a key fault, and which are side-effects of the main fault. Doing nothing means leaving the flight crew to sort the fault messages out, and determine which to deal with first. Option 1 keeps the flight crew in the decision loop, by presenting them with possible checklists (in order to save time and reduce mis-selection) but leaving the decision as to which one to use first to the user. Option 2 goes a step further, with the ECL determining the order of completion, although as the flight crew can see the full list of checklists, this prioritisation can be overridden. Option 3 takes the decision making away from the flight crew, which reduces distraction and workload, but could result in the wrong checklist being followed if the prioritisation system of the ECL system does not have all the correct information.

Table 1 Factors to Consider when Assessing Options for ECL System Features

Feature	Options	Factors to Consider
Internal logic	None, or: One or both of the following: 1. Internal logic within each individual checklist. 2. Logic within the ECL system, whereby one checklist can view the status of another checklist and present items accordingly.	Whether an ECL system senses aircraft state, switch positions or only crew inputs, it may still have some internal logic. Some logic within an individual checklist (1) is recommended. For example, ensure that a checklist cannot be declared complete until all items within it have been checked (or overridden). Another form of internal logic is for a checklist to present different check items depending on the answer to a previous item (replacing 'branching' or 'if' clauses). This can reduce the potential for selecting the wrong branch and reduce workload, though some loss of situational awareness may result. (2) More sophisticated logic might involve one checklist determining which other checklists should be presented, or pre-checking certain items in one checklist depending on the status of items in another checklist. This can provide more sophisticated error trapping and greater workload reduction, but the potential loss of situational awareness is also greater. Providing information to the aircrew on which items have been pre-checked can reduce the loss of situational awareness.

1.5 The features noted above can be seen in terms of greater or lesser degrees of automation. Automation can have both safety benefits and safety disbenefits. For ECL systems, the most relevant benefits and disbenefits (referring back to Chapter 1 paragraph 6 on principles and requirements) can be summarised as follows:

1.6 Benefits of greater ECL automation:

- Error-trapping: reduced potential for slips, lapses and mistakes to occur and to go uncorrected. For example, selecting the wrong checklist can be prevented where the correct checklist is presented automatically; clearing an item that has not been completed can be detected if the checklist system senses the status of the item.
- Reduced workload: for example, presenting the correct checklist, or the correct route through a checklist.

1.7 Disadvantages of greater ECL automation:

- Reduced situational awareness: reducing the need for flight crew to scan, check and make decisions can make them more remote from the system.
- Reduced practice in diagnosing and handling errors: where many problems can be resolved automatically through automation, flight crew will have less opportunity to practice problem solving, which could affect their ability to solve a problem which cannot be handled automatically. This can be mitigated by including problem solving skills as part of crew training.

1.8 The decisions to be made are therefore decisions about the level of automation which optimises the net benefit. This balance cannot be determined by considering the ECL system in isolation. Other important factors to consider are:

- Aircraft manufacturer's approach to flight deck automation.
- Compatibility with overall flight deck philosophy.
- Expectations, experience and training of the crew.

2 Which Drills should be Available as ECLs?

2.1 A simple rule would be that those drills that have paper checklists, and only those drills, should have ECLs. However, ECL systems do provide an opportunity for additional checklists that might not be practical to use in paper form. For example, certain short drills which need to be completed urgently may be committed to memory, since the time needed to locate the correct checklist in the QRH may be longer than the time available to complete the drill. With ECLs such drills may be found more easily (and in the case of sensed systems, may be presented automatically), and therefore provide an additional benefit in ensuring all actions are taken.

2.2 Nevertheless, operators should not allow checklists to proliferate simply because the ECL system allows them to be created or used more easily. Checklists should not, for example, be specified for very simple routine actions where the ECL contributes no safety benefit or where other systems or procedures can achieve the benefit more effectively. The requirement to have a paper back-up available for all checklists (see Chapter 8) should restrict the increase in the number of checklists available.

2.3 Some ECL systems provide only emergency and abnormal drills, others only normal checklists. There is an advantage in having all drills available electronically in terms of consistency and not having to switch between systems. In particular, it means that flight crew will be familiar with the operation of the abnormal and emergency ECL system from regular use of normal checklists.

2.4 Benefits of greater ECL automation: Electronic checklists should be consistent in presentation and content with their paper equivalents except where there is a demonstrable safety or operational benefit, or where the display area dictates a change. For example, it is likely that fewer items will be displayed on the ECL screen than on one side of paper. However, each item should still be separated from the preceding and following items on the screen, and not grouped together with other items to save space. An ECL can be specific to the right or left engine, whilst a paper checklist may combine the two drills. The electronic version, being more specific, reduces the possibility of confusion between left and right. Other differences between paper and ECL may occur because of the additional functionality of the ECL. For example, an ECL can display a countdown timer that is started automatically, and reminds the pilot if a task is not completed within a specified time limit.

3 Additional Facilities Possible on an ECL System

3.1 Additional facilities that may be available on an ECL system include:

- Display of system status information.
- Facility for the flight crew to make notes within the ECL.
- Highlighting of actions required urgently.

- Deferment of items from one checklist to another.
- Reference to expanded reasons for action and other supporting information.
- Storage of the responses made to the checklist by the flight crew.

3.2 Table 2 presents some of the considerations for each of these facilities.

Table 2 Additional Facilities for ECL Systems

Facility	Advantages	Disadvantages
Display of system status information, reasons for action and other supporting information	Additional information, quickly accessed, can improve situational awareness and decision making. For example, it could help flight crew detect where suggested action is incorrect in cases where the aircraft is configured differently from ECL system manufacturers' expectations. All such links should be clearly marked, without distracting from the checklist itself.	Extra information will require more screen space. It can increase workload and distract flight crew from actions to be taken. Care is needed to ensure integration of the ECL system and other status and warning systems – the boundaries and linkages need to be logical, and users need to be aware of them.
Notes	This provides a convenient mechanism for recording information that may be required later in the flight.	Notes facility may encourage use of system beyond intent, resulting in distraction or additional workload.
Highlighting urgent actions	Can improve decision making and reduce workload, by helping crew prioritise actions and avoid less important tasks distracting flight crew from urgent actions.	May be over-compelling, distracting flight crew from other, non-checklist tasks.

Table 2 Additional Facilities for ECL Systems

Facility	Advantages	Disadvantages
Deferment of items from one checklist to another	Some items in a checklist may not need to be done immediately, but may be need to be done at a time associated with another checklist. Deferment to another checklist can ensure such an item is completed at the correct time. For example, if a non-normal checklist calls for the cabin pressurization system to be operated manually, the outflow valves need to be manually opened just before landing. Keeping the non-normal checklist open just for that one item will clutter the display, and the item may be forgotten when using the normal checklist.	The checklist it is deferred to needs to be one that will be completed later. The 'receiving' checklist will look different on different occasions. The normal checklist may be followed 'automatically' by the aircrew, such that the deferred item is not noticed and not actioned.
Storage of the responses made to the checklist by the flight crew.	This would provide additional information in the event of an incident, as well as detail of configurations that could be used in training.	

Chapter 3 Positioning of the ECL

1 The checklist display should be in view of the flight crew, and each pilot should have access to an input device for the ECL system.

2 Display screens should be positioned where glare and other adverse lighting conditions will be minimised. Ideally, it should be possible to divert the ECL from its normal display to an alternative display on the flight deck – this may be particularly important in smoke.

3 If the checklist display needs to be reached (for example, to select soft keys surrounding the display, or where a touch screen is used) the display should be within easy reach of the pilot, when the pilots seat is adjusted correctly for other flight deck equipment. Where a joystick or similar input device is used to move the position of a pointer on the screen and to select checklist items, this should be positioned such that a pilot can hold it comfortably, with the arm supported (at the wrist, forearm or elbow). To accommodate the needs of different pilots, a joystick or similar input device should ideally have some amount of adjustment possible. Appendix 3 provides more specific advice on input devices.

4 Although it is important to follow guidelines on the positioning of items, guidelines cannot alone ensure an optimum layout. Ideally, anthropometric modelling of the flight deck, or the use of full-scale mock-ups tested by representative users should be used to assess the optimum position of the ECL system inputs and outputs.

Chapter 4 Physical Display Issues

1 Screen Characteristics

1.1 Many ECLs will be displayed on screens used for other purposes, in which case there may be less control over the display characteristics than for dedicated ECL displays. However, the following advice applies broadly to any display used by flight crew.

1.2 So far as possible, the ECL display should remain legible under all conditions, including situations where the ambient lighting falls differentially across the display. Colours, brightness and contrast should be appropriate for viewing conditions. To cope with varying conditions, it may be necessary to provide pilots with brightness and contrast controls. See Appendix 2 paragraph 5.

1.3 So far as possible, a facility should be made available to read the ECL even when there is smoke in the cockpit. For example, there are methods available of maintaining a smoke-free 'corridor' of air between a pilot's face and the screen, such as using an inflatable transparent bag. Where possible, the physical nature of the screen should minimise the likelihood of become obscured – e.g. by repelling smoke or dust particles, and by being easy to clean.

