EUROPEAN AVIATION SAFETY AGENCY
AGENCE EUROPÉENNE DE LA SÉCURITÉ AÉRIENNE
EUROPÄISCHE AGENTUR FÜR FLUGSICHERHEIT

Research Project EASA.2012/1

Principles and guidelines relative to the design of checklists and working methods in the cockpit

easa.europa.eu

European Aviation Safety Agency

[Executive Directorate]

[Safety Analysis & Research Department]

Report

Aviation Checklists; normal/abnormal & emergency for Fixed-wing & helicopters

April 2012

Report

Contact name and address of the author: Ali Feiz Barazandeh

Work: ali.barazandeh@easa.europa.eu
Private: shemroen@yahoo.com
European Aviation Safety Agency
Safety Analysis and Research Department
Postfach 10 12 53
50452 Köln
Germany

AVIATION CHECKLIST; NORMAL/ABNORMAL & EMEGENCY FOR FIXED-WING & HELOCOPTERS

A RESEARCH ON THE CURRENT METHODS APPLIED TO DESIGN AND IMPROVE NORMAL/ABNORMAL & EMERGENCY CHECKLIST AND WORKING METHODS IN THE COCKPIT.

Under Supervision of Project Research Manager of EASA, Mr. Werner Kleine Beek.

AKNOWLEDGMENTS

I would like to use this opportunity to convey my appreciation to whom provided me with their assistance from different parties such as National Aviation Authorities, research organisations i.e. National Aeronautics and Space Administration (NASA), Federal Aviation Administration(FAA), Civil Aviation authority of United Kingdom etc. European/Non-European operators, aircraft manufactures, educational intuitions, European Cockpit Association (ECA) and many more which unfortunately I could not thank them all by name because of confidentiality or other constrains.

I am extremely grateful to these people because without them none of this would have been possible. In particular, my supervisors at European Aviation Safety Agency (EASA); Mr. Werner Kleine Beek, Research Project Manager and Mr. Dominque Verdoni, Safety Recommendation officer and of course other colleagues.

My Special thanks to Mr. Nicklas Dahlström for his constructive and thoughtful feedbacks.

ABSTRACT

Performing normal/abnormal and emergency checklist is one of the key tasks of the flightcrew. This paper present a summary of the results of studies and works done, as well as latest instructions and directives issued by Civil Aviation Authorities (CAAs), concerning the principles and guidelines relative to the design of checklist and working methods in the cockpit for fixed-wing and helicopters. This allows European manufacturers and operators as well as National Aviation Authorities (NAAs) to have clear references on the state of the art in the design and application of checklists. Numerous accidents and occurrences caused by performing checklist incorrectly were searched and analysed. Various research institutions, National Aviation Authorities, operators and aircraft manufacturers have given their feedbacks on how to design and perform a checklist. Also Human Factor has been taken into account.

CONTENTS

GLOSSARY OF TERMS

TERM	DEFINITION
Abnormal/Non-Normal Procedures	Procedures that require actions to maintain safe flight, and prevent further incidents from occurring.
Action items	Those actions which are carried out as part of the drill. These are also referred to as reference items.
Aircraft Flight Manual (AFM)	The Aircraft Flight Manual produced by the manufacturer and approved by the CAA. This forms the basis for parts of the Operations Manual and checklists. The checklist procedures must reflect those detailed in the AFM.
Checklist	Set of written procedures/drills covering the operation of the aircraft by the flightcrew in both normal and abnormal conditions. The checklist forms part of the OM. The checklist may be split into several parts, the Normal Flight Deck Checklist, the Emergency and Abnormal Checklist (or Quick Reference Handbook), and the Expanded Checklist. The Checklist is carried on the flight deck.
Deferred Items	Those actions, which form part of a drill, that are delayed until a later phase of flight.
Emergency and Abnormal Checklists	A checklist containing the Emergency and Abnormal procedures. This forms part of the OM. This is sometimes divided into two separate Checklists: i) an Emergency Checklist; and ii) an Abnormal Checklist.
Emergency Procedures	Procedures that require immediate action in relation to situations that threaten physical danger to people, and/or damage to the aircraft.
Expanded Checklist	Explanatory material associated with procedures may be supplied by the manufacturer and will be kept either separately or in the OM. This forms part of the OM.

Manufacturer's Operating Manual (MOM) Flight Crew Operating Manual (FCOM) Flight Operating Manual (FOM)	Detailed description of recommended operating procedures, produced by the manufacturer, which may or may not be adopted by the operator.
Memory Items/Mandatory Drills	Those actions normally resulting from an Emergency situation which must be performed immediately by the crew without reference to any checklist, but which, nevertheless, are included in the checklist for verification purposes. These are also referred to as recall items.
Non-Normal Checklist	This is equivalent to an Abnormal Checklist and details the drills associated with non-routine operation.
Normal Flight Deck Checklist	The main Checklist used on the flight deck for normal operations. It may also include Emergency and Abnormal procedures for simple aircraft types.
Operations Manual (OM)	The aircraft OM is produced by the operator and may reflect part(s) of the information contained in the MOM. It contains all the instructions and information necessary for operational personnel to perform their duties. The OM may be divided into several parts, and includes a Normal Flight Deck Checklist and a separate Emergency and Abnormal/ Non-Normal Checklist. Parts of the OM will be carried on the flight deck.
Pilot Flying	The Pilot who is controlling the path of the aircraft at any given time, in flight or on ground.
Pilot Not Flying/Pilot Monitoring	The Pilot who is monitoring the events and actions on the flight Deck.
Quick Reference Handbook (QRH)	A handbook containing procedures which may need to be referred to quickly and/or frequently, including Emergency and Abnormal procedures. The procedures may be abbreviated for ease of reference (although they must reflect the procedures contained in the AFM). The QRH is often used as an alternative name for the Emergency and Abnormal Checklist.

.

ABBREVIATIONS

AAIB	Air Accident Investigation Branch (United Kingdom)
AEG	Aircraft Evaluation Group
AFM	Aircraft Flight Manual
ALS	Approach Lighting System
ASR	Air Safety Report
ATC	Air Traffic Control
ATPL	Air Transport Pilot License
BCL-M	Bestämmelser för Civil Luftfart-Materielbestämmelser (Sweden Civil Aviation Regulations- Equipment Rules)
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication
CDV	Challenge-Do-Verify
CHAT	Checklist Assessment Tool
CHIRP	Confidential Human Factors Incident Reporting Programme
CPL	Commercial Pilot License
CRM	Cockpit Resource Management
CVR	Cockpit Voice Recorder
DODAR	Diagnose, Options, Decision, Assign Task, Review
DV	Do Verify
EASA	European Aviation Safety Agency
ECL	Electronic Checklist
EICAS	Engine Indicating and Crew Alerting System
FAA	Federal Aviation Authority
FCOM	Flight Crew Operating Manual
FE	Flight Engineer
FL	Flight Level
FLM	Flight Manual
FMC	Flight Management System
FMEA	Failure Modes and Effects Analysis
FMGS	Flight Management Guidance System
FOI	Flight Operations Inspector
FOM	Flight Operating Manual
FSB	Flight Standard Board
GPWS	Ground Proximity Warning System
HEMS	Helicopter Emergency Medical Service
HF	Human Factors
IFR	Instrument Flying Rule
IOE	Initial Operating Experience
JAR-FCL	Joint Aviation Requirements – Flight Crew Licensing
JAR-OPS	Joint Aviation Requirements – Operations
KIAS	Knots Indicated Air Speed
Kts	Knots-Speed Unit
M	Memory Item
MFD	Multi-Function Display
MMEL	Master Minimum Equipment List
MOM	Manufacturer’s Operating Manual

ABBREVIATIONS

MOR	Mandatory Occurrence Report
NTSB	National Transportation Safety Board (USA)
OEM	Original Equipment Manufacturer
OM	Operations Manual
OODA	Observe, Orientate, Decide, Act
PAI	Principal Avionics Inspector
PC	Proficiency Checks
PF	Pilot Flying
POIs	Principal Operations Inspector
PM	Pilot Monitoring
PMI	Principal Maintenance Inspector
PNF	Pilot Not Flying
QRH	Quick Reference Handbook
SIC	Second in Command
SOP	Standard Operating Procedure
TCAS	Traffic Collision Avoidance Warning System
TOWS	Take off Warning System
UK	United Kingdom
USA	United States of America
VMC	Visual Meteorological Conditions
VFR	Visual Flying Rule

INTORDUCTION

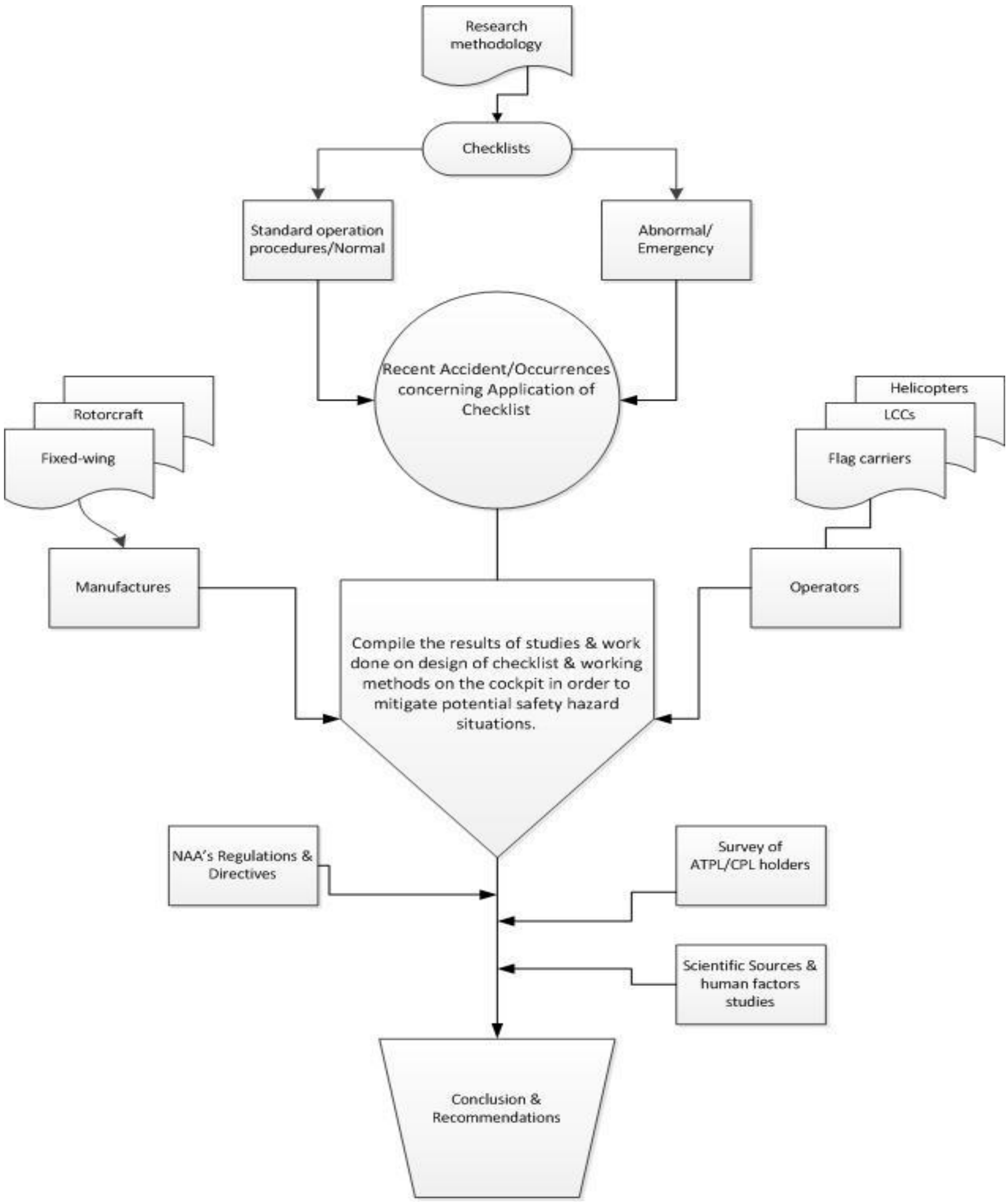
Flightcrew failure to follow prescribed procedures has been regarded as a factor in many aviation occurrences. Checklists are used to ensure that critical tasks are completed by the crew in different phases of flight. There are two distinct type of checklists, Normal checklist also known as Standard Operating Procedures (SOPs) and Abnormal/Emergency checklist.

Some of these occurrences included incorrectly performing checklist; skipping items, omitting or not completing the checklist thoroughly.

After recent occurrences involving checklists, European Aviation Safety Agency has received recommendations to start a research to compile the results of studies and works done, as well as of any instructions and directives issued by civil aviation authorities to date, concerning the principles and guideline relating to the design of checklists and working methods in the cockpit. This paper presents a brief summary of this research.

At first the recent occurrences related to checklist with fixed-wing as well as helicopter is investigated. Chapter 2 provides checklists definitions, internal/external aspects of checklists design, interruptions and distractions occurred while performing a checklist and strategies applied to mitigate these. Chapter 3 explains a model of how to develop a procedure. Guidelines for checklist design are briefly developed in chapter 4. Latest method applied to design a checklist is explained in chapter 5. Chapter 6 provides human factor aspects of checklists & procedures design. At last but not least in Conclusions & Recommendations section feedbacks received from aircraft manufacturers, operators and ATPL/ CPL holders regarding improvement and problems of current applied checklist is elaborated.

At the end of this report appendices presented about electronic checklist design, the presentation of paper checklist, human factor checklist audit tool and questionnaire of ATPL/CPL holders & manufactures performed for this paper.



FLOW CHART OF RESEARCH METHODOLOGY

1 OCURRENCES INVOLVING CHECKLISTS

This section provides a brief analysis of occurrences with fixed-wing as well as helicopter associated with checklist or cockpit procedures.
Please be aware that occurrences mentioned in this section are used merely as examples in order to show a vivid picture of incorrectly performing checklist and should not be assumed as apportioning blame or liability to any particular organisation or individual.

1.1 CASE 1[1]

1.1.1 BACKGROUND

The MD-82 passenger plane, registered EC-HFP, was destroyed when it crashed on takeoff at Madrid-Barajas Airport (MAD), Spain on August 20, 2008. Of the aircraft's occupants, 154 were killed, including all six crew members, and 18 were seriously injured. The MD-82 aircraft operated from Madrid-Barajas (MAD) to Gran Canaria (LPA).

1.1.2 FINDINGS

The crew lost control of the aircraft as a result of a stall immediately after takeoff, when the plane was not configured correctly, with the flaps/slats not being deployed, following a series of failures and omissions, with the absence of a warning of the incorrect takeoff setting.
The crew did not identify the lack of warnings nor correct the situation after takeoff momentarily retarding engine power levers, increasing the pitch angle and failure to correct the roll deteriorating the flight conditions.

1.1.3 HF ISSUES

The crew did not detect the configuration error by not properly using the checklists containing items to select and check the position of flaps/slats in the work of flight preparation, namely:

- ✓ Failure to conduct the action of selecting flaps/slats (in the "After Start Checklist");
- ✓ No cross-checking was made of the position of the lever and the status indicator lights for flaps and slats during the "After Start" checklist;
- ✓ Omission to check the flaps and slats under "Take Off Briefing" in the taxi checklist;
- ✓ The visual inspection of the position of the flaps and slats at the point "Final Items" of the "Take Off Imminent" checks was not made, as shown by the instruments of the cockpit.

Contributory factors

- ✓ The absence of a notice of the incorrect takeoff configuration because the TOWS did not work and therefore did not alert the crew that the takeoff configuration of the aircraft was inappropriate. It was not possible to determine conclusively the cause why the TOWS system did not work.

[1] Online source: http://www.fomento.gob.es/NR/rdonlyres/EC47A855-B098-409E-B4C8-9A6DD0D0969F/107087/2008_032_A_ENG.pdf [retrieved 03-03-12].

- ✓ Inadequate crew resource management (CRM), which did not prevent the diversion of procedures in the preparation of the flight.

CASE 2[2]

1.1.4 BACKGROUND

Airbus A330, on October 2008, Montego Bay, Jamaica.

1.1.5 FINDINGS

During pre-departure preparations, the crew were unable to locate the aircraft's performance manual. The captain contacted the flight dispatch department via telephone to request that the take-off performance data be calculated and relayed the relevant information. The resultant figures were read back to the captain, the telephone was then passed to the first officer and this process repeated as a check. The figures were then entered into the FMGS.

During takeoff, the aircraft appeared to accelerate as normal, however the aircraft did not 'feel right' at rotation, so the captain applied TO/GA thrust and the aircraft became airborne and climbed away.

While the exact source of the error could not be identified, the investigation determined that a TOW of 120,800 kg was used by the dispatcher instead of 210,183 kg, resulting in V speeds which were too low for the aircraft's actual weight. The procedure for calculating and verifying the calculations was not completely carried out, as a second dispatcher was not used to verify what was entered by the first dispatcher.

1.1.6 HF ISSUES

- ✓ No performance manual available in the cockpit.
- ✓ Incorrect performance of the crew

1.2 CASE 3[3]

1.2.1 BACKGROUND

Boeing 767, December 2008, Manchester, United Kingdom.

1.2.2 FINDINGS

During calculation of the take-off performance parameters, the crew inadvertently entered the ZFW instead of the TOW. The calculated V speeds and thrust setting were then entered into the FMC. The aircraft left the gate about 15 minutes behind schedule.

---

[2] Online source: http://www.aaib.gov.uk/sites/aaib/publications/bulletins/november_2009/airbus_a330_243__g_ojmc.cfm [retrieved 03-03-12].

[3] Online source: http://www.aaib.gov.uk/publications/bulletins/july_2009/boeing_767_39h__g_ooan.cfm [retrieved 28-02-12].

While taxiing, it began to rain heavily and the engine anti-ice was required to be on. Accordingly, the first officer re-calculated the V speeds and informed the captain there was no change. The crew's attention was focussed on the taxi, due to works in progress on some taxiways.

During takeoff, the captain noted the aircraft had sluggish acceleration and delayed the V_1 call. Upon rotation the tailskid message illuminated, indicated the aircraft had sustained a tailstrike.

The investigation determined that the captain had flown a number of sectors in an empty Boeing 767 prior to the accident flight; consequently the slow V speeds did not trigger an alert to him. The crew were distracted by the works in progress on the taxiways and the delay in departing led to a time pressure on the crew.

1.2.3 HF ISSUES

- ✓ Lack of Multitasking training
- ✓ CRM training recommended

1.3 CASE 4[4]

1.3.1 BACKGROUND

Piper PA 34 Seneca, on 6 July 2009, Gothenburg City Airport (Säve), Sweden.

The pilot took off from Säve for a private flight to Sindal in Denmark. After take-off the pilot was unable to retract the landing gear. After repeated attempts at both retraction and extension, the pilot left the landing gear lever in the extended position and requested a return to land back at Säve. On the initiative of air traffic control a fly-by was carried out for visual assessment from the control tower. However a definitive statement concerning the landing gear status could not be given from the tower.
The pilot then continued with an approach for landing. The indications in the aircraft showed that none of the landing gear wheels were down and locked. When interviewed the pilot stated that he thought this was an incorrect indication, which was why he did not use the emergency landing gear extension system. He said that he had never practised emergency extension of the landing gear while undergoing proficiency checks (PC). When the aircraft touched down all three landing gear struts folded and the aircraft slid along the asphalt runway before coming to a halt 1,000 metres along it. No fire broke out and those on board – who with help from the rescue services were able to leave the aircraft themselves – were not injured.

1.3.2 FINDINGS

A technical examination revealed that certain components in the electric motor that drives the pump for the hydraulic system was worn out, which meant that the landing gear could not be extended in the normal way.
The examination also discovered that the aircraft emergency checklist did not contain either the emergency landing gear extension procedure or that for landing with the landing gear position uncertain. On the basis of the regulations in BCL-M (Bestämmelser för Civil Luftfart -

[4] Online source: http://www.havkom.se/virtupload/reports/RL2010_06e.pdf [retrieved 02-02-12].

Materielbestämmelser – Swedish Civil Aviation Regulations – Equipment Rules) it was also determined that the checklists were incorrect and incomplete in several respects.
After a dialogue with the appropriate authority (Transportstyrelsen – the Swedish Transport Agency) it was revealed that in respect of checklists and emergency checklists there was no operative approval or inspection procedure.
The accident was caused by lack of knowledge and understanding in respect of the landing gear and its emergency extension system. Contributory factors were inadequate checklists and the absence of training in respect of emergency procedures.

1.3.3 HF ISSUES

- ✓ Ensure that rules are prepared in respect of the minimum requirements for the content of checklists for aircraft operated within the national supervision
- ✓ Ensure that an operational oversight process for checklists for aircraft operated within the national supervision
- ✓ Work towards that training of emergency procedures for aircraft with retractable landing gear is introduced at Proficiency Checks regarding private aviation

1.4 CASE 5[5]

1.4.1 BACKGROUND

Boeing 717-200, on 13 October 2010, Kaligoorlie Airport, Western Australia

1.4.2 FINDINGS

During the approach to land on runway 29 at Kalgoorlie Airport, the stick shaker activated. The copilot, who was the pilot flying, reduced the aircraft's pitch angle and continued the turn onto final. About a minute later, the approach was no longer stabilized and the flight crew conducted a go-around. On the second approach to land and after turning onto final, the copilot noted that the aircraft was below the required profile. As the copilot increased the aircraft's pitch attitude, the stickshaker activated for about 2 seconds. Following recovery actions, a go-around was conducted. The third approach was conducted by the pilot in command at an airspeed that was about 15 kts higher than the previous approaches.
The investigation identified several organizational issues that had the potential to adversely affect the safety of future operations. Those issues related to the format of the aircraft load sheet, the verification check by the flight crew of the TOW against the load sheet and the lack of an independent validation check of the FMS-generated landing weight. In response, the operator has made a number of enhancements to the format of the 717 load sheet, the FMS weight data entry and verification procedures, the weight validation checks and the 717 simulator training in respect of recovery from stick shaker activation.

[5] Online source: http://www.atsb.gov.au/publications/investigation_reports/2010/aair/ao-2010-081.aspx [retrieved 02-02-12].

1.4.3 HF ISSUES

- ✓ In response to the stick shaker activations, the flight crew did not follow the prescribed stall recovery procedure and did not perform an immediate go-around.(Cockpit Procedures)
- ✓ The operator's recurrent training programs did not address the recovery from a stall or stick shaker activation such that the on-going competency of their flight crew was not assured.
- ✓ CRM training is recommended.

1.5 CASE 6[6]

1.5.1 BACKGROUND

From the evidence available, the following findings are made with respect to the tailstrike and runway overrun at Melbourne Airport, Victoria on 20 March 2009 that involved Airbus A340-541, registered A6-ERG and should not be read as apportioning blame or liability to any particular organisation or individual.