1.4 To allow viewing of the screen from a number of angles, text should not run up to the edges of a screen that is mounted inset from its surrounding panel.

2 Character Attributes

2.1 Text displayed on the screen should be legible at the normal viewing distance of the flight crew. Details of current advice on how to satisfy this general requirement are provided in Appendix 2. This includes recommendations for viewing distance, character height, width and stroke width, and for spacing around letters.

2.2 Sans serif fonts (such as arial) are recommended for use in an ECL. Sentence case (i.e. with a capital letter at the start of an item, with remaining words in lower case except for abbreviations etc.) should be used, as this is easier to read than all upper or all lower case.

3 Emphasis

3.1 It will often be necessary to draw the flight crews' attention to specific checklist items such as:

- Non-completed/ deferred checklist items.
- The next item for completion on the ECL.

3.2 It may also be necessary to distinguish checklist items such as:

- Memory items (which may have been completed before the ECL is displayed).
- Particularly important/ significant items.
- The use of a different method of emphasis for some items needs to be balanced with the visual confusion which can be created by the use of too many methods of highlighting, and by the disbenefit of drawing attention to some items at the expense of others.

3.3 When designing an ECL system, the display should first be optimised for use on a monochrome display. Colour (see paragraph 5) can be added later as a redundant feature to enhance the user interface. Ways of adding emphasis without using colour are shown in Table 1.

Table 1 Methods of Emphasis

Method of Emphasis	Comments
Increasing luminous intensity (brightness) of the characters	Emphasised text at least twice as bright as normal text – works well on most screen types
Emboldening	Increase the stroke width – works well on most screen types
Reverse video (reversing the dark-light normal dark/light convention for text and background)	Stroke width for light on dark background should be thinner than for dark on light background – works well on most screen types
Flashing text.	Use sparingly if at all, only to draw to the pilot's attention to critical items requiring an immediate response. See A2.6 for more information.
Italicising	Effectiveness is variable depending upon the basic font used on the display.
Underlining	Text more difficult to read, with reduced apparent line spacing. Underlines may cut descenders of lower case characters. Overall, it increases display density making text more difficult to read.
Boxing or vertical lines	Simple single lines should be used (i.e. not drop shadow or 3-D effects). Increases display density or reduces the amount of information which can be displayed on the screen. However, if used sparingly (e.g. for current checklist item only) can work well.

3.4 No more than two categories of emphasis should be used on one piece of text, and in most cases one is sufficient.

3.5 Care should be taken to ensure that emphasised text is not confused with the other conventions used to display section and sub-section headings.

3.6 Methods of emphasis should, wherever possible, be consistent with other flight deck displays. Conventions used in paper checklists (such as that for indicating memory items) should also be considered to provide consistency where appropriate.

4 Symbology

4.1 Symbols can be provided to make the status of each item in the checklist clear. For example, a checkbox can be placed next to each item in the checklist, with a tick used

to indicate completion. A cursor or item box or arrow can be used to indicate the current item. An asterisk can be used to mark deferred items. These are not the only conventions allowed, but whatever symbols are chosen, they should be used consistently, and their meaning should be in line with the expectations of the crew. For this reason, a tick in a box is a better form of indicating completion than a cross in a box, since a cross is associated with something incorrect.

4.2 In general, pictograms (i.e. representations of a physical device or system) are not recommended for ECLs, as they require a large amount of space to display well. If displayed too small they may be difficult to interpret or distinguish. In addition, their meanings may not be obvious to the aircrew.

4.3 Symbology should be consistent with other flight deck displays and, where appropriate, with paper checklists.

5 Colour

5.1 As suggested in paragraph 3, a screen design should first be optimised for use on a monochrome display. This will make the screen easier to interpret in poor lighting conditions (where colours may be more difficult to distinguish) and in emergencies (where the pilot may misinterpret the meaning of a colour). Once this has been done, colour can be added in a redundant manner.

5.2 A maximum of seven colours should be used, but in most cases even this number of colours will not be required for an ECL.

5.3 Some broad guidelines on choosing colours are:

- Colours should be easily discriminated in all operating conditions.
- Colours should be consistent in their use.
- There should be only one meaning per colour.
- The colours used should be consistent with external conventions (e.g., those used on other flight deck displays or in aviation more generally).
- Users should not be able to change the colour conventions on a display.

5.4 Colour is commonly used to distinguish the status of items. For example, white text for the current item, green for completed items.

5.5 The meaning that one person may attribute to a particular colour may be different from those assumed by another person. Table 2 shows some common associations for colours. This shows the range of meanings that can be attributed to each colour. This is further complicated by the fact that, for example, even if red is understood to mean ‘danger’, if a control is red, does this mean that activating it is dangerous, or that the button should be activated if a dangerous situation occurs? Therefore, where colour is used as a method of conveying information the flight crew needs to be informed of the meanings associated with the various colour codes for this system. This may be during training and in flight deck documentation. Where possible, colour meanings should also be available via the display unit.

Table 2 Common Associations for Colours (for European / United States users)

Colour	Common Associations
Red	Danger, Emergency, Failure, Stop, No Go, Fire/Hot
Blue or Cyan	Mandatory, Inactive, Water, Sky, Off, Cold
Green	Safe condition, Proceed, Safe passage, Exit, Healthy
Yellow or Amber	Caution, Ambient, Delay, Warm
White	Operational, Pure, Cold, New
Magenta	Active

5.6 Users should not be expected to determine a different meaning for a message according to its colour (for example, where the same text is a status message if in white, but a warning if in amber)

6 Layout

6.1 Consistency of Layout with Paper Checklists

As far as possible the layout of items on an electronic checklist system should be based on the same layout as the equivalent paper version. The line length and page size will probably be different (because of the smaller size of the screen compared to the paper sheet) but the use of headings, sub-headings and titles can be consistent.

6.2 Standard Contents

6.2.1 Each screen should have a title at the top of the screen, with some form of emphasis (e.g. bold text) to distinguish it from the remaining text.

6.2.2 Where a checklist is too long to fit on one screen, an indication should be given of how many screens are used for that checklist, and how far through the screens the current screen is, for example 'screen 2 of 5' or 'page 2 of 5'. Where only one checklist item is shown at a time, the importance of showing the flight crew how far through the checklist they are is even more important, and this can be done with a label such as 'item 6 of 15'. These position indications will normally be at the bottom of the screen, in the position that a reader would expect a page number in a paper document.

6.2.3 The end of each checklist drill should be clearly indicated.

6.3 Format

6.3.1 Screen density should not exceed 60% (i.e. the number of character spaces filled as a percentage of the number of character spaces available). Where the checklist consists of a list of instructions, the text should be left justified, with a 'ragged' right hand edge. Fully justified text can result in uneven spacing between words, which makes text harder to read. In addition, the ragged right margin provides a strong visual cue to enable the reader to keep their place in the text. An alternative format for the checklist is tabular. For example, with two columns as follows:

- 1st column: contains the 'challenge'. This is normally the name of the system or control or parameter involved in the action, for example 'cab fans' or 'approach speed'. This should be left justified.

- 2nd column: contains the 'response'. This is normally the required status of the system or control, or the required value for the parameter in the challenge, for example 'off' or 'Vref + 10'. This should be right justified.

6.3.2 The layout should make it clear which challenge is associated with which response. If necessary, a dotted line or similar method can be used to connect the challenge with its associated response.

6.3.3 The wording of the challenge and response should make it clear what action is required, for example to check the status of a control and set it to a particular setting if it is different from that stated.

6.3.4 With a tabular presentation, colour may be used selectively to improve discrimination between columns, but this must take account of any colour coding used to indicate the different status of each item.

6.4 Size of Checklist Items

Where possible, keep each item on the checklist to one line of the screen. However, this should not be at the expense of readability, as excessive brevity can increase the time taken to understand an instruction.

6.5 Spacing between Checklist Items

6.5.1 Where checklist items are more than one line of text, the space between checklist items should be greater than the space between each line of text within the checklist item. Where a tabular format is used, e.g. for the challenge – response format, the spacing between rows of checklist items may need to be greater, because of the potential for larger spaces between each column of text.

6.5.2 Where drills are divided into blocks, the layout should make clear where a block of instructions starts and finishes.

6.6 Size of Each Checklist

6.6.1 Where possible, there should be one drill per screen. Where drills are shorter than one screen, do not have two drills per screen.

6.6.2 Where a drill is too long for one screen, separate into logical 'chunks' with each chunk contained on one screen. A clear indication (e.g. a continuation arrow) should be provided that the drill goes onto next screen. Each drill should be broken into sensible size chunks, for example do not have most of a drill on one screen, and one line on a second screen – the pilot may think the procedure is complete on the first screen. Division into screens may also be able to take account of the systems affected by each set of instructions, or the positioning of the required switches and controls in the flight deck.