Although there are a number of factors identified directly relating to this accident, the accident needs to be taken in the context of the long history of similar take-off performance events identified by this investigation. Even though the events leading to this accident may be particular to this case, the previous events highlight that there are a multitude of ways to arrive at the same situation, placing the aircraft and passengers in an unsafe situation before the aircraft has even been pushed back from the terminal. The preferred safety actions will be those that address the whole situation, not just those that address the specific factors identified in this accident.

1.5.2 FINDINGS

- ✓ The first officer inadvertently entered the incorrect take-off weight into the electronic flight bag to calculate the take-off performance parameters for the flight.
- ✓ The captain was distracted while checking the take-off performance figures in the electronic flight bag, which resulted in him not detecting the incorrect take-off weight.
- ✓ During the pre-departure phase, the flight crew did not complete all of the tasks in the standard operating procedures, which contributed to them not detecting the error.
- ✓ When conducting the loadsheet confirmation procedure, the first officer called out 362.9 tonnes as the FLEX take-off weight, rather than the 262.9 tonnes that was recorded on the master flight plan, which removed an opportunity for the captain to detect the error.
- ✓ The first officer changed the first digit of the FLEX take-off weight on the master flight plan during the loadsheet confirmation procedure, believing it had been transcribed incorrectly, which removed an opportunity for the flight crew to detect the error.
- ✓ The lack of a designated position in the pre-flight documentation to record the green dot speed precipitated a number of informal methods of recording that value, lessening the effectiveness of the green dot check within the loadsheet confirmation procedure.
- ✓ The flight crew's mixed fleet flying routinely exposed them to large variations in take-off weights and take-off performance parameters, which adversely influenced their ability to form an expectation of the 'reasonableness' of the calculated take-off performance parameters.

---

[6] Online source: http://www.atsb.gov.au/publications/investigation_reports/2009/aair/ao-2009-012.aspx [retrieved 02-02-12].

- ✓ The operator's training and processes in place to enable flight crew to manage distractions during the pre-departure phase did not minimise the effect of distraction during safety critical tasks.
- ✓ The rotation manoeuvre was commenced at an airspeed that was too low to permit the aircraft to become airborne but sufficient to overpitch the aircraft, resulting in the tailstrike.
- ✓ The application of the calculated (high) FLEX temperature during a reduced thrust take-off led to a reduced acceleration, an extended take-off roll, and the subsequent runway overrun.
- ✓ The flight crew did not detect the reduced acceleration until approaching the end of the runway due to limitations in human perception of acceleration, which was further degraded by reduced visual cues during a night takeoff.
- ✓ The existing take-off certification standards, which were based on the attainment of the take-off reference speeds, and flight crew training that was based on the monitoring of and responding to those speeds, did not provide crews with a means to detect degraded take-off acceleration.

1.5.3 HF ISSUES

- ✓ The design of the flow of information from the electronic flight bag into the aircraft systems and flight documentation was complex, increasing the potential for error.
- ✓ The available Cross Crew Qualification and Mixed Fleet Flying guidance did not address how flight crew might form an expectation, or conduct a 'reasonableness' check of the speed/weight relationship for their aircraft during takeoff.

1.6 CASE 7[7]

1.6.1 BACKGROUND

On 4 November an Airbus A380 outbound from Singapore, ran into serious problems when a turbine on its Rolls-Royce Trent 900 engine suffered an uncontained failure. There were five pilots.

1.6.2 FINDINGS

The Airplane was relatively light and consequently used a relatively low thrust setting for departure. Taking off to the south-west out of Singapore requires a left turn, tracking out towards the Indonesian island of Batam. As it were climbing and accelerating, basically completing their acceleration stage to clean configuration, passing through around about 7,000ft, the No2 engine, without any warning, exploded. The reason of the incident is still under investigation by Airbus but crew professionally dealt with the incident, and they succeeded to land safely.

1.6.3 HF ISSUES

Well CRM training is a necessity including common sense and excellent airmanship skills (aviate, navigate and communicate).

1.7 CASE 8[8]

[7] Online source: http://www.atsb.gov.au/media/2888854/ao-2010-089%20preliminary%20report.pdf [retrieved 02-02-12]

1.7.1 BACKGROUND

Sikorsly S-76C Helicopter crashed into water with substantial damage on 18 September 2004, Skräckskär, Sweden. The helicopter with a crew of five on board took off from Gotland. The flight took place under VFR in darkness with the commander as pilot flying (PF). During the landing as the helicopter approached the final, the commander stated that he intended to make a relatively steep approach. Shortly after the pilot had made visual contact by the spotlights to his ground bench mark in the direction of flight it sunk below 100ft. A few second later bench operator saw helicopter rapidly approaching the water level, in the backward direction and crashed into the water

1.7.2 FINDINGS

Act to ensure the operators who fly to places which are not established takeoff and landing grounds possess, and follow, operational procedure for such flights similar to those used for IFR flights.
Act to ensure that operators flying under IFR, with two pilots or with and HEMS crew member, develop and follow some form of cooperation for VFR flight corresponding to that in used for IFR flight.

1.7.3 HF ISSUES

- ✓ The accident caused by a lack of adequate routines and procedures for the activity in question
- ✓ Existing procedures were not followed completely.
- ✓ Consider, not any sortie is a routine flight.

CASE[9]

1.7.4 BACKGROUND

Eurocopter SA 342 on 22 March 2007 at Broby säteri, Sweden. Helicopter destroyed.

1.7.5 FINDINGS

The day before departure the company's pilot wanted to make a short flight to check how the helicopter worked as intended. The pre-flight inspection was rushed and so the checklist before take-off was not fully adhered to. After operating in the vicinity for about 10 minutes and when at about 150 meters height the engine suddenly stopped. The investigation found that the engine stoppage was due to fuel starvation

1.7.6 HF ISSUES

Not performing normal procedures completely due to rush and under stress.

[8] Online source: http://www.havkom.se/virtupload/reports/rl2006_16e.pdf [retrieved 02-02-12]

[9] Online source: http://www.havkom.se/virtupload/news/rl2008_05e.pdf [retrieved 25-03-2012]

2 CHECKLIST

What is a checklist? If you ask this question from 10 customers, one will get 11 different answers; Pilot Checklist, Quick Reference Handbook, Abbreviated Checklist, Checklist, Operational Checklists, etc.

According to Degani[10] (1993), the major function of the flight deck checklist is to ensure that the crew will properly configure the airplane for any given segment of flight. It forms the basis of procedural standardization in the cockpit. The complete flight checklist is sub-divided into specific task-checklists for almost all segment of the flight, i.e., PREFLIGHT, TAXI, BEFORE LANDING, etc.; and in particular before the critical segments: TAKEOFF, APPROACH, and LANDING. Two other checklists are also used on the flight-deck: the abnormal and emergency checklist.

The omission of an action or an inappropriate action in the cockpit is the largest primary causal factor in approach and landing accident[11]. Omission of an action or inappropriate action is:

- A causal factor, along with other causal factors, in 45 % of fatal approach and landing accidents, and
- A factor, to some degree, in 70% of all approach and landing accidents.

The intent of this section is to recognise and distinguish between two types of checklists used in cockpit. Analyse the factors effecting the checklists, possible interruption & distraction situations and at the end strategies of how to mitigate them.

2.1 STANDARD OPERATING PROCEDURES (SOPS)

According to Boorman[12] (2001), normal checklist items consist of airplane settings, such as *Flaps… set*, or crew activities, such as *Briefing… Completed*, that is checked at identifiable points in a normal flight sequence. Most operators use normal checklist to confirm key steps after completion of memorized normal procedures. SOPs should be accomplished by recall using a defined flow pattern for each cockpit panel; safety-critical points (i.e., primarily items related to aircraft configuration) should be cross-checked with reference to Normal Checklists[13].

Normal checklists enhance flight safety by providing an opportunity to confirm or correct the systems and aircraft configuration for critical items. Normal checklists are not read-and-do lists and should be accomplished after performing the flow of actions defined in the standard operating procedures (SOPs).
The correct completion of normal checklists is essential for safe operation during all flight phases, particularly for takeoff and during approach and landing. For an effective use of normal checklists, the following generic rules should be considered.

---

[10] Dr Asef Degani, have worked primarily in the aviation industry (NASA) and recently moved to the automotive industry (GM). He has worked on specific problems such as, Formal Methods in Human Factors, Information Organization, and Pattern Languages for Human Perception and Human-Machine Interaction). He has also published many literatures on checklist subject.

[11] Flight Safety foundation 1998-1999

[12] D. Boorman, Author of many literatures on checklist subject such as *Safety Benefits of Electronic Checklists: an Analysis of Commercial Transport Accidents.* 2001.

[13] Airbus Flight Operations Briefing Notes on Normal Checklists, 2004

The normal checklist should have the following objectives (Degani, 1993);

1. Provide a standard foundation for verifying aircraft configuration that will attempt to defeat any reduction in the flightcrew's psychological and physical condition.
2. Provide a sequential framework to meet internal and external cockpit operational requirements.
3. Allow mutual supervision (cross checking) among crew members.
4. Dictate the duties of each crew member in order to facilitate optimum crew coordination as well as logical distribution of cockpit workload.
5. Enhance a team concept for configuring the plane by keeping all crew members "in the loop."
6. Serve as a quality control tool by flight management and government regulators over the flightcrews.

2.1.1 INITIATING NORMAL CHECKLISTS

Normal checklists should be initiated (called) by the pilot flying (PF) and read by the pilot not flying (PNF), If the PF fails to initiate a normal checklist, the PNF should suggest the initiation of the checklist (by applying good CRM practice).
Normal checklists should be called in a timely manner during low-workload periods (conditions permitting) to prevent any rush or interruption that could defeat the safety purpose of the normal checklists.
Time and workload management (i.e., availability of other crewmember) are key factors in the initiation and effective conduct of normal checklists.

2.1.2 CONDUCTING NORMAL CHECKLISTS

Normal checklists are based on the challenge-and-response concept. Critical items require response by the PF; some less-critical items may be both challenged and responded to by the PNF alone.
To enhance communication and understanding between crewmembers, the following standard rules and phraseology should be used at all times:

- The responding crew member should respond to the challenge only after having checked or corrected the required configuration;
- If achieving the required configuration is not possible, the responding crewmember should announce the actual configuration;
- In all cases, the challenging crewmember should wait for a positive response (and should cross-check the validity of the response, as required) before moving to the next item; and,
- The PNF should verbalize the completion of the checklist by calling loudly "[...] checklist, complete".

A320/A330/A340 families feature electronic normal checklists (i.e., TAKEOFF and LANDING MEMO) that allow a positive identification of:

- Items being completed; and,
- Items still to be performed (blue colour coding).

2.1.3 ROUTINE OF CALLS AND RESPONSES

Memory-guided checklist (Degani, 1993). There is temptation, on the part of experienced pilots, to memorize a checklist and avoid the burden of reading it from the card. In several instances during night operation, we observed that the checklist card was drawn out of its slot (above the glare shield), but no light was turned on to allow reading. Consequently, the checklist was performed from memory. A similar habit was observed in both day and night operation: the pilot would stretch his hand out and touch the checklist card situated on the glare shield, but would not draw the checklist out of its slot. It is interesting to note here that pilots had a habit pattern of associating a motor action (reaching for the checklist card) with the checklist procedure.

Verification, in some cockpits, the task of verification was left only to the pilot responding to the checklist. The pilot making the challenge calls read the checklist items but did not move his eyes away from the list to cross-check his partner. Therefore, the mutual redundancy embedded in the checklist procedure was not utilized. Often, the pilot flying would answer with the proper response immediately when he/she heard the challenge call from the pilot not flying, not verifying that the item called was set accordingly. This was evident in high workload phases of flight such as during the approach for landing. In this case, the pilot must rely on his memory to judge whether checklist items were set correctly. The setup redundancy embedded in the procedure was lost.