Chapter 5 Interaction Issues

1 Organisation of Checklists

1.1 With paper checklists, the checklists are organised in one manner. The most common method is to differentiate and physically separate normal checklists from emergency and abnormal checklists, and organise the checklists within those groupings. If a second method of organising checklists was required (e.g. alphabetically) duplicate copies of checklists would need to be provided. With an ECL system, the aircrew may be provided with a number of alternative methods of accessing each checklist.

1.2 In some systems a checklist may be displayed automatically, in response to an error condition. Where the pilot selects the checklist, it should be possible to do so via keywords or by aircraft system without consideration of whether a checklist is normal, abnormal or emergency. However, particularly where pilots are in transition from paper to ECL, or where paper checklists are still used in parallel, the ECL system should also enable selection of a checklist using the same criteria as for paper checklists (e.g. according to the 'emergency/abnormal' division and in the same index order as paper checklists).

1.3 Other methods of organising the checklists include:

- Alphabetically – by first letter of the checklist title.
- By subject – with broad subject categories, such as engine sub-systems, and drills grouped within each subject. Subjects and checklist titles within subjects may in turn be listed alphabetically.
- By urgency/priority.

1.4 A checklist can be listed more than once in a menu structure if it can logically be grouped in more than one way.

1.5 Selection of some checklists may be required very urgently (if these are not memory items). For example, the emergency evacuation drill and the rejected take-off and overrun drills should be particularly easy and quick. For example, checklists for these drills can be placed on the top level menu, or could have dedicated function keys for selection. In addition, paper copies of all checklists should be readily available in the cockpit.

1.6 The overriding aims of designing a menu structure for accessing drills should be:

- To reduce the average time / number of key strokes / cursor movement needed to reach each checklist.
- In particular to reduce the time / key strokes / cursor movement for urgently needed checklists.
- Once a checklist is in use, the time / key strokes / cursor movement to reach the checklists which are most likely to be used next should be minimised.

2 Selecting and Initiating the Correct Checklist

2.1 Accessing the correct checklist should be at least as quick and accurate as with a paper-based checklist. There should be a way for flight crews to bring up any ECL they believe necessary at any time. Paragraph 1 on Organising checklists described some methods for organising checklist menu structures that should help make selection easy, quick and not prone to error.

2.2 A variation to the use of a menu structure for selection would be to allow the pilot to enter or select a keyword, and then for the ECL system to ask a series of yes / no questions to direct the pilot to the correct checklist.

2.3 Where there are multiple problems, pilots should be able to display a list of potential checklists, ideally correlated against any warning messages on other displays.

2.4 Where the ECL system is able to sense the aircraft state, the correct (or most likely) procedure may be presented automatically following detection of a fault. There are benefits in terms of time (workload) and minimising the chance of selecting an incorrect checklist, but bear in mind the possible loss of situational awareness and the limitations of fault diagnosis – pilots may accept the offered checklist too easily

2.5 There are ways, other than the detection of a fault, by which a checklist can be brought up on the display automatically. These include, for example, a time lapse since something else happened or since a previous checklist was used, or a trigger altitude or aircraft configuration. Note that some of these options may be available even with stand-alone systems, provided there is some internal logic. Pilots should be able to call these checklists earlier if required. Such systems reduce workload and reduce the probability of omitting a checklist. However, these advantages should be weighed against the possibility of distraction from more important tasks, possible over-reliance on their ability to remind the flight crew to perform (in particular) the normal checklists, and associated loss of situational awareness. In particular, time delays and other automatic features could be undesirable in some emergency situations, and so should be easily over-rideable by the aircrew.

3 Auditory Alerting

3.1 In most aircraft there will already be a large range of noises – alarms, alerts, communications between flight crew, communication with ATC and so on. The ECL should not add unnecessarily to these noises.

3.2 If an ECL has separate alerting sounds, these should only be provided for:

- Alerting flight crew to the automatic display of a checklist (In this case a warning sound may also be forthcoming from the failed system.).
- Alerting flight crew to an omission or potential error in completion of a checklist (for example, to alert the flight crew that they are about to remove a checklist item from the screen which has not yet been checked). This is likely to be at the level of an advisory.
- Alerting sounds should not be provided for completion of an item, completion of a list and other such trivial items.

3.3 Auditory information is transitory and therefore easy to forget, especially in times of high workload. A visual back-up should therefore be provided where possible for reference at a later point. For example, non-completed items in an ECL may be highlighted visually (see Chapter 4 paragraph 3) to indicate that a step has been left out.

3.4 Further requirements for auditory warnings are provided in Appendix 3.

4 Navigation within the Checklist

4.1 Methods of Navigation

4.1.1 The display area on modern flight decks is restricted. Many checklists contain more items than can be displayed on a single small screen, and hence some method is needed to navigate between items on a checklist. The relatively small size of current flight deck display screens make window-type ('frames') display options unsuitable. Consequently, movement through a checklist can be achieved through 'paging' or 'scrolling'.

4.1.2 Scrolling involves the text moving a line at a time, so that as each new line is displayed at the bottom, a line disappears at the top of the screen. Two forms of scrolling are possible:

a) 'Camera' scrolling – where the window appears to move over a fixed piece of text (as a camera would move over a fixed scene). In this case 'up' means the window (camera) moves up over the text (the scene), such that earlier items in the checklist are displayed.

b) 'Film credit' scrolling – where the text is moved under the window (as the credits on a film appear to move under the television or cinema screen). In this case 'up' means that the text is moved up, such that the later items of text are shown.

4.1.3 In general, the 'camera' metaphor is more natural and intuitive. However, consideration should be given to how other flight deck systems work, in order that the flight crew do not have to work with two (or even three) different metaphors.

4.1.4 Whichever scrolling metaphor is used, use of commands called 'forward' and 'backward' can avoid the potential confusion of which direction a pilot expects the checklist to move when using 'up' and 'down' commands.

4.1.5 With paging, the current screen of text is removed and replaced with a new screen or 'page' of text. Usually paging is controlled with commands labelled 'next' and 'previous', although 'forward' and 'backward' are also acceptable if used consistently.

4.1.6 Careful management of scrolling / paging is needed to ensure that checklists cannot be completed whilst items remain incomplete. For example, if an item cannot be completed, the flight crew may scroll down to act on future items, such that an incomplete item disappears off the top of the screen. Once the end of the checklist has been reached, if the pilot signals that the checklist is complete, the incomplete items should be re-presented to the flight crew before the checklist is removed.

4.1.7 In most cases, the flight crew will concentrate on the currently displayed checklist item. However, a limited number of items before and particularly after the current item need to be shown to provide the context for the current item.

4.1.8 The checklist title should be displayed above the items, and remain visible and distinguished throughout the checklist (i.e., even when the first checklist item is no longer visible).

4.1.9 Protocols for scrolling / paging / item removal should be designed to avoid the inadvertent completion of a checklist when only completion of an item was intended. Clearing the whole checklist should require a different action to clearing an item.

4.2 Paging

4.2.1 In a paging system, the items remain in a fixed place on the screen, such that the current item can be anywhere on the screen, depending on how far down the list the flight crew have progressed. Once all items on the current screen have been checked, the crew may 'page' to the next set of items.

4.2.2 By convention, when the user pages 'next' or 'forward' the checklist should move to the later items in the drill.

4.2.3 Where a checklist is divided into discrete screens, each screen should be labelled to indicate how far through the checklist the current page is, for example 'page 2 of 5'.

4.3 Scrolling

4.3.1 When a screen that can be scrolled first appears, at first the pilot can work down the list of items as for a paged checklist. However, when the last item on the screen is reached, a scrolled checklist will tend to bring only the next item up. This tends to mean that for the rest of the drill, the pilot is reading from the bottom of the screen. The alternative is to scroll the checklist automatically on the completion of each item (ensuring that uncompleted items do not scroll off the screen). The advantage of this is that the current item is always in the same place, and a number of items are always shown after the current item for context. The disadvantage is that such automatic scrolling can make it difficult for aircrew to remain aware of where they are in the list.

4.3.2 Scrolling can be achieved using scroll bars or keystrokes (or both). Where a scroll bar is used, this should be placed at the right of the displayed items. A symbol such as a box or rectangle should be displayed on the scroll bar to represent the relative location of the portion of checklist currently displayed (e.g., whether near the start, half way through or near the end). Where long checklists are provided, pilots should ideally be able to 'drag' this 'current' symbol along the scroll bar to move through the list.

4.3.3 Where keystrokes are used, the user should be able to step through the checklist one item at a time.

4.3.4 By convention, when the user scrolls 'down' (e.g. using a down cursor, or moving the 'current' symbol down the scroll bar) the displayed checklist items should move up the screen (and vice versa) giving the impression of moving through a document.

4.4 Conclusions on Scrolling and Paging

4.4.1 Paging means the flight crew can clearly see where they are in the current set of items – there is no unexpected movement of the screen, and an item always appears in the same place on the screen.