Several pilots who were interviewed stated that they have their own checklist procedure which they perform from memory just prior to takeoff to assure themselves that the plane is configured correctly. They viewed this as an additional safeguard against a poorly conducted checklist procedure. We found similar techniques during our observations.
These memory techniques have some inherent hazards:

- They are dependent on the availability of time after the quick completion of the checklist.
- They are vulnerable to distractions such as air traffic control (ATC) communications, outside scan, starting an engine during TAXI segment, and more.
- They are based on memory, and not on a step-by-step challenge-and-response procedure.

"Short-cutting" the checklist, several pilots deviated from the challenge-and-response method to a much faster routine, calling several challenge items together in one "chunk," while the other pilot would reply with a series of chunked responses. This technique undermines the concept behind the step-by-step challenge-and-response method. It is also dependent on the pilot's short-term and long-term memory as to the completion an order of checklist items. This dependency, in fact, is exactly what the checklist procedure is supposed to prevent.

2.1.4 INTERRUPTING AND RESUMING NORMAL CHECKLISTS

Operators must establish procedures to ensure that the correct checklist sequence is re-established when unusual events interrupt the normal sequence of a flight. For example, crewmember actions during normal sequences of flights are interrupted when long delays are encountered on taxi-out or when crewmembers vacate the flight deck (Federal Aviation Authority (FAA), 2007)[14]

Vacating Flight Deck with Visitors in Cockpit, Operators must establish additional checklist management procedures for checklist interruptions that occur when any flightcrew member who is assigned to a flight deck duty station vacates the cockpit to perform other duties, leaving persons who are occupying cockpit observer seats or who visit the cockpit during such absence with unsupervised access to unmanned flight deck duty stations.

[14] Federal Aviation Administration. *Volume 3 General Technical Administration.* 2007.[see Bibliography]

How to manage this:

- If the flow of a normal checklist needs to be interrupted for any reason, the PF should announce a formal and explicit hold such as "hold (stop) checklist at [item]".
- An explicit call such as "resume (continue) checklist at [item]" should be made.
- Upon resuming the normal checklist after an interruption, the last known completed item should be repeated - as an overlap – to prevent another item from being omitted.
- The SOPs, in the applicable FCOM and QRH, provide aircraft-type-related information.

- Verification of Items Accomplished. The flightcrew must verify the accomplishment of all items on checklists that have been accomplished up to the point where the current checklist was interrupted.
- Minimum Requirement. As each checklist item is accomplished, the minimum that is required is a verification that switches, control handles, knobs, or levers are in the positions prescribed and that the associated indicator lights and instrument readings confirm the proper positioning of the applicable switches, control handles, knobs, or levers.

  Additional Requirements:

  - If the verification check reveals that any switch, control handle, knob, or lever is not in the position prescribed, then the full procedure, including any associated checks for the particular checklist item(s), must be reaccomplished.

  - If the indicator lights or instrument readings associated with the proper positioning of particular switches, control handles, knobs, or levers are not in agreement with the prescribed positions of these control means and reaccomplishment of the full procedure, including any associated checks for the particular checklist item(s), does not correct the disagreement, then the flightcrew must log the discrepancy in the aircraft maintenance log. The operator must either correct this discrepancy before the next flight or, if permitted, defer correction in accordance with the certificate holder's approved minimum equipment list (MEL) procedures.

2.1.5 TRAINING ASPECTS

Disciplined use of SOPs and normal checklists should begin during the transition training course, because habits and routines acquired during transition training have a recognized lasting effect.
Transition training and recurrent training also provide a unique opportunity to discuss the reasons for the rules and procedures, and to discuss the consequences of failing to comply with them.
Conversely, allowing a relaxed adherence to SOPs and/or a relaxed use of normal checklists during transition or recurrent simulator training may encourage corresponding deviations during line operation.
Line checks and line audits should reinforce strict adherence to SOPs and Normal Checklists.

2.1.6 FACTORS AFFECTING THE USE OF NORMAL CHECKLISTS

To ensure effective compliance with published normal checklists, it is important to understand why pilots sometimes omit partially or completely a normal checklist.
Pilots rarely omit the performance of a normal checklist intentionally; such a deviation from SOPs often is the result of operational circumstances that disrupt the normal flow of cockpit duties.
The following factors and conditions often are cited in discussing the complete or partial non-performance of a normal checklist.

Out-of-phase time scale, whenever a factor (such as tail wind or a system malfunction) modifies the timescale of the approach or the occurrence of the trigger-event for the initiation of the normal checklist;

- Distractions (e.g., due to intra-cockpit activities);
- Interruptions (e.g., due to pilot / controller communications);
- Task saturation (i.e., inadequate multi-tasking ability or task overload);
- Incorrect management of priorities (i.e., absence of decision-making model for time-critical situations);
- Reduced attention (tunnel vision) in abnormal or high-workload conditions;
- Incorrect CRM techniques (absence of effective cross-check, crew coordination and/or backup);
- Overreliance on memory (overconfidence);
- Less-than-optimum checklist content and/or task sharing and/or format; and,
- Insufficient emphasis on strict adherence to normal checklists during transition training and recurrent training.

2.2 ABNORMAL/EMERGENCY PROCEDURES

Abnormal checklists accomplished in response to non-normal airplane system events, such as a hydraulic system failure, or abnormal operating context, such as ditching the airplane at sea. Most abnormal/emergency checklist are used to guide procedures in real-time that the crew has not memorized, although a small subset of abnormal checklists contains memory items that the crew later confirms with reference to the checklist.

Emergency and abnormal checklists used in civil aviation are typically presented to flightcrews in paper or electronic formats. Aeronautical engineers and/or pilots generally develop them using aircraft system design, historical precedent, and their own preferences and best judgment to guide their checklist design decisions. Relatively little guidance from the human factors community regarding checklist design exists. What is available typically focuses on a limited number of design factors, such as typography (Degani, 1992), or is rather cursory and incomplete (Burian, 2006)[15].

Two of the most complete documents pertaining to checklists that are currently available can be obtained from the United Kingdom Civil Aviation Authority. The first, Civil Aviation Publication (CAP) 676[16] (See Appendix 2), provides general guidance on the design, presentation and use of emergency and abnormal checklists and pertains primarily to those presented on paper (Civil Aviation Authority, United Kingdom, 2006). CAP 708[17] provides guidance as to the design, functionality and use of normal, emergency, and abnormal checklists that are presented electronically (Civil Aviation Authority, United Kingdom, 2005). However, neither of the CAP documents fully addresses all of the aspects that need to be dealt with when constructing paper or electronic emergency and abnormal checklists (Burian, 2006).

---

[15] B.K. Burian is Author of *Design Guidance for Emegency and Abnormal Checklists in Aviation,2006.* .[see Bibliography]

[16] Online source: http://www.caa.co.uk/docs/33/CAP676.PDF [retrieved 04-03-12]

[17] Online source: http://www.caa.co.uk/docs/33/CAP708.PDF [retrieved 04-03-12]

Overall Purpose of Emergency and Abnormal Checklists: The final major aspect of emergency and abnormal checklist design that comprises the model pertains to the degree to which a checklist serves its overall purpose: to guide and direct flightcrew response to an emergency or abnormal situation. For example, does a checklist assist crews to manage and distribute workload, maintain awareness of the overall situation, make appropriate decisions accordingly, and facilitate communication and coordination with other parties such as ATC and cabin crew? Checklist actions should also be evaluated regarding the degree to which they are consistent with and complement any checklists or procedures used by cabin crews when responding to the same emergency or abnormal situation (Burian, 2006).

2.3 INTERNAL ASPECTS OF CHECKLISTS DESIGN

When developers consider "checklist design," some of the "internal" aspects discussed below are what most often come to mind. Fourteen different but often inter-related "internal" features of checklist design have been identified and comprise this aspect of the model.

The first feature has to do with the ***physical properties and interface*** of the checklist or checklist system. Paper checklists are typically compiled in a manual referred to as the Quick Reference Handbook (QRH). The physical properties and interface of paper checklists and QRHs include such things as size, weight, type of materials used, ability for the QRH to be held in one hand (or not), as well as section divider pages, tabs, and similar features which pilots use to "operate" the QRH. Electronic checklists are typically presented on either a hand-held or laptop computer (sometimes as a part of an electronic flight bag) or are presented on a flight deck multi-function display unit. Touch pads, touch screens, computer mice, dedicated buttons (both hard and soft), and keyboards are the typical methods by which pilots interact with electronic checklist systems.

Organization and access pertain to how the pilots find their way to a desired checklist and how quickly and easily this can occur. Clearly, the physical properties and interface methods of an electronic checklist system or QRH will influence access, but so too will the kind, number, and organization of indexes, tables of content or checklist menus, and even the titles given to checklists. Some electronic checklists are linked to the aircraft caution and warning system and to various aircraft components through a system of sensors. Thus, when a particular alert is displayed, its related checklist is queued or displayed automatically, allowing very quick access indeed.

Another internal aspect of checklist design pertains to ***typography and use of symbology***. Typography is probably the single checklist design feature that has been addressed the most often by the human factors community (Burian, 2006; Degani, 1992). Font size and type, boldface, italics and other such features of typography have direct relevance on the readability and legibility of checklists, particularly in low visibility situations such as when smoke is in the cockpit. Some checklists also include various symbols, such as stop signs to signify the end of a checklist. The degree to which these symbols are intuitive and conspicuous are important considerations related to their use.

Checklist ***layout, format, and display*** also strongly influence the usability and readability of checklists. Some checklist developers do not pay enough attention to the visual look of the checklist and the arrangement of items on the page, or use enough "white space" resulting in paper checklists that are hard to read and difficult to follow (Burian, 2006).

There are a multitude of other issues concerning the layout, format, and display of electronic checklists, many of which involve the overall ways in which the checklists function and the ways that crews are to complete items and navigate through the displays. One of the most important issues has to do with the size of the electronic display space, which affects the number of lines of text that can be shown at one time. Typically, electronic displays allow for far fewer lines of text to be shown on a screen than can be shown on a single page of a paper checklist. Thus, even short paper checklists become multiple "page" electronic checklists and designers must decide the best ways for crews to access all of the items within a single checklist, such as through scrolling or paging conventions (Burian, 2006).

Checklist ***length and workload*** are especially important emergency and abnormal checklist design features. Checklist length pertains to both the physical length of a checklist and the amount of time it takes to read checklist information and complete checklist actions (i.e., the "timing" length or duration). The evaluation of a checklist's workload requires a consideration of not only the physical effort involved in completing actions but also the cognitive complexity and mental effort required. The workload of an abnormal or emergency checklist cannot be evaluated in isolation, however. The workload and task demands related to various phases of flight where the checklist may be used must also be considered (Burian, 2006).

Many emergency and abnormal checklists are written with separate sets of steps to be completed depending upon the specifics of the situation being faced. Likewise, it is not uncommon for crews to be directed in one checklist to additional checklists or other information, such as aircraft performance tables, when responding to a single malfunction. Thus, ***navigation, progression and jumping*** refer to movement within checklists and between checklists and other types of information. They pertain to the number of these "jumps" required and the ability of crews to easily work through a checklist and locate the set of items, additional checklists, or other material needing to be accessed.

The navigation of electronic checklists also involves the functionality of the electronic checklist system as a whole. For example, when an item on an electronic checklist is completed, it might be replaced on the display with the next item to be accomplished or, conversely, a "current item box" might move from the completed item to the next item for accomplishment. The decision to use scrolling vs. paging conventions on electronic checklist displays also affects how crews navigate through electronic checklists.

Nomenclature and abbreviations involves the exact terms and labels used as well as the kind and number of abbreviations employed within checklists. ***Language, grammar, and wording*** pertain to verb tense, the use of active or passive voice, reading difficulty level, degree to which actions are compulsory (i.e., "must" versus "may") and even whether a checklist is written in English or in a different language.

Checklist designers must also consider the ***purpose*** of a checklist, or sets of items within a checklist. Some checklists or, sets of items, are intended to fix a particular malfunction and restore a system to its normal operating condition. Another purpose might be to stabilize a malfunction and allow continued operation in an altered state. Designers must be clear about the intent of the checklist or sets of items within a checklist to ensure the checklist is as clear and logical as possible.

Whereas checklist purpose pertains to the intent of checklist actions relative to the status of aircraft system functioning, checklist item ***objectives*** pertain to the goal of each type of item within a checklist relative to communicating with and guiding the crew members who are completing the checklist. Twenty-five (25) different types of emergency and abnormal checklist items and elements have been identified (Burian, 2006) and they fulfil different objectives or fulfil similar objectives in different ways. For example, in paper checklists there are three types of items or elements that help to meet the objective of ensuring that the correct checklist has been accessed by the crew: 1) checklist titles, 2) condition statements or descriptions, and 3) reproductions of illuminated lights or alert messages. Checklist designers must be clear about their objectives throughout the checklist to make sure that the proper types of checklist items or elements have been used in its construction.

Determining the proper ***level of detail*** to include within checklists has always been a dilemma for checklist developers. Cognitive limitations experienced by humans when dealing with stress, concurrent task demands, and time pressure (e.g., decreased working memory capacity) underlie many of the errors made by crews when responding to emergencies including more information in checklists can reduce memory load and other cognitive demands. However, the more information included in a checklist, the longer it becomes and the more time needed to complete it (Burian, 2006).

A checklist's ***engineering completeness*** pertains to whether all the necessary steps are included in the checklist and whether the steps included are, in fact, the correct actions to take. Closely related to engineering completeness is ***engineering coherence***, which refers to whether or not checklist actions are presented in the correct order from the "perspective" of the aircraft and aircraft systems. For example, if a desired system response requires that action A is accomplished before action B, does step A appear before step B in the checklist? Engineering coherence also pertains to the temporal "spacing" of items on the checklist, again related to aircraft and aircraft systems requirements. If it takes an aircraft system 10 seconds to finish the action initiated by step A, and the action in step B must not be initiated prior to the completion of the step A action, does the checklist delay the crew from performing step B for at least 10 seconds after accomplishing step A?

The final internal aspect of checklist design is ***logical coherence***. Just as engineering coherence pertains to checklist steps "making sense" to aircraft systems, logical coherence involves the degree to which checklist steps make sense to the pilots completing them. Several errors made by pilots during the accomplishment of checklists appear to be related to the confusing nature of some checklists and specific checklist actions (Burian, 2006). The logical coherence of a checklist can only be evaluated by examining the items within a checklist relative to each other.

2.4 EXTERNAL ASPECTS OF CHECKLISTS AND PROCEDURES DESIGN

The second major set of design features comprising the emergency and abnormal checklist model involves aspects that are "external" to the checklists themselves. Like the 14 internal design features described above, the following seven sets of external factors must also be considered and should influence the design and content of emergency and abnormal checklists.

One set of external considerations affecting checklist design pertains to the ***specific aspects of emergency or abnormal situations*** themselves. Emergency and abnormal situations vary in terms of degree of threat and level of time criticality, as well as the extent to which they are novel, ambiguous, and complex. For example, flightcrews can typically handle excessive engine bleed air temperatures or pressures fairly easily and an emergency landing is generally not needed; including such landing guidance in the checklists for these conditions is unnecessary.

In addition to time criticality and situation complexity, checklist designers should also anticipate the amount of increase in workload a situation might cause for a crew. Similarly, situations such as an in-flight fire might cause the cascading loss of other systems. Workload and the probability of related, multiple, or cascading failures must be considered and should influence not only the length of checklists but also the guidance given to the crews about how to respond. For example, guidance to perform an emergency landing should be given early in in-flight fire checklists so that a descent can be initiated before the crew becomes incapacitated or control of the aircraft is lost.

Checklists should also be designed to conform to air carrier standard operating procedures (SOPs) and aviation regulations. However, crews should be reminded in checklists that SOPs and regulations can and should be violated to the extent necessary if the safety of the aircraft and crew warrants doing so in an emergency. In 1996, the first officer of a DC10 began to slow to airspeed of 250 knots to comply with regulations requiring 250 knots or less below an altitude of 10,000 feet. The captain on this flight urged the first officer to "keep the speed up," violating this regulation, because they had an uncontrollable cargo fire on board and were performing an emergency descent and landing (National Transportation Safety Board (NTSB), 1998).

Other ***operational requirements***, such as those related to different phases of flight, dealing with adverse weather (including icing conditions), and flying over mountainous terrain or oceans, comprise another set of external checklist design factors influencing emergency and abnormal checklist design. The failure of an engine during flight has different implications for the crew when the aircraft is at cruise altitude over the Rocky Mountains as compared to when the aircraft is at cruise altitude over Kansas. Both kinds of implications need to be accounted for in the checklist for this condition. Similarly, pilots have encountered difficulties when checklists they were to use in response to a hydraulic failure were written for such failures in flight rather than when the hydraulics failed while the aircraft was taxiing on the ground. Checklist designers need to make sure that actions are included in a checklist for all phases of flight during which the checklist might be needed.

Human performance capabilities and limitations under high workload and stress are often not fully considered by designers when developing emergency and abnormal a human's ability to hold and manipulate information in working memory, perform mental calculations, and to shift mental sets when performing different tasks concurrently .And yet, it is not uncommon to find checklists that require crews to perform multiple steps from memory and to mentally perform complex mathematical calculations in response to system malfunctions (Burian, 2006).
Furthermore, when under stress, humans have a natural tendency to fixate on cues that are associated with a particular threat, such as a fuel gage with a rapidly decreasing quantity indicated. This fixation or tunnelling can cause crews to miss other cues and information that has importance for their emergency or abnormal situation, and to lose perspective on the status of the overall situation, i.e., situation awareness. Checklist designers can accommodate this normal human behaviour by including items within checklists that remind crews of information they may not easily recall and other cues they should attend to as they respond to a particular situation.

In multi-crew cockpits there are a variety of ***social and cultural influences on crew performance, behaviour and checklist usage.*** This is certainly true under normal operating conditions but also during emergency and abnormal situations, even if only one crew member accomplishes all of the checklists. It is not uncommon for two crew members who do not share the same native language or culture to share the cockpit. In these circumstances, cultural or language barriers may interfere with good crew communication and coordination necessary for emergency situation response. Crew members who do not speak English fluently may have difficulty understanding some of the guidance or information printed in checklists and checklist designers must be particularly cognizant of this when writing checklist items.

Checklist developers also need to consider the number of crew members who will be involved in accomplishing checklist items. One crew member may complete emergency and abnormal checklists without the input or involvement of any other crew members. On the other hand, one crew member may be primarily responsible for checklist accomplishment but another may monitor or even be fully engaged in assisting with checklist completion. In three-person cockpits, it is not uncommon for two or even all three crew members to be involved in the completion of steps within emergency and abnormal checklists. When it is necessary for more than one crew member to be involved in accomplishing a checklist action, checklists should specifically identify the titles or role of those crew members (e.g., pilot flying) and note the level of their required involvement (Burian, 2006).

It should go without saying that ***aircraft systems requirements*** will significantly influence the content of emergency and abnormal checklists. Through a failure modes and effects analysis (FMEA) engineers and pilots determine the ways in which a system might fail and the actions necessary to either return the system to a normal operating state or to stabilize it and allow for its operation in an alternate mode. Additional information about how various actions should be performed and any operating limitations that exist are also identified for inclusion in checklists.

There are other issues related to the aircraft and aircraft systems that also should be considered when developing emergency and abnormal checklists, however. The relationship of the checklists to the aircraft caution and warning system may influence the titles of emergency and abnormal checklists and may even influence how the checklists may be accessed. Malfunction cues that may be ambiguous or misleading warrant the inclusion of extra information in checklists to assist flightcrews in making a differential diagnosis to ensure that they complete the correct checklist for their situation. Similarly, checklists for conditions that are known to have a high rate of false warnings (e.g., some types of smoke detectors) should include procedures for determining the reliability of the alert.

Checklists should also include guidance as to the proper level of automation for crews to use in response to some types of emergency and abnormal situations. This information is particularly important for inclusion in checklists for flight control problems. Automation can be confusing for crews to use even under normal operating conditions; it can even be more confusing when aircraft systems are operating in degraded states (Burian, 2006).

2.5 COCKPIT INTERUPTIONS & DISTRACTION

Most pilots are familiar with the December 1972 L-1011 crash that occurred when the crew became preoccupied with a landing gear light malfunction and failed to notice that someone had inadvertently bumped off the autopilot. More recently, a DC-9 landed gear-up…when the crew, preoccupied with an unstabilized approach, failed to recognize that the gear was not down because they had not switched the hydraulic pumps to high(Dismukes et.al 1998)[18].
There are few categories associated with lapses of attention causing interruptions, distractions, or preoccupation with one task to the exclusion of another task (Dismukes et al. 1998).

2.5.1 COMMUNICATION

Incident Example: "Co-pilot was a new hire and new in type; first line flight out of training IOE. Co-pilot was hand-flying the aircraft on CIVET arrival to LAX. I was talking to him about the arrival and overloaded him. As we approached 12,000 feet (our next assigned altitude) he did not level off even under direction from me. We descended 400 feet low before he could recover. I did not realize that the speed brakes were extended, which contributed to the slow altitude recovery.

In this example, the Captain was attempting to help the new First Officer, but the combination of flying the airplane and listening to the Captain was too much for the new pilot. Tellingly, the act of talking distracted the Captain himself from adequately monitoring the status of the aircraft.
Research studies have shown that crews who communicate well tend to perform better overall than those who do not. But conversation has a potential downside because it demands a substantial amount

[18] Robert K. Dismukes, Chief Scientist for Aerospace Human Factors at NASA and author of Cockpit Interruptions and Distractions.

of attention to interpret what the other person is saying, to generate appropriate responses, to hold those responses in memory until it is one's own time to speak, and then to utter those responses. One might assume that it is easy to suspend conversation whenever other tasks must be performed. However, the danger is that the crew may become preoccupied with the conversation and may not notice cues that should alert them to perform other tasks. Special care is required to avoid distraction when others enter the cockpit, because they may not recognize when the pilots are silently involved in monitoring, visual search, or problem-solving.

2.5.2 HEAD DOWN WORK

Incident Example: "...Snowing at YYZ. Taxiing to runway 6R for departure. Instructions were taxi to taxiway B, to taxiway D, to runway 6R….as First Officer I was busy with checklists [and] new takeoff data. When I looked up, we were not on taxiway D but taxiway W…ATC said stop….".