4.4.2 Scrolling allows the user to view previous items on the checklist and forthcoming items simultaneously. However, scrolling needs much more careful management of the display and additional controls such as a scroll bar. In most cases, these requirements make it less suitable as a form of interaction for an ECL system.

5 Branching and Conditionals

5.1 Many abnormal and emergency scenarios require conditional branching of procedures. A facility to allow conditional branching of checklists should therefore be available.

5.2 Presentation of Routes through a Branching Checklist

5.2.1 Two standard approaches are possible in presenting branching procedures:

- Only the 'correct' branch (i.e. that resulting from the response to a conditional question) is displayed. This has the advantage that the flight crew are presented with only the information they require. This reduces screen clutter and distraction, and allows the aircrew to concentrate on the correct instructions.
- Displaying only the correct branch in response to some sensed item, where the flight crew are not aware that a conditional branch is present, may have a

detrimental effect on situational awareness. It may also make error recovery more difficult if a pilot has inadvertently made an incorrect selection leading to this branch.

- The correct branch is made more prominent, e.g. by shading the incorrect branch. The current step in the correct branch still needs to be indicated separately. This approach helps situational awareness, by keeping the flight crew involved in deciding which branch to follow, but can lead to excessive information on the screen, affecting workload and clarity. Where this approach is adopted, providing the crew with the ability to remove the non-required branch once they have reviewed the options and made a decision (and to recall the branch if necessary) can overcome the disadvantages of excessive information.

5.2.2 The decision between the two approaches outlined in paragraph 5.2.1 is an example of the balance between the benefits and disbenefits of greater automation (see Chapter 2 paragraph 1)

5.2.3 Where the flight crew are expected to make a decision in order to branch in a checklist, the checklist item should be worded such that the decision is objective where possible. Also, decisions which ask for a relative judgement (e.g., 'is there more smoke than before?') are easier to answer than absolute judgements (e.g., 'is there a lot of smoke?').

5.3 Wording of Conditional Decisions

5.3.1 It is best to avoid 'IF' clauses within a checklist, e.g. by using YES/NO questions instead. For example, it is generally clearer to ask a question such as:

is the pressure greater than XXX? -- (YES/NO)

than to write:

if pressure is greater than XXX

as a heading to a branch.

5.3.2 Do not ask negative questions. For example, if the questions is 'Is the valve light no longer illuminated' the answer 'no' logically means that the valve light is still illuminated. However, it would be easy to confuse the answer, especially where English is not the first language.

5.3.3 Where an IF statement is used, it needs to be made clear what action is required where the IF statement is not true, or made clear that no action is required if this is the case.

5.3.4 Where 'IF' clauses are used, layout and highlighting (e.g. use of indentation) should make routes clear and indicate clearly where IF clauses terminate.

5.3.5 If repeated conditional tests are required with exactly the same meaning, the question should be phrased in exactly same way. Conversely, if a slightly different question is being asked, ensure the question is clearly different.

5.3.6 Where checklist items branch, this would seem to be one of the areas where electronic checklists provide a clear advantage over their printed counterparts, in tailoring the display to the current situation, and reducing the amount of distracting information.

6 Clearing/Confirming Items in the Checklist

6.1 Item Status

6.1.1 The ECL system should use a limited number of methods of highlighting (see Chapter 4 paragraphs 3 to 5) to indicate the status of the list. In particular, a clear method is needed for indicating:

- The current item, i.e. the next item in the checklist to be read;
- Completed items, i.e. those that have already been completed;
- Future items, i.e. those that remain to be actioned.

6.1.2 Chapter 4 gives guidance on methods of highlighting, including use of emphasis, symbols and colour.

6.1.3 For sensed systems, a distinction can be made between those items completed by the flight crew and those completed automatically, through sensing. This will help to maintain situational awareness, but adds to the number of methods of highlighting required, potentially causing confusion.

6.1.4 A further distinction could be made between the status of a checklist item that has been checked by a pilot, but not activated in the aircraft system, and those which have been checked and activated. The item may not have been activated because the aircraft system did not respond, because the crew forgot to take the action, or because they want to defer the item until later, but not to be reminded about it now. At the point where a pilot attempts to close a checklist, a sensed ECL system can remind the flight crew of any items that, although checked, have not been activated. The crew need to have the ability to override or defer the items.

6.2 Completing an Item on the Checklist

6.2.1 When an item in a checklist has been completed, the pilot needs a very simple method of indicating this to the system. It should be technically possible for either crew member to be able to indicate a completed item, although in practice the task sharing philosophy means that only one crew member will.

6.2.2 Simple normal methods of indicating completion include:

a) Move the 'current' indication to the checklist item (e.g. using cursor keys or pointer device);

b) 'Click' on the current item (for example using a keypad key, a function key, or a button within a joystick).

6.2.3 As an item is completed, it should be displayed as complete. The item should not be removed from the screen immediately. The flight crew should have the chance to review and if necessary reverse the completion indication. Hence, if the item completed is the last item on a screen, the screen should not automatically page or scroll to the next item, removing the just completed item from view.

6.2.4 It would be possible for an ECL system to impose a time lag between items cleared, to prevent rushing through the list or double-hitting the 'cleared' button/key/device and to give time for consideration (especially if the whole page might otherwise disappear from the display). Such a mechanism if available should be used with caution, giving consideration to the time pressure under which the flight crew may be at the time of using a particular checklist, and the fact that even small time delays can seem like a long time in a stressful situation.

6.3 Cancelling Items on a Checklist

6.3.1 Cancellation of previous items (i.e. making the status of an item 'incomplete' again) may be required if a pilot has changed an item to 'complete' in error (e.g. by inadvertently hitting a key). Alternatively, it may not have been possible to complete the task described by the checklist item, and the flight crew may wish to use the checklist facility to remind them to attempt the task again later.

6.3.2 To enable cancellation, the crew should be able to review previous responses in the current checklist, including those no longer on display. This facility may also assist situational awareness.

6.3.3 A simple method should be provided for cancelling the completed status of a checklist item. This can be provided by repeating procedure as described in paragraph 6.2.2 for marking an item as complete (that is, treating these actions as toggle switch operations):

a) Moving the 'current' indication to the item completed (e.g. using cursor keys or pointer device);

b) Clicking on the current item (for example using a keypad key, a function key, or a button within a joystick).

6.3.4 The status should then revert to incomplete, and the highlighting should indicate this.

6.3.5 A mechanism should be provided for repeating all or part of a checklist, from any point in the checklist, even where the system has previously cleared those items or even the whole checklist.

6.3.6 Most checklists should be automatically cancelled at the end of each trip, so that items are not carried over to a new flight. However, there may be items within some checklists that need to keep their status between flights; a decision not to cancel an item automatically needs to be justified, and should be the exception.

6.3.7 Automatic reset of checklists between flights needs to be implemented carefully, since it may be difficult to define the moment when one flight is complete and the next flight is about to start.

6.4 Over-riding Items

Pilots should be able to manually skip or omit an item. The pilot should be able to indicate that an item is 'not needed' or 'not applicable' rather than 'completed', to enable correct review of completed checklists.

7 Reminders and Deferment

7.1 Reminders

Systems may be able to remind pilots to clear items if they have not done so when required. For example, a sensed checklist could alert the pilot to a particular action once a flight parameter reaches a critical value. An unsensed system with an internal clock could prompt the pilot to the need to clear the item after a pre-set time. The benefits of such reminders need to be weighed against the possibility of distraction from more important tasks.

7.2 Deferred Items

Deferred checklist items or similar features may be used to lessen flight crew reliance on memory. The ECL should automatically display them at an appropriate point later in the flight. For example, deferred items related to landing preparation could be automatically attached to normal Approach or Landing checklist.

8 Interrupting or Completing the Checklist

8.1 Where an incomplete checklist is put on hold, the status of each item in the checklist needs to be stored, such that when a pilot returns to the list, current and future items are indicated as they were before interruption. Actions on another (now 'current') checklist may affect the status of items in the stored checklist. In this case, even where the checklist system does not interact with the aircraft systems, it will be advantageous if internal logic causes the items in the stored checklist to be changed to reflect the changes in the current checklist.

8.2 Where using one checklist resets a large proportion of the items in a stored list, it may be better to require the entire stored list to be re-started from the beginning.

8.3 Where the checklist can sense aircraft status, the items in the list may have been re-set by actions taken during an interruption. This means that the checklist may look different when returned to. Training should make aircrew aware that this can occur, and inform them which items are affected.

8.4 A 'checklist complete' message should be displayed once all items have been cleared.

8.5 A manual override should be provided to allow a checklist to be omitted by the pilot. In such cases it is better if a pilot indicates that the checklist is 'not needed' or 'not applicable' rather than 'completed'.

8.6 A method should be available of identifying and viewing unaccessed or unfinished checklists and choosing which checklists to complete in what order.

9 Prioritisation

Sensed systems can prioritise checklists – in some cases allowing the checklist for a more important fault to interrupt an ongoing checklist, where compatible with system and operational requirements. This can reduce workload and help decision-making, but may adversely affect situational awareness. Whether or not such a feature is beneficial needs to be considered in the context of the overall flight deck operational philosophy.

Chapter 6 Language

1 General

1.1 As stated in Chapter 1 these guidelines do not address functional content of checklists. However, there are some general comments that can be made about the type of content within the checklist, and the ordering of information. This chapter seeks to present those comments.

1.2 In this chapter the term 'item' refers to the line in a checklist which will usually include the name of a system or state, and an 'action' to be performed. The action may be implied by the inclusion of a required status in the item. For example:

Left hydraulic pump ..... OFF

The item is the whole line 'Left hydraulic pump .... OFF', the action required is to check that the left hydraulic pump is off, and if it is on, to turn it off.

2 Writing Checklists

2.1 Ensure that all the items needed are included in a checklist, and that items are in the most appropriate checklist. There are examples where pilots have made errors because some items considered obvious by the writer have been omitted in practice. In some situations, the writer may expect the flight crew to use two or more checklists together, and hence an item may be omitted from one checklist because it is assumed that it will be completed in another. The writer needs to consider whether a situation could occur where only one of the checklists is completed, or where it is completed long enough before the other checklist that the omission could cause a problem.

2.2 Another aspect to consider with ECLs is the possibility of combined checklists (e.g. where there is both an engine fire and a hydraulic failure). With a paper system, this is usually impractical, because of the difficulties of locating such combined checklists and because it could result in an over abundance of paper lists. However, the easier selection of checklists which an electronic system allows (e.g. using menu structures – see Chapter 5) could make it feasible and beneficial to provide checklists for more complex situations. Such a checklist could reduce flight crew workload, by taking some decisions about which actions in which checklist should be completed first, and which become irrelevant because of the dual failure. It will not be possible to specify checklists for all combinations of failure, but writers should consider the benefits to be gained from checklists for more common failure combinations. Consistency with the paper back up should be a consideration, however – flight crew will need to know that such combined lists are not available in the QRH.

2.3 The number of checklist items should be minimised to the extent necessary to efficiently complete the required actions. Although the constraints of fitting a checklist onto two sides of a sheet or card which are present with paper checklists are removed with an electronic checklist, this should not be seen as an opportunity to add items to the checklist which do not have a safety benefit (see also Chapter 4 paragraph 6.6 for guidance on the length of checklists with regard to display size).

2.4 Writers of checklists should consider carefully what to include in each checklist, such that references to other checklists are minimised. With paper checklists, the need to

avoid duplication (and hence increasing the thickness of checklist folders) must be balanced against the need to minimise cross-referencing. Hence, a common sub-drill, which may be part of a number of different drills may be referenced out to a separate drill in a paper checklist system. However, providing it does not make a checklist too long or complex, with an electronic system the sub-drill can be included as part of each checklist.

2.5 Where cross-references are required to other ECLs, a short-cut should be provided to the called checklist. Where an ECL references a paper checklist, a clear reference should be provided.

3 Ordering of Items within Checklist

3.1 Items in a checklist should be in the order in which the pilot is most likely to be required to complete them. This should minimise the need to defer items.

3.2 In addition to the requirement in paragraph 3.1, the following criteria should be considered:

- Ensure that the most urgent or important items are carried out, by placing them early in the checklist.
- Reduce the workload in carrying out the tasks, e.g. by considering the layout of the flight deck panels so that a pilot can scan from left to right across a row of instruments, or from top to bottom down a column of switches when following the checklist items. This criterion should be applied when a set of items has to be completed in a short space of time, but the actual order of items is not important.
- Reduce the workload in using the ECL system, such that the pilot does not have to change screens at a time when workload may be expected to be highest.
- Provide items in the order the flight crew expect to see them, for example by using the same order in different drills that contain the same sub-sequence of common actions. However, care is needed to avoid the possibility of diverting pilots into performing another drill. This is most likely where there is a long sequence of common items for an unfamiliar drill, which is similar to a more familiar drill.

3.3 For abnormal and emergency checklists, there are different types of drill action. The usual order of items within a checklist will be as follows:

a) Where a drill includes memory items, these should normally be at the start of a drill so that they can be checked first.

b) Immediate clean-up or corrective actions.

c) Restoration of failed system (if permissible or possible).

d) Configure aircraft optimally, given the residual failures after restoration has been attempted.

e) References to expanded reasons for actions, other emergency or abnormal drills and alternative operations (if provided).

f) Consistency with the paper checklists may also need to be considered where they are used in parallel.

4 Consistency of Terminology/Abbreviations

4.1 Ideally, ECLs should be consistent within an air operating Company. However, there may be a need for variations between fleets within a Company, and sometimes between aircraft variants within each type. Where this is the case, such differences should be made clear to flight crew in training.

4.2 Technical terms, abbreviations and acronyms should only be used if easily understood by flight crew. Where used, they must be used consistently, and be consistent with other material used by the flight crew (such as the aircraft's flight manuals).

4.3 Specification of an airline 'glossary' to be used in all checklists will improve the consistency of terms throughout checklists. This will need to take account of the fact that there may be some terms that are specific to particular aircraft. For example:

Engine 1/2

on a two-engine aircraft could cause confusion for a flight crew who previously flew three-engine or four-engine aircraft. A less ambiguous alternative, providing it is consistent with the terminology used elsewhere in the aircraft is:

Left / right engine

4.4 An exception to the guideline requiring the use of an airline glossary is that terminology and abbreviations in the checklist should be consistent with manufacturers labelling on switches, controls and displays, and in the operating manual. If it is not possible to change labels and the operating manual to use the airline glossary, training will need to ensure that aircrew understand the terminology and abbreviations used.

5 Checklist Titles

5.1 Checklists should have unambiguous titles in order to reduce the likelihood of incorrect selection. Where a checklist is associated with an alert message or caution display, the title of the checklist and the alert message should be consistent.

5.2 ECL titles should normally be the same as those for paper checklists. However, with an ECL system, there could be the potential to give each checklist a second title if it was felt that the paper checklist titles were not ideal. In this way, the flight crew could look for a checklist under either title. This additional flexibility needs to be balanced with the potential for additional confusion created by dual naming.

5.3 Where checklist titles (both paper and electronic) are being considered for revision the consistency of the titles should be assessed. A 'grammar' can be defined for the titles, e.g. system – action required:

Engine - fire management

Passenger - evacuation

Hydraulic pump - failure management

6 Phrasing

6.1 Common and simple words should be used whenever possible. Informal or humorous expressions should be avoided.

6.2 Phrasing should be positive, avoiding double negatives. Phrasing should also be clear, avoiding phonetic and semantic confusions, for example 'there' versus 'their' or 'continually' versus 'continuously'. Short active expressions should be used, for example:

switch off left hydraulic pump

rather than:

left hydraulic pump should be switched off.

An alternative is to use the challenge – response format described in Chapter 4 paragraph 6.3, e.g.:

Left hydraulic pump ..... OFF

6.3 The language used should reduce the amount of translation that the flight crew needs to do in order to understand the instructions. For example, units used should be those on the aircraft displays. An ECL system with some internal logic can tailor the checklist for a particular problem, even where no sensing of aircraft systems is available. For example, in the case of an engine failure, the checklist could ask the flight crew to identify the problem engine at the start, and then present a tailored checklist.

6.4 Where a checklist applies to parallel systems (e.g. left and right engines, thrust levers 1 and 2) a sensed ECL can identify which of these is the problem system and present the flight crew with a tailored checklist.

6.5 Checklist items should be concise and simple, but sufficiently long to contain the meaning. Each item should contain only one step or action. The main object or control involved should appear early in the checklist item. Each item in the checklist should use a consistent ordering of noun-verb pairs. For example:

autopilot disengage

is consistent with:

altitude gauge monitor.

But the following is inconsistent with both of these:

override extract fan.

6.6 For most checklist items it will not matter who performs each item, and operators will have their own policies on allocation of tasks between handling and non-handling pilot. However, on occasions there may be instances where a task is to be carried out by a specific role. For example, for authorisation reasons it may be necessary for the Commander to do something rather than a first officer, regardless of who is flying. In another situation, it may be important that the non-flying pilot carries out an action. In either case, the checklist item should state in such cases who should respond to the challenge. Commonly, abbreviations 'PF' and 'PNF' are used for pilot flying and pilot non-flying respectively.

7 Negatives and Modifiers

7.1 Wherever possible, the use of negatives in statements should be avoided. This includes multiple negatives, qualifying negatives and nested clauses, examples of which are given below:

- Negative statement: 'This is not an auto-pilot function'.

- Multiple negatives: 'Non-operational engine is not to be switched on'. See also Chapter 5 paragraph 5.3.2.
- Qualifying negatives: 'except'.
- Nested clauses: 'the engine that the pilot has identified as on fire should be switched off'.