Monitoring the Pilot who is flying or taxiing is a particularly challenging responsibility for several reasons. Much of the time the monitoring pilot has other tasks to perform. Monitoring the other pilot is much more complex than monitoring altitude capture because the other pilot is performing a range of activities that vary in content and time course. Thus, it is sometimes difficult for the monitoring pilot to integrate other activities with monitoring because he or she cannot entirely anticipate the actions of the other pilot. Furthermore, serious errors by the pilot who is flying or taxiing do not happen frequently, so it is very tempting for the pilot who is not flying to let monitoring wane in periods of high workload. Periods of head-down activity, such as programming the FMS, are especially vulnerable because the monitoring pilot's eyes are diverted from other tasks. Also, activities such as programming, doing paperwork, or reviewing approach plates, demand such high levels of attention that attempting to perform these tasks simultaneously with other tasks substantially increases the risk of error in one task or the other. Some FMC entries involving one or two keystrokes can be performed quickly and may be interleaved with other cockpit tasks.

However, attempting to perform longer programming tasks, such as adding waypoints or inserting approaches during busy segments of flight, can be problematic. It is not possible for the Pilot Not Flying to reliably monitor the Pilot Flying or the aircraft status during longer programming tasks, and it is difficult to suspend the programming in midstream without losing one's place.

2.5.3 SEARCHING FOR VISUAL METEOROLOGICAL CONDITIONS (VMC) TRAFFIC

Incident Example: "PRADO 5 Departure. Cleared to climb (and) received TCASII TA (which) upgraded to an RA, monitor vertical speed. While searching for the traffic we went past the NIKKL intersection...for the turn to the TRM transition. We had discussed the departure before takeoff; special procedures, combined with many step climb altitudes in a short/time/distance, made this a more demanding departure than most. Next time on difficult departures I will use autopilot sooner...will try to be more vigilant in dense traffic areas."

One of the insidious traps of interruptions is that their effects sometimes linger after the interruption. For example, descending through 4500 feet, a crew might be instructed to report passing through 3000 feet. They might then respond to and quickly resolve a traffic alert, but forget the instruction to report by the time they reach 3000 feet. In this hypothetical example, searching for traffic preempts the reporting instruction from the crew's conscious awareness. The instruction presumably is still stored in memory in an inactive form, and if reminded, the crew probably will recognize that they were given the instruction. However, lacking such a reminder and being preoccupied with other activities, they do not remember to contact ATC as they pass through 3000 feet.

2.5.4 RESPONDING TO ABNORMAL SITUATIONS

Incident Example: "Large areas of thunderstorms; we had to deviate considerably. Several (equipment malfunctions) in short period...then cabin pressure started climbing slowly in cruise (FL290). Troubleshooting...to no avail. Requested immediate descent. Descending through FL180, both crew members forgot to reset altimeters, putting us 300 feet low at FL130. To prevent this from occurring again during any abnormal, I will: 1) delegate tasks; have one person focus on flying the airplane while the other troubleshoots and state clearly who will do what, 2) strictly adhere to company procedures."

It is especially easy to forget to reset altimeters if this action is not linked in pilots' minds to other actions. (For this reason some pilots make resetting altimeters part of a cluster of action items they routinely perform together, e.g., making a passenger announcement and turning on the seat belt sign. Some companies make resetting altimeters part of the descent checklist.) In principle, the problem is similar to that of monitoring for altitude level-off, except more vulnerable to error. In air carrier operations the crew is normally aided with altitude level-off by altitude alerting devices and by the formal procedure of making a thousand-foot call, confirmed by both pilots, before reaching the assigned altitude.

2.6 STRATEGIES FOR REDUCTION OF INTERRUPTIONS AND DISTRACTION IN THE COCKPIT

Dismukes identifies the following lines of defence against the crew error explained above. They are not perfect solutions but it may reduce the occurrence of error in the cockpit.

1) Recognize that conversation is powerful distracter

Unless a conversation is extremely urgent, it should be suspended momentarily as the aircraft approaches an altitude or route transition, such as altitude level-off or a SID turn. In high workload situations, conversation should be kept brief and to the point. Even in low workload situations, crew should suspend discussion frequently to scan the status of the aircraft and their situation. This requires considerable discipline because it goes against the natural flow of conversation, which usually is fluid and continuous.

2) Recognize that head-down tasks greatly reduce one's ability to monitor the other pilot and the status of the aircraft.

If possible, reschedule head-down tasks to low workload periods. Announce that you are going head-down. In some situations it may be useful to go to a lower level of automation to avoid having one crew member remain head-down too long. For example, if ATC requests a speed change when cockpit workload is high, the crew may set the speed in the Mode Control Panel instead of the FMS. An FMS entry might be made later, when workload permits. Also, some airlines have a policy that FMS entries should be commanded by the Pilot Flying and implemented by the Pilot Not Flying. This approach minimizes the amount of attention the Pilot Flying must divert from monitoring the aircraft.

3) Schedule/reschedule activities to minimize conflicts, especially during critical junctures.

When approaching or crossing an active runway, both pilots should suspend all activities that are not related to taxiing, such as FMS programming and company radio calls, until the aircraft has either stopped short of the runway or safely crossed it. Crews can reduce their workload during descent by performing some tasks while still at cruise, for example, obtaining ATIS, briefing the anticipated instrument approach, and inserting the approach into the FMS (for aircraft so equipped). Also, it may be useful for companies to review their operating practices for optimal placement of procedural items.

For instance, could some items on the Before Takeoff Checklist be moved to the Before Start Checklist, since the latter is performed during a period that usually has lower workload?

4) When two tasks must be performed concurrently, set up a scan and avoid letting attention linger too long on either task.

In some situations pilots must perform two tasks concurrently, for example, searching for traffic while flying the airplane. With practice, pilots can develop the habit of not letting their attention linger long on one task, but rather switch attention back and forth every few seconds between tasks. This is somewhat analogous to an instrument scan, and like an instrument scan it requires discipline and practice, for our natural tendency is to fixate on one task until it is complete. Pilots should be aware that some tasks, such as building an approach in the FMC, do not lend themselves to time-sharing with other tasks without an increased chance of error.

5) Treat interruptions as red flags.

Knowing that we are all vulnerable to preoccupation with interruptive tasks can help reduce that vulnerability. Many pilots, when interrupted while running a checklist, place a thumb on the last item performed to remind them that the checklist was suspended; it may be possible to use similar techniques for other interrupted cockpit tasks. One of us has developed a personal technique using the mnemonic "Interruptions Always Distract" for a three-step process: (1) Identify the **I**nterruption when it occurs, (2) **A**sk, "What was I doing before I was interrupted" immediately after the interruption, (3) **D**ecide what action to take to get back on track. Perhaps another mnemonic for this could be "***Identify***-Ask-Decide."

6) Explicitly assign Pilot Flying and Pilot Not Flying responsibilities, especially in abnormal situations.

The Pilot Flying should be dedicated to monitoring and controlling the aircraft. The Pilot Flying must firmly fix in mind that he or she must concentrate on the primary responsibility of flying the airplane. This approach does not prevent each pilot from having to perform concurrent tasks at times, but it does insure that someone is flying the airplane and it guards against both pilots getting pulled into trying to solve problems.

7) Cockpit Resource Management (CRM)

According to advisory circular of FAA (1998)[19], Cockpit Resource Management is the effective use of all available resources: human resources, hardware, and information. CRM training intends to solve the flight deck confusion by emphasizing on crew performance among themselves or with the third parties such as ATC controllers. This would improve the skills of crew members in the delegating of cockpit tasks, such as described in SOPs, better interactions, crisis management, monitoring each other's actions and communications (Loren et al, 1993), workload management and situational awareness and team building maintenance.

[19] Online source: http://www.faa.gov/documentLibrary/media/Advisory_Circular/21-49.pdf [retrieved 03-03-12]

2.7 ALTERNATIVE TO CURRENT PAPER CHECKLISTS

In the 1980s ,accident research carried out by Boeing and other investigation parties revealed that crew procedural errors, and specifically errors in accomplishing checklists, were causal or contributing factors in a substantial number of incidents and accidents(Boorman,2001), In response to the new safety data, Boeing flight deck research and development teams began looking at methods to prevent these errors. This led to development of Electronic checklist (ECL). According to advisory circular of FAA, Electronic checklist is a checklist that is displayed to the flightcrew by means of some electronic device.

It is important to mention that ECL tool may yield many benefits, such as shorter checklist accomplishment times, lower cognitive workload, decreased training time and attractive marketing material. The primary design driver was simply to create an automation tool that would prevent or mitigate the crew errors associated with paper checklists. According to Boorman (2001), there are 320 Boeing 777's are in service with 27 operators, all using the ECL.

Table 1 illustrates a few errors made using paper checklist. Here is short elaboration of each item:

#	Paper Checklist Error Mode	777 ECL Feature
	Both Normal and Non-normal Checklists	
1	One or more items skipped in checklist	Current line item box jumps to incomplete item. "CHECKLIST COMPLETE" indication will not display until all items complete
2	Place lost in checklist when crew distracted by higher priority task or checklist	Automatic place holding when returning to an incomplete checklist
3	Incorrect switch selected	Sensed line items will not turn green
4	Item incorrectly confirmed complete	Sensed line items will not turn green. "CHECKLIST COMPLETE" indication will not display
5	Excessive psychomotor workload due to holding, turning/marking pages, recovering dropped or misplaced paper checklist	Panel mounted display and one-hand cursor controller
6	Checklist unreadable due to poor illumination	Display readable in any lighting condition
	Normal Checklists (NC) Only	
7	NC skipped (subsequent checklist accomplished before critical flight phase)	Next normal checklist in sequence always displayed
8	NC omitted (all checklists related to critical flight phase are omitted)	Not prevented. Checklist is displayed later when ECL next accessed, providing error feedback
	Non-normal Checklists (NNC) Only	
9	Incorrect NNC accomplished for the annunciated condition	Correct NNC automatically placed in queue when airplane system fault message displayed
10	NNC skipped or left incomplete	Checklist queue lists incomplete or unaccessed checklists. Amber "NON-NORMAL" indication displayed
11	Incorrect steps accomplished in a branching checklist	Current line item box moves to next step in correct branch. Incorrect branch displayed in cyan
12	Steps to be accomplished later in flight not accomplished	Deferred line items automatically attached to Approach or Landing checklist
13	Operational notes or revised limitations following a malfunction forgotten	Notes automatically collected for review at any time; must be reviewed to complete Approach checklist
14	Wrong steps accomplished when multiple related failures have conflicting actions	Correct steps are collected in single checklist. Consequential checklists inhibited
15	Omitted NNC or other errors due to excessive cognitive workload in multiple failure case	ECL cognitive workload and accomplishment times lower than paper

Table 1 Paper Checklist Errors(Boorman,2001)

One or More Items Skipped in Checklist (Mode #1)

An example of this error mode occurred in 1996 in Houston, Texas (NTSB, 1997). The DC-9 flightcrew was on approach with the first officer (FO) as pilot flying (PF). The captain accomplished the In-Range checklist (Figure 1) but skipped over the item HYDRAULICS...ON & HI. This item ensures that both engine-driven hydraulic pumps are set to high-flow, enabling normal operation of landing gear and flaps. The flaps did not extend normally nor did the landing gear. The approach speed (216 knots at 500 feet AGL) was far above normal, and the captain became over-focused on the goal of landing instead of executing a go-around. Ground proximity and configuration aural warnings sounded due to the gear up condition, but the pilots were saturated by the airplane control task and failed to attend to and identify the meaning of the alerts. The Landing checklist was neither called for nor accomplished. On short final, the FO questioned the decision to land. The captain responded by taking control and landing the airplane gear up. Fortunately, the airplane avoided impact with ground obstacles, and the passengers and crew evacuated safely.