7.2 Noun modifiers should be used rather than successive subordinate clauses.

For example:

ascending aircraft

is easier to understand than:

aircraft which is ascending

7.3 Vague, weak, redundant and contradictory modifiers should be avoided.

Examples of each include:

- Vague modifiers, e.g. 'many'.
- Weak modifiers, e.g. 'quite', 'rather', 'well', 'fairly'.
- Redundant modifiers, e.g. 'very extreme'.
- Contradictory modifiers, e.g. 'quite extreme'.

Chapter 7 Training and Education

1 Differences between Training and Education

Training in this respect refers to teaching a psycho-motor skill, i.e. enabling the crew to carry out a set of operations. This requires knowledge of what tasks need to be carried out, and practice in carrying out the tasks. In this context, education means something broader than training, in that it seeks to change an understanding of something, and bring about a different set of attitudes.

2 Training

2.1 Training should ensure familiarity with the practical use of ECLs across a wide range of situations. To enable this, any simulation used should represent the way in which the ECL system works as realistically as possible. Pilots need to be informed of any differences between the simulator ECL and the aircraft.

2.2 Ensure adequate training so that pilots are familiar with the structure of checklists as presented, and any differences between the paper checklists and the ECL.

2.3 The limitations of ECL systems need to be understood by the flight crew.

2.4 Training should cover:

- System components and operation;
- Access to checklists;
- Crew check-off of completed items;
- Use of additional features, e.g. automatic timing;
- Checklist prioritisation;
- Menu structure;
- Relationship to other flight deck equipment and displays;
- Use of deferred items;
- Reporting procedures for ECL failures / errors.

2.5 In addition, the following items will need to be covered for training related to sensed ECL systems:

- Understanding of which items are sensed and from what (i.e. aircraft state or switch position);
- Interface with other aircraft systems.

3 Education

Education should aim to ensure that pilots:

- understand the philosophy and concepts behind the operation of the ECL system;
- understand what is assumed about their own role in interaction with the ECL system;
- appreciate what the ECL system can do;

- appreciate the limitations of the ECL system;
- understand the relationship of the ECL system to crew resource management (CRM). In particular, crew co-ordination, allocation of tasks between flight crew members, and managing a (partly) automated process to maintain situational awareness;
- understand the mechanism by which they can provide feedback to the operator on difficulties or potential improvements.

4 Methods of Training and Education

In addition to simulator training normally provided, it may be possible to provide personal demonstrations of the ECL system to pilots for them to practice with on a desktop or laptop PC. Clearly such versions will not demonstrate sensing and relationships with switches, but they could improve familiarity with the menu structures, layout and interaction methods used. Manufacturers and operators are encouraged to develop such packages and make them available to flight crew.

Chapter 8 Operational Use

1 A paper back-up of all abnormal and emergency checklists should be immediately available on the flight deck of each aircraft, for use in the event of a failure of the ECL system. In the future, if ECLs have a high enough proven availability, it may be possible to eliminate the need for paper back-ups. However, without the paper back-up, the ECL system becomes a no-go despatch item.

2 Avoid situations where a procedure is started on the ECL and completed on paper, or where the flight crew have to refer to paper in order to follow a procedure. Where this situation is unavoidable (e.g. in an emergency where it may be necessary to switch off the ECL to reduce power) adequate training should be provided, and in most cases the crew should be trained to start the paper checklist from the beginning.

3 Avoid situations where a paper bulletin is posted against the ECL to notify aircrew of a change to the checklist procedure. In the stress of accomplishing a checklist during an emergency it is likely that a pilot will forget the bulletin and follow the ECL, especially considering the compelling nature of the ECL display.

4 Chapter 5 paragraph 6.1.3 raised the issue of how to deal with a checklist item that can be sensed. Three alternatives are:

- remove the sensed item from the screen when completed;
- change the highlighting of the completed sensed item to indicate completed status;
- make no change to the highlighting of the completed sensed item.

Application of the third alternative would imply a requirement for the flight crew to check the item, which could be confirmed by the ECL system against the sensed status. The decision on which option to choose needs to balance the usefulness of reducing workload by automating the completion of the item, and maintaining situational awareness by requiring the flight crew to check the item.

Chapter 9 Evaluation and Feedback

1 Pilots should be involved in the development and evaluation of checklists, whether paper or electronic. In the case of ECLs, pilots need to review the interaction with the checklist as well as the contents.

2 Pilots involved in evaluations can include line pilots, pilots with technical or training responsibility. However, efforts should be made to ensure a representative sample of users.

3 Evaluation at early stages of the lifecycle can involve individual interviews, group discussions and use of paper based simulations (for example, to discuss the structure and contents).

4 As the lifecycle progresses, increasingly realistic simulations of the ECL system can be provided, for example using PC based simulations.

5 At the later stages of the lifecycle, before final operational use, feedback needs to be collected from aircraft simulator sessions. In most cases, these will be part of the general line checks and training. Full briefing of training captains can improve feedback from these sessions, in particular to identify recurrent problems.

6 Checklists need to be validated for all conditional branches, during all likely flight phases and operational conditions that could affect accomplishment of the checklists.

Chapter 10 Management of Modifications

1 Operators should ensure that there is a demonstrable controlled procedure for managing modifications to checklists. This includes modifications that the operator is able to make, and those that need to be carried out by the manufacturer. The process for managing modifications should include details of:

- Collection of feedback from line and technical pilots and training captains.
- Documentation required for each change requirement.
- Review required for each change requirement and the rationale for each change.
- The competence required of the people who authorise, modify and check changes to ECLs.
- How modifications to ECLs and their justification shall be recorded.
- How ECL changes have been incorporated in applicable aircraft.
- How the accuracy of modifications has been verified.
- Configuration management, including version control with dates and tracking of ECL revisions and their applicability to individual aircraft in the operator's fleet.
- Control of new software releases.
- The method the operator uses to maintain consistency between the paper back-up version of the checklist and the electronic version.

2 Procedures should allow ECLs to be easily, quickly and controllably updated, so that all aircraft in a fleet can be updated within a short period of time.

3 Avoid paper updates to ECL. Changes in procedure should be represented in ECL through controlled release of software, not through QRH add-on.

4 Where a paper update is unavoidable, a Flight Crew Notice or equivalent is recommended to bring outstanding errors in the ECL to the crews attention. In such cases it may be better to inhibit use of the particular ECL altogether, to avoid the crew following the uncorrected ECL.

Chapter 11 References

[1] Civil Aviation Authority (1997). Guidelines for the Design and Presentation of Emergency and Abnormal Checklists (CAP 676). London

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[3] Federal Aviation Administration (1996). Human Factors Design Guide (Version 1). William J. Hughes Technical Center, Arlington VA.

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[5] ISO 9241-3 (1993) Visual Display Requirements.

[6] Ministry of Defence (1989). Human Factors for designers of Equipment: Defence Standard 00-25 (part 8 – Issue 1): Auditory Information. London.

[7] Ministry of Defence (1992). Human Factors for designers of Equipment: Defence Standard 00-25 (part 10 – Issue 1): Controls. London.

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[10] Reason, J. (1990). Human Error. Cambridge: Cambridge University Press.

Appendix 1 Human Error and Mental Workload

1 How to Minimise Mental Workload

1.1 An operator's ability to perceive and interpret information from displays as the designer intends depends on their mental state. In order to undertake correct actions the operator needs to have accurate situational awareness. This awareness is strongly influenced by the information presented in visual displays and by the operator's level of mental workload when the displays are viewed. When using an electronic checklist system in abnormal operating conditions it is likely that the flight crew will already be in a higher than normal workload situation. The electronic checklist system should be optimised to reduce the pilots' workload in these situations, not add to it.

1.2 ISO 10075 gives guidance on design to avoid excess workload. The list below shows some of the general principals given in ISO 10075, with examples provided specific to ECL:

a) Provide unambiguous information and suppress information (or detail) that is not task relevant. This will remove the need for interpretation by providing adequate information (e.g. by displaying only the required branches of a checklist).

b) Avoid reliance on long-term memory (the main purpose of a checklist of any type). For example, do not refer to information on previous screens.

c) Reinforce task goals. Checklists are commonly titled with the name of the failure which has occurred (e.g. FUEL IMBALANCE), and where the desired recovery action is obvious and unique, this may be sufficient. In some cases, however, it may also be important to indicate clearly what the drill is trying to achieve – pilots may wish to review whether this is the most appropriate aim in the specific circumstances. Phrase checklist items to make clear the desired outcome.

d) Provide meaningful cues to the type of response expected. For example, a conditional statement could provide YES/NO response boxes, rather than leaving the form of response 'open'. For some failures it may be necessary to give more detailed instructions on what to do, rather than the 'Challenge-Response' format alone (in which the action to be taken is implicit).

e) Avoid forcing absolute judgements by providing a reference where possible so relative judgements can be made instead (e.g. 'is there more smoke than before?' is better than 'is there a lot of smoke?').

f) Present information at appropriate rates, to avoid overloading short-term memory. Do this by:

- avoiding time delays that cause anticipation;
- avoiding rapid sequential presentation of similar information that needs to be recalled later;
- where possible provide information sequentially in discrete 'chunks' unless comparisons need to be made.

g) Minimise noise and redundancy.

h) Avoid the need for mental transformation and conversion (e.g. between flight level and altitude) by having the system calculate values rather than provide raw data (e.g. 'Vref + 10' can be avoided if Vref is known and entered).

i) Maximise compatibility with user expectations and conceptual models (e.g. defining aircraft systems which accord with pilots mental models and experience, rather than those of system engineers).

j) Maximise discriminability by reducing noise and redundancy. In particular, avoid screen clutter, unnecessary text and superfluous emphasis.

2 Reducing Human Error

2.1 Categorisation of Human Error

Human errors have been categorised to help discussion of what causes error, and what can be done to reduce human error. One often-used system of classification is based on Reason (1990) and divides human error into three categories:

- Skill-based.
- Rule-based.
- Knowledge-based.

Skill-based errors concern routine actions, which are familiar enough to the person carrying them out as to be almost automatic. Rule-based and knowledge-based errors occur when carrying out problem solving activities. Whereas rule-based errors relate to the use of rules, knowledge-based errors occur when trying to apply knowledge in new ways.

It is possible to make some suggestions as to how good design of an ECL system can reduce the probability of human error for some of the categories of error shown in Figure A1.1.

2.2 Skill-based

A common skill-based error is the omission of an action following an interruption, or repetition of a step already carried out. The work of aircrew is fraught with interruptions – from other crew members, from ATC, from other aircraft systems. A key advantage of an ECL over a paper checklist is that on returning to the ECL after interruption, the user can see very quickly which items have been checked, and what needs to be checked next. Chapter 4 paragraphs 3 to 5 provide guidelines on how to use emphasis, symbols and colours to reduce the likelihood of errors of this kind.

2.3 Rule-based

A common rule-based error is to apply the wrong branch of a conditional. Rule-based errors can be reduced by the use of an ECL through appropriate design of conditional statements within a checklist, as explained in Chapter 5 paragraph 5.

2.4 Knowledge-based

An example of a knowledge-based error would be the selection of the wrong checklist, because of incomplete or incorrect knowledge about the aircraft state, or because of over familiarity with the incorrectly selected checklist over the correct one. Chapter 5 paragraphs 1 and 2 provide guidance on organising checklists to improve the likelihood of correct selection of a checklist. Automatic presentation of a checklist in response to an aircraft fault may be possible in some situations. Where more than one checklist may be suitable, the ECL system may present a list of possible checklists to allow the aircrew to select the correct one. Further advice on this topic is provided in Chapter 2 paragraph 1.

Appendix 2 Requirements for Character Attributes

This appendix provides references to existing standards for a variety of character attributes. In applying any of these standards, the reader should be aware of the source of the recommendations, and ensure that they are applicable for their application.

1 Character Size

1.1 The required character size for display depends on the viewing distance from the reader. In general, characters should subtend a minimum angle of 16 minutes of arc at the eye for reliable general readability in good illumination, although 21 minutes of arc is preferable and should also be considered as the minimum size for colour electro-luminous displays (FAA Human Factors Design Guide).

1.2 DEF-STAN 00-25 (part 7) prescribes that the minimum distance an electro-luminous display should be from the user is between 500mm and 700mm. If, however, controls associated with a display are adjacent to the display (for example in the case of the 'soft-keys' surrounding many CDUs) then the distance to the display should be no greater than 635mm in order to be well within the functional reach of the user.

1.3 For viewing distances within the range 500mm to 1000mm the minimum character size for non-critical information recommended by DEF-STAN 00-25 (part 7) and the FAA Human Factors Design Guide is 4·7mm.

1.4 Some checklists may be longer than one screen-full at the required character size. The temptation should be resisted to reduce the character size in order to fit more on the screen.

1.5 The character stroke width required depends on whether dark characters are displayed on a light background, or light characters are displayed on a dark background. In the latter case (which is currently more common on the flight deck) the edges of the characters tend to 'bleed' into the darker background, and hence the character stroke may be smaller. Desirable ratios for the width of the character stroke (as a proportion of the character height) are given for both screen types in Table 1, along with a summary of the other requirements of this section.

Table 1 Summary of Requirements for Character Size

Attribute	Requirement	Source
Viewing distance: preferred range when user needs to reach the display	500-635 mm	DEF-STAN 00-25 (part 7)
Angle subtended at the eye	21 minutes of arc preferred (16 minutes minimum)	FAA Human Factors Design Guide and ISO 9241
Minimum character size at 500-1000 mm for non-critical information	4·7 mm	DEF-STAN 00-25 (part 7) and FAA Human Factors Design Guide
Character stroke width for dark characters on a light background	12·5%-17% of character height	FAA Human Factors Design Guide
Character stroke width for light characters on a dark background	8% of character height	DEF-STAN 00-25 (part 7)

2 Character Size and Display Luminance

Table 2 shows the adjustments that need to be made to character sizes with respect to display luminance and the nature of the information to be conveyed (as specified by DEF-STAN 00-25). It is recommended that the higher bounds should be applied.

Table 2 Character Size (in mm) and Luminance (from DEF-STAN 00-25, part 7), Assuming a Viewing Distance of 600mm

Purpose	Below 3·5 cd/m^2	Above 3·5 cd/m^2
Non-critical Information	1·25 - 4·25 mm	1·25 - 4·25 mm
Critical information in fixed positions	3·50 - 6·75 mm	2·10 - 4·25 mm
Critical information in variable positions	4·25 - 6·75 mm	2·50 - 4·25 mm

3 Character Height/Width Ratio

Table 3 summarises requirements for character width to height ratios.

Table 3 Summary of Requirements for Character Width to Height Ratios

Which letters	Width: height ratio	Reference
All letters	0·7 - 0·9:1	DEF-STAN 00-25
Letters excluding m, w, l, i, t	0·68 - 0·75:1	FAA
'm' and 'w'	0·8:1 or more	FAA
'l', 'i' and 't'	Less than 0·68:1	FAA

4 Requirements for Spacing around Character

Table 4 outlines the requirements for spacing around characters from a number of sources. Where more than one requirement is stated the operator can decide which is appropriate, although the stricter standard is recommended in each case.

Table 4 Requirements for spacing around characters

Attribute	Requirement	Reference
Spacing between adjacent characters within a word	Approximately 10% of the standard character height	FAA Human Factors Design Guide
Spacing between words	Width of a standard character (or the width of an upper case 'N').	FAA Human Factors Design Guide
Spacing between lines in the same paragraph[1]	More than 15% of character height or two stroke widths	FAA Human Factors Design Guide
Spacing between lines in the same paragraph[1]	At least one pixel	DEF-STAN 00-25
Spacing between lines in the same paragraph[1]	At least four pixels	CCIR Study Group (1981)

1. Space is over and above the additional space required for capital letters on the line below, descenders on characters in the line above and any accents, i.e. this is the space between the lowest descender and the highest ascender.

5 Contrast Ratios and Luminance

DEF-STAN 00-25 (part 13: Human-Computer Interaction) specifies that contrast ratios should be user adjustable between 5 and 10:1 for light text on a dark background (that is, the ratio between the brightness of the display characters and the display background). For dark text on a light background, these ratios are reversed. DEF-STAN 00-25 also recommends that CRT-type displays should be capable of producing a minimum luminance of between 80-160cd/m^2. Greater luminance will be needed if there are high ambient light levels in the cockpits.

6 Flashing Text

In general, flashing text is not recommended. If used, it should be used sparingly to draw the attention of the flight crew to critical items requiring immediate response. The FAA suggests a frequency of 3-5Hz for flashing, with a 50% duty cycle (the ratio of the active display interval versus the flashing interval expressed as a percentage). In contrast, DEF-STAN 00-25 specifies a maximum of 2Hz for displayed text with the minimum possible duty cycle.

Appendix 3 Considerations for Input and Output Methods

1 Physical Input Devices

1.1 Requirements of Input Devices

1.1.1 For an ECL system input is needed to:

- Position a pointer or cursor on the screen.
- Select an item under the cursor, in most cases in order to 'check-off' that item.

1.1.2 Actions commonly required by other computer-based systems such as 'edit' and 'quantify' are not expected to be needed.

1.2 Suitability of Input Devices

Table 1 summarises the suitability of a variety of input devices for use in an ECL system. Additional guidance on some of these input devices is provided in the following paragraphs.