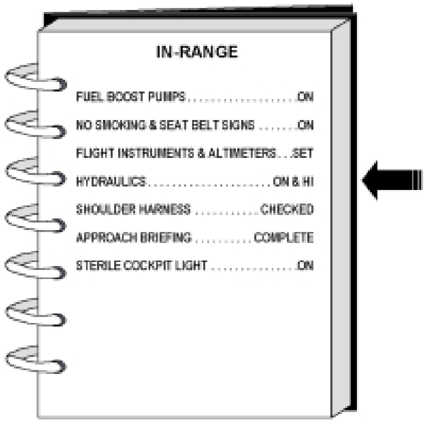


Figure 1 In-Range, Paper checklist

How would this scenario have transpired if all else was equal but the airplane had an ECL on board? Figure 2 denotes the In-Range checklist as it would appear in ECL. The current line item box moves down the checklist, preventing the pilot from skipping a line item. The entire accident scenario, which originated with a procedural error, would have been averted from the beginning.

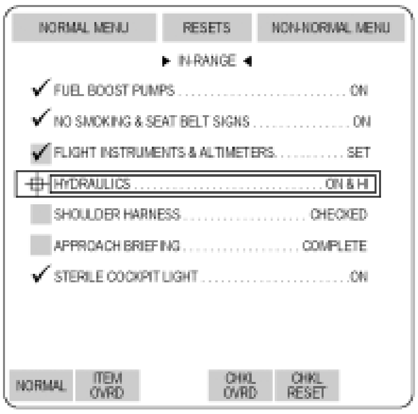


Figure 2 In-Range, ECL version

Normal Checklist Skipped (Mode #7)

This error occurs when a crew skips a checklist and accomplishes the subsequent checklist in the normal series, never realizing that the first checklist was skipped. The best example of this error occurred in 1987 in Detroit, Michigan. (Boorman, 2001). The MD-80 crew accomplished the After Start checklist, then were subject to many distractions during taxi-out due to errors in communication and navigation on the airport surface. They failed to set the flaps for takeoff. They skipped the Taxi checklist, but the FO read the items of the Before Takeoff checklist prior to beginning the takeoff roll. However, only the Taxi checklist included the item FLAPS...SET(Figure 3).

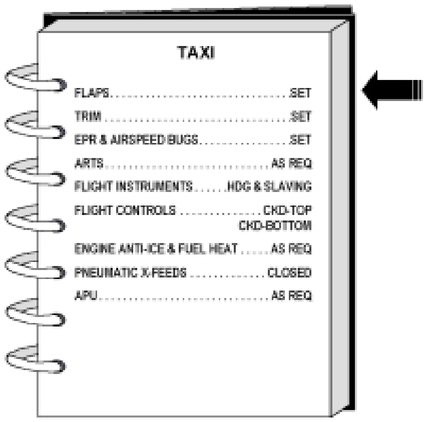


Figure 3 Taxi, Paper checklist

During the acceleration phase, the takeoff warning system should have alerted the crew to the unsafe configuration, but did not function for undetermined reasons. The airplane took off in a nearly stalled condition, struck obstacles and crashed, killing 154 on board and two on the ground. The NTSB found the probable cause to be the flightcrew's "failure to use the Taxi checklist".
Replaying the scenario with an ECL installed, shows what would have happened when the FO decided to accomplish the Before Takeoff checklist. Since ECL always displays the next checklist in the normal sequence, the Taxi checklist (Figure 4) would have been displayed instead of the Before Takeoff checklist. The Taxi checklist would clearly indicate the incomplete status of the *FLAPS...SET* item until the flaps and slats were in the planned takeoff position. It is highly probable that an ECL would have prevented this accident.

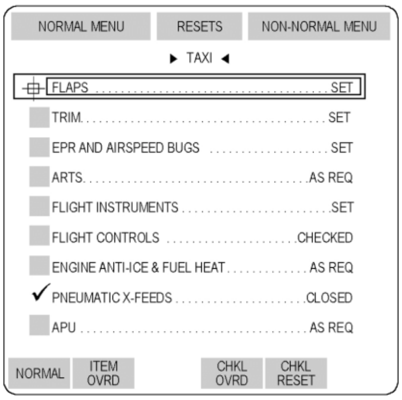


Figure 4 Taxi, ECL version

2.7.1 TYPES OF ECL

Variant 1 - Non-integrated ECL. This variant might someday be incorporated in a stand-alone "electronic flight bag" tool or installed on an older technology airplane such as a DC-9 or 737 without a sophisticated alert message system. It is similar to the 777 ECL except non-normal checklists cannot be linked to the aircraft's alert message system (EICAS). Therefore, pilots must select non-normal checklists from menus, and could commit errors in this task with no feedback from the ECL. Also, the non-integrated ECL does not feature checklist line items that automatically turn green when they are complete (sensed line items). Therefore, pilots may accidentally select the wrong switch or incorrectly identify an item as complete with no error feedback from the ECL (Boorman, 2001).

Variant 2 - Integrated ECL. This is the 777 ECL implementation. It is fully integrated with the airplane's data buses, automatically selects the correct non-normal checklists based upon the annunciate condition, and senses the position of many switches and selectors in the flight deck.

Variant 3 - Integrated ECL with alerting. This is similar to the 777 ECL but has an additional feature. At critical phases of flight, specifically before takeoff and before landing, if appropriate checklists have not been completed, the pilots are automatically alerted. This is a possible "next generation" ECL that prevents error mode #8, *Normal checklist omitted*.

3 A MODEL FOR PROCEDURE DEVELOPMENT

Most the time manufacturers provide a set of procedures. But each airliner modifies them according to its own style of operations or states regulations. Thus the same piece of equipment may have very different operating procedures (Degani 1998). But what are the basic requirements to design a procedures and what is the best procedures in terms of compatibility, consistency and compliance?

I. PHILOSOPHY

Degani (1997) identifies a link between the organization's *philosophy*, *policies*, and the standard operating *procedures supplied* to the pilots. *Three P's* of cockpit operations. Obviously there is a *Fourth P, practices which* is described in sub-section IV*.*

The cornerstone of the "Three P's" model is an organization's philosophy of operations. By philosophy we mean that the airline management determines an over-arching view of how they will conduct the business of the airline, including flight operations. A company's philosophy is largely influenced by the individual philosophies of the top decision makers on how to conduct operations. It is also influenced by the company's culture, a term that has come into favour in recent years to explain broad-scale differences between corporations.
Although most high-ranking managers, when asked, could not clearly state their philosophy of operations, such philosophies do indeed exist within airlines; they can be inferred from working procedures, policies, punitive actions, organizational structure, and training. For example, one company that we surveyed had a flight operation philosophy of granting great discretion (they called it "wide road") to the individual pilot. Pilots were schooled under the concept that they were both qualified and trained to perform all tasks. Consistent with this philosophy, the company allowed the first officer to abort a takeoff, a manoeuvre which is the captain's absolute prerogative at most airlines.

II. POLICY

The philosophy of operations, in combination with economic factors, public relations campaigns, new aircraft, and major organizational changes, generates policies. Policies are broad specifications of the manner in which management expects things to be done (training, flight operations, maintenance, exercise of authority, personal conduct, etc.). In some cases, policies that are actually remote from flight operations can affect cockpit procedures. For example, one airline's new public relations policy led to a procedure that called for the captain to stand at the cockpit door and make farewells to the passengers as they departed the cabin. In particular, the marketing department wanted the pilot to be in place at the cockpit door in time to greet the disembarking first-class passengers. This dictated a procedural change in that most of the "SHUT-DOWN" checklist had to be done single-handed by the first officer. Thus checklist procedures which would normally be conducted by both pilots had to be significantly changed in deference to public relations imperatives.

III. PROCEDURE

Procedures, then, should be designed to be as much as possible consistent with the policies (which, in turn, should be consistent with the philosophy). But just what are procedures? In general, we argue, a procedure exists in order to specify, unambiguously, the following:

- What the task is.
- When the task is conducted (time and sequence).
- How the task is done (actions).
- By whom it is conducted.
- What type of feedback is provided to other crew members

The function of a well-designed procedure is to aid flightcrews by dictating and specifying a progression of sub-tasks and actions to ensure that the primary task at hand will be carried out in a manner that is logical, efficient, and also error resistant. Another important function of a cockpit procedure is that it should promote standardization—the application of procedures to promote crew coordination and quality control. In airline operations, standardization of procedures is a critical aspect of flight operations; mainly because flightcrews are paired for a particular trip without consideration to whether they know one another; also because operations are conducted remotely, and no direct management supervision can be maintained over every flight. So strong is the airline industry's dependency on SOPs that it is believed that in a well-standardized operation, a cockpit crew member could be plucked from the cockpit in mid-flight and replaced with another pilot, and the operation would continue safe and smoothly. Nevertheless, any human operator knows that adherence to a particular set of SOPs is not the only way that one can operate equipment; there may be several other ways of doing the same task with a reasonable level of efficiency and safety.

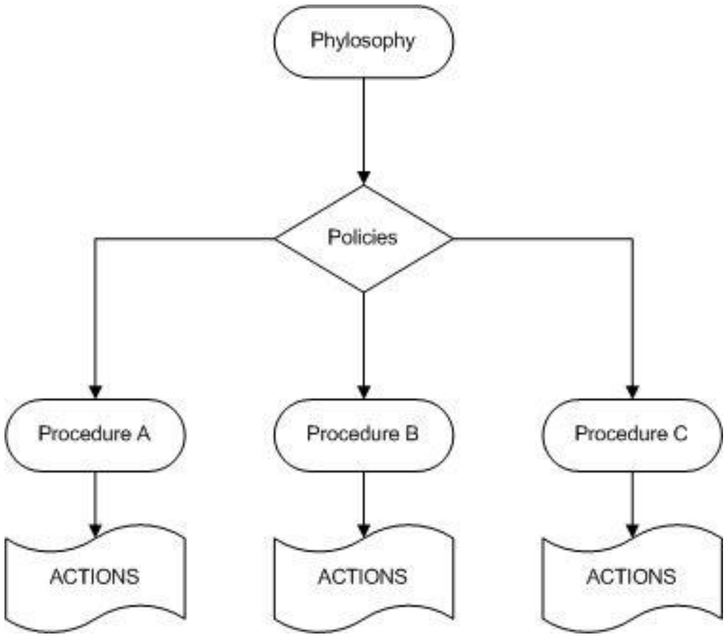


Figure 5 the "Three P's"model

The following bullets provide a better elaboration of Figure 5

- *Philosophy*: Automation is just another tool to help the pilot.
- *Policy*: Use or non-use of automatic features (within reason) is at the discretion of the crew.
- *Procedure*: The flightcrew will first decide what level of automation to use (manually, manually with computer guidance, semi-automatic, fully automatic), which determines what must be done to configure the cockpit.
- *Sub-tasks (or actions)*: Follow from procedures (e.g., identify and tune the signal from the landing site, select automation mode, set the altitude criterion for a missed approach, etc.).