Table 1 Suitability of Input Devices in an ECL System

Input device	Benefits	Dis-benefits
Cursor keys	Fast and accurate for small cursor movements. May be remote from screen.	Slow for large cursor movements. Keys must be within reach.
Hard function keys (function does not change throughout)	Each key has only one function, avoiding errors of transposition. May be remote from screen.	Inflexible assignment of keys reduces functions available. Keys must be within reach.
Soft function keys (function depends on current mode)	Flexible assignment of keys	Screen must be within reach
Light pens (used to point directly at a position on the screen)	Easy to use	Stowage problems; screen obscured in use; fatiguing; screen must be within functional reach.
Touch screen (screen is touched with fingers)	Easy to use; no stowage problems.	Visibility problems – screen obscured in use, and becomes dirty. Screen must be within reach.
Mouse	Fast and accurate for large cursor movements; reasonable for smaller movements; may be remote from screen.	Stowage problems for mouse; large flat area required to operate mouse

Table 1 Suitability of Input Devices in an ECL System

Input device	Benefits	Dis-benefits
Trackball	Fast and accurate for large cursor movements; may be remote from screen; no stowage problems	Only fair for small cursor movements; ball can get blocked with dirt and grease.
Touchpad	Fast and accurate for large cursor movements; no moving parts; space efficient; may be remote from screen.	Only fair for small cursor movements; erratic operation with if damp or humid. Needs flat area.
Joystick	Reasonably fast and accurate for large cursor movements; may be remote from screen.	Can be poor for small cursor movements.

1.3 Cursor Movement Keys

The key to move upward should be placed centrally at the top; down cursor should be in the middle at the bottom; and the keys to move the cursor left and right should be arranged to the left and right of the previous two keys. The position of the cursor on the display should be clearly visible on the screen. If the cursor keys are being used to select an item from a list or a menu, the item should be clearly indicated (e.g. by emboldening or reverse video).

1.4 Soft Function Keys

Soft function keys are provided around a display screen on many existing aircraft, and can be used to select items from pre-defined menus. Care should be taken that the function assigned to a key at any point in time is clearly indicated on the display, so that the user does not have to remember its meaning.

1.5 Indirect and Direct Pointing Devices

1.5.1 A mouse, trackball, touchpad and joystick are all examples of indirect pointing devices. In addition to the benefits and disbenefits described in Table 1, a further benefit is that because the devices do not interact directly with the screen the problems of obscuring the screen are avoided. However, they do require a greater deal of cognitive processing and hand eye co-ordination than direct pointing devices such as the touchscreen or light pen, because the pointing device is remote from the display surface itself.

1.5.2 For indirect pointing devices, the ratio of movement of pointing device to movement of pointer should be no more than 1:1 (i.e. the user should not have to move the pointing device further than the pointer moves on the screen.)

2 Speech Input: Speech Recognition Systems

2.1 Speech recognition systems (or direct voice input – DVI) come in two basic forms, speaker dependent and speaker independent systems.

2.2 A speaker dependent system requires the user to train the system to develop a 'voice template', by reading it a list of words. Where the vocabulary used in the system is restricted (associated with pre-defined system functions) the list of words need only be those used in the system. Where free text entry is required, a much larger

vocabulary must be used to achieve a workable level of accuracy. For speaker dependent systems with a limited vocabulary (up to 100 words) recognition rates can be up to 90%.

2.3 The use of a speaker dependent system to control an electronic checklist would present some logistical problems, since pilots do not fly the same aircraft on a regular basis. Theoretically, the flight crew could carry around a disc containing their personal voice template that would require loading into the electronic checklist system prior to each flight.

2.4 Speaker independent systems do not require template training by the user, but their recognition rates tend to be much poorer and their vocabularies even more restricted.

2.5 Both types of speech recognition systems require a manual control (such as a 'press to talk' switch) to indicate to the system that the user is making a voice input. Some DVI systems require two controls, one to indicate to the system that the user is making a system command input (e.g. 'open file' or 'cursor up'), another for making a textual entry into the editing area.

2.6 Changes in inflection or pronunciation can result in the incorrect or non-recognition of the voice input command. Repeated non-recognition of a voice input can result in a further change of inflection in the user's utterances either in an attempt to speak more slowly and clearly or as a result of frustration and stress. Stress may also be a result of situational factors, such as an aircraft equipment malfunction or high workload. These factors will make correct recognition even more difficult.

2.7 Until there is a breakthrough with speech recognition technology, the number of voice-controlled tasks for interaction with an electronic checklist system will be quite small, probably limited to the selection and execution of items. Where voice input is provided, a manual control option should also be provided as a back-up, or for those who simply prefer conventional controls.

3 Output

The use of speech or auditory output for ECL systems is generally advised against, and if used must be considered in the context of other sounds already present in the cockpit. The following information is provided as background for those interested in how speech or other sounds could be used in ECL systems in the future.

3.1 Speech Output

3.1.1 Speech output can be used in two ways:

- As an auditory alerting system, to gain the attention of the flight crew and provide information to direct them to the relevant display system. In this case, the function is not to provide all the information that the flight crew need by speech. The flight crew will look at a visual display for more information on action required.
- As a means of providing the checklist item. In this case, there will need to be a mechanism for a pilot to request repetition of an item. Ideally a visual back-up should be provided where a pilot prefers to read the checklist items, or in the event of a speech output failure.

3.1.2 Speech warnings have the advantage that the meaning of the sound is clearer than a set of arbitrary warning sounds. However, speech output can become lost in the background cockpit noise (including communications from ATC and the 'party line') unless steps are taken to avoid this problem. One way of overcoming this problem is to introduce the message with a warning tone or tones, so that the pilot mentally

'tunes in' to the message to come. These introductory tones can also advise the pilot of the priority of the warning. For example top priority warnings may be introduced by three discrete tones; cautions may be introduced by two discrete tones and advisories a single tone. If a speech warning is to be introduced by a tone, a gap of at least 500 ms should be left between the tone and the speech message. Without such a gap, 'forward masking' will occur, with the first part of the speech message appearing obliterated to the listener.

3.1.3 Speech messages should be kept as short as possible. Messages that are too long or too complex will over burden the capacity of the pilot's working memory.

3.1.4 As with written text, care is needed to avoid ambiguity of meaning when using speech output to convey information. Additional considerations are needed with speech output, taking account of words which can sound similar (but which may be spelt differently) and have a different meaning.

3.2 Auditory Alerts

3.2.1 In general, alerting systems on the flight deck fall into three categories Warnings (the highest priority calling for immediate action), Cautions and Advisories. Within the scope of these guidelines, alerting refers to:

- Alerting flight crew to the automatic display of a checklist. (In this case a warning sound may also be forthcoming from the failed system.)
- Alerting flight crew to an omission or potential error in completion of a checklist (for example, to alert the flight crew that they are about to remove a checklist item from the screen which has not yet been checked). This is likely to be at the level of an advisory.

3.2.2 Where there is an auditory alerting signal at one of the higher two levels, this needs to take precedence over advisory alerts from the ECL.

3.2.3 Auditory information is transitory and consequently is easy to forget, especially in times of high workload. A visual back-up should therefore be provided where possible for reference at a later point. For example, non-completed items in an ECL may be highlighted visually (see Chapter 4 paragraph 3) to indicate that a step has been left out.

3.2.4 To be effective, an auditory signal needs to be heard, recognised and understood. The function of any auditory alert signal should be to draw the attention of the flight crew to a problem. It should not try to convey further information, for example, concerning the corrective actions required.

3.2.5 Requirements for an auditory alert signal are shown in Table 2.

Table 2 Requirements for an Auditory Alert Signal

Requirement	Reason/Comment
The auditory signal should be a minimum of 15-20dB above the amplitude of background noise at any given frequency, in any relevant flight phase (DEF STAN 00-25 (part 8))	Similar frequencies in background noise should not mask the signal (frequency masking). The amplitude of the ambient noise should not mask the signal (amplitude masking).
An alerting signal should be composed of at least four different tones at different frequencies (i.e. not a pure tone).	If one or two frequencies are masked by ambient noise, there will still be enough sound above the threshold level for the alert to be heard and discriminated.
Auditory signal should not be set higher than 120dB. A limit of 100dB is preferred. (DEF STAN 00-25 (part 8))	Noise above this level will be uncomfortable, and potentially damaging
Increase the onset of the signal over approximately 300-500ms before reaching full power. (DEF STAN 00-25 (part 8))	To avoid a startle reaction from the flight crew that would occur if the signal had a rapid onset. The startle reaction may decrease the ability of the flight crew to deal with potential problems
Either turn the alerting signal off automatically after a short number of repetitions (up to 5 repeats) or provide a facility for cancelling the signal once it has sounded.	Continued sounding of a alerting signal can cause irritation, and distract flight crew from other tasks.

3.2.6 There are six general methods by which auditory signals can be made to sound different:

- Different pitch.
- Mixing different frequencies to produce differing chordal qualities.
- Different timbre, e.g. buzzer, bell, whistle type sounds.
- Different rhythm.
- Different number of repeats.
- Different length of sound.

These methods may be applied either singly or in combination.

3.2.7 It is difficult to discriminate between several sounds played in isolation. Hence, no more than four different alerting sounds should be used by the ECL system. In addition, the design of alerting sounds for the ECL needs to take account of the number of other alerting sounds already present on the flight deck.

3.2.8 Tonal alerts alone convey no meaning. The meaning corresponding to an auditory signal is dependent upon the pilot's ability to discriminate it from other sounds and being able to recall the meaning associated with the sound.