IV. THE FOURTH P: PRACTICES

The goal of flight management is to promote “good” practices by specifying coherent procedures. But we must also recognize that this is not always the case: procedures may be poorly designed. The crew can either conform to a procedure or deviate from it. The deviation may be trivial (e.g., superimposing some non-standard language on a procedural callout), or it may be significant (e.g., not setting the auto-brakes according to the takeoff procedures). For example, we once observed a captain who, in response to the first officer’s question regarding the conduct of a *mandatory* taxi procedure, replied “I just don’t do that procedure.” That captain, unequivocally, elected to deviate from the procedure. The immediate consequences of the failure to conform to a procedure can be seen in the following report submitted to the NASA's Aviation Safety Reporting System (ASRS):

Our flight departed late in the afternoon for San Francisco. During the flight we discussed the necessity to request lower altitudes from air traffic control (ATC), when approaching the San Francisco Airport, due to tendency to be “caught high” on arrival in this aircraft type. Area arrival progressed smoothly and we were cleared for the approach to the runway. When changing radio frequency from approach to tower (head down), the First Officer selected “open descent” to 400 feet. The autopilot was off, both flight directors were engaged, and auto thrust was on. After contacting San Francisco tower, I became aware that we were below the glideslope, that airspeed was decaying, and that we were in an "open descent" mode. I instructed the first officer to engage the “Vertical Speed” mode in order to stop our descent, restore the speed mode for the auto throttles, and continue the approach visually. Company procedures explicitly prohibit selecting an altitude below 1500 feet for engaging the "Open Descent" mode, since this places the aircraft close to the ground with engines at idle. It is suspected that this was the cause of a recent aircraft accident in Asia. "Highly automated" aircraft demand explicit following of established procedures. Unfortunately it is possible to fly the aircraft in numerous ways that will degrade your safety margin rapidly. Adherence to procedures would've prevented this incident. (ASRS Report No. 149672, Degani et al, 1997)[20].

4 GUIDANCE FOR CHECKLIST DESIGN AND USAGE

According to elaboration above, there is a list of guidelines for designing and using flight-deck checklists. These considerations are not specifications, and some, when applied individually, may conflict with others. Therefore, each should be carefully evaluated for its relevance to operational constraints (Degani, 1993), see appendix 1 and 4.

1. Checklist responses should portray the desired status or the value of the item being considered, not just "checked" or "set."
2. The use of hands and fingers to touch, or point to, appropriate controls, switches, and displays while conducting the checklist is recommended.
3. A long checklist should be subdivided to smaller task-checklists or chunks that can be associated with systems and functions within the cockpit.
4. Sequencing of checklist items should follow the "geographical" organization of the items in the cockpit, and be performed in a logical flow.
5. Checklist items should be sequenced in parallel with internal and external activities that require input from out-of-cockpit agents such as cabin crew, ground crew, fuelers, and gate agents. We note here that this guideline could conflict with No.4.
6. The most critical items on the task-checklist should be listed as close as possible to the beginning of the task-checklist, in order to increase the likelihood of completing the item before interruptions may occur. We note that this guideline could conflict with Nos. 4 and 5 above. In most cases where this occurs, this guideline (No. 6) should take precedence.
7. Critical checklist items such as flaps/slats, trim setting, etc., that might need to be reset due to new information (arriving after their initial positioning), should be duplicated on the ground phase checklists.
8. The completion call of a task-checklist should be written as the last item on the checklist, allowing all crew members to move mentally from the checklist to other activities with the assurance that the task-checklist has been completed.
9. Critical checklists, such as the TAXI checklist, should be completed early in the ground phase in order to decouple them from the takeoff segment.
10. Checklists should be designed in such a way that their execution will not be tightly coupled with other tasks. Every effort should be made to provide buffers for recovery from failure and a way to "take up the slack" if checklist completion does not keep pace with the external and internal activities.
11. Flightcrews should be made aware that the checklist procedure is highly susceptible to production pressures. These pressures set the stage for errors by possibly encouraging

[20] Online source: http://ti.arc.nasa.gov/m/profile/adegani/Procedures%20in%20Complex%20Systems.pdf [retrieved 14-04-12]

substandard performance, and may lead some to relegate checklist procedures to a second level of importance, or not use them at all.

5 METHODS OF CHECKLIST DESIGN

Operators may choose from at least two accepted methods of checklist design: the "challenge-do-verify" (CDV) method and the "do-verify" (DV) method. Available evidence suggests that safety is enhanced when the operator adopts and applies a consistent checklist design policy. The Principal Operations Inspectors (POIs) should use the following informative guidance when reviewing the design of an operator's aircraft checklists (FAA, 2007).

5.1 CHALLENGE-DO-VERIFY

The CDV method consists of a crewmember making a challenge before an action is initiated, taking the action, and then verifying that the action item has been accomplished. The CDV method is most effective when one crewmember issues the challenge and the second crewmember takes the action and responds to the first crewmember, verifying that the action was taken. This method requires that the checklist be accomplished methodically, one item at a time, in an unvarying sequence. The primary advantage of the CDV method is the deliberate and systematic manner in which each action item must be accomplished. The CDV method keeps all crewmembers involved (in the loop), provides for concurrence from a second crewmember before an action is taken, and provides positive confirmation that the action was accomplished. The disadvantages of the CDV method are that it is rigid and inflexible and that crewmembers cannot accomplish different tasks at the same time.

5.2 DO VERIFY

The DV method (or "clean-up" method) consists of the checklist being accomplished in a variable sequence without a preliminary challenge. After all of the action items on the checklist have been completed, the checklist is then read again while each item is verified. The DV method allows the flightcrew to use flow patterns from memory to accomplish a series of actions quickly and efficiently. Each individual crewmember can work independently, which helps balance the workload between crewmembers. The DV method has a higher inherent risk of an item on the checklist being missed than does the CDV method.

5.3 SELECTION OF DESIGN METHOD

Both the CDV and the DV methods of checklist design are currently being successfully used for normal checklists. Traditionally, operators have preferred the DV method for normal checklists and the CDV method for non-normal and emergency checklists. Operators have, however, successfully used the CDV method for all checklists. POIs may approve either method for normal checklists. In most circumstances non-normal and emergency checklists are more effective when the CDV method is used. The correct accomplishment of the actions and procedures incorporated in the non-normal and emergency checklist categories is critical and warrants a methodical approach. Since these checklists are seldom used, however, crewmembers are usually not as familiar with the procedures incorporated into these checklists as they are with the procedures in normal checklists. In addition, many non-normal and emergency checklists do not lend themselves to developing flow patterns that crewmembers can readily recall. The CDV method also enforces crew coordination, cross-checking, and verification, all of which aid the crewmember in overcoming the adverse effects of stress. POIs should not approve or accept the DV method for non-normal or emergency procedures unless the operator can provide substantial evidence that the method is effective for this application.

5.4 MECHANICAL OR ELECTRONIC CHECKLISTS

Mechanical or electronic devices differ in format from paper, hand-held checklists, but not in the design method or use. The actions these checklists contain and their sequencing shall be consistent with the paper version (when required) available to the flightcrew. Some electronic checklists will have an ability to automatically detect the completion of an action based on switch position, system state, or both. In electronic checklists, the verification in the CDV or DV methods may be a matter of observing that the items are complete via the display method used (for example, completed items turn green). The CDV or DV methods can be applied to any type of checklist. POIs should encourage the use of such aids when operators find them effective.

5.5 VERIFICATION

POIs should keep in mind that all checklist designs are subject to human error. Crewmembers may omit and skip checklist items. Crewmembers may erroneously respond to a checklist at times believing that an item or task was accomplished when it was not. At times, crewmembers may see what they expect to see rather than what has actually been accomplished. Both the CDV and the DV methods are subject to such human errors. POIs must ensure that operators have developed policies for using checklists that require stringent cross-checking and verification to overcome these human limitations. These policies must be compatible with the operator’s crew resource management (CRM) philosophy. POIs shall review the operator’s policies as an integral part of the review process.

5.6 POLICIES FOR MANAGING THE ACCOMPLISHEMENT OF CHEKCLISTS

POIs must ensure that the appropriate sections of the operator’s manuals contain the specific crewmember responsibilities for monitoring, verifying, and managing the accomplishment of checklists. These responsibilities should appear either as policy statements or as specific directives. POIs should use the guidance that follows when evaluating an operator’s policies for the accomplishment of checklists.

5.6.1 OBJECTIVE OF POLICY STATEMENTS AND DIRECTIVES

The primary objective of the operator’s policy statements or directives is to standardize crewmember interaction. These statements should include, but not be limited to, the following items:

- Flightcrew responsibilities for maintaining aircraft control, analysing situations, and for requesting the appropriate checklist in non-normal and emergency situations
- The specified crewmember responsible for initiating each checklist
- The specified time when each checklist is to be initiated
- The specified crewmember responsible for accomplishing each item on the checklist
- The specified crewmember responsible for ensuring that each checklist is completed and for reporting that completion to the crew
- Crewmember responsibilities for bringing to the attention of the pilot-in-command (PIC) and the rest of the crew any observed deviation from prescribed procedures

5.6.2 METHODS FOR MANAGING CHECKLIST ACCOMPLISHMENT

The following subparagraphs each contain a discussion of recommended methods an operator may use for managing checklist accomplishment. These methods are not all-inclusive and may not meet all of the operator's needs. POIs shall not interpret these methods as the only ones that are acceptable.

- For single-pilot aircraft, the FAA recommends that operators mount the before-takeoff checklist and the before-landing checklist on the instrument panel by means of a placard. When aircraft characteristics allow, the operator should develop touch-verification procedures that contain a requirement that the pilot touch each control to verify it is in the correct position.

- For two-pilot aircraft in which only the PIC has ground steering control, the recommended method for accomplishing checklists is for the second-in-command (SIC) to read all checklists when the aircraft is in motion on the ground. The recommended method for those aircraft in which either pilot can steer on the ground is for the pilot not flying (PNF) to read all checklists. In all two-pilot aircraft, the PNF should read all checklists when the aircraft is airborne.

- For three-crewmember aircraft, the recommended method is for the SIC to read the flight engineer (FE) portion of the before-engine-start checklist, so that the PIC can observe and verify the configuration of the FE panel as the FE responds to each item on the checklist. Since the PNF is the crewmember most subject to interruptions from radio communications, it is recommended that the FE should read all normal checklists and verify that each pilot action has been taken when the aircraft is in motion. The FE should have the explicit task of verifying that critical items have been performed by the pilots, whether or not the FE has verbal responses for those items. In those non-normal or emergency situations that involve significant activity by the FE, it is recommended that the PNF read the checklist and verify FE actions while the FE performs and responds to the items.

- For all aircraft, the crewmember responsible for reading the checklist should be responsible for ensuring that the checklist is completed systematically and expeditiously. This crewmember should be responsible for managing interruptions, cross-checking controls and indicators to ensure that the required actions have been accomplished, and for reporting that the checklist has been completed.

- The pilot-flying (PF) should not be distracted from controlling the aircraft to perform a checklist item that another crewmember can accomplish. The PF should activate only those switches or controls (other than the manual or automatic flight controls, throttles, and nose wheel steering) that are not within practical reach of another crewmember. Only one pilot should be "heads down" at any time.

- In the prestart phase, flight guidance and navigation checklist items have proven to be critical items. A response should be required from both pilots (and FE, if applicable) when the same setting is required for more than one device (such as computers, flight instruments, and altimeters). Inertial platform alignment and computer programming should be accomplished by one crewmember and independently confirmed by another crewmember. As many of these checklist items as possible should be accomplished and verified before the aircraft is moved.

- In the taxi and pre-takeoff phases, aircraft configuration (such as flaps, trim, and speed brakes) and flight guidance items (such as heading, flight-director, altitude select panel settings, and airspeed bugs) have proven to be critical. All flightcrew members should confirm these items, and at least two crewmembers should respond to applicable checklist items.

- On approach, flight guidance checklist items have proven to be critical items. At least two crewmembers should confirm and respond to these items. A response should be required from each pilot when the same setting is required on two separate devices (such as computers, flight instruments, or altimeters).

  NOTE: One operator was able to reduce altitude deviations from an average of two per week to one per quarter by using stringent procedures for setting and verifying the altitude alerter.

- All checklist items that are critical in the before-landing phase vary with the type of airplane involved. In the operation of small airplanes, the landing gear has proven to be a critical checklist item, and both pilots should confirm and respond to this item. Although the landing gear and flaps are critical items for large, transport category airplanes, the multiple warning devices and systems that are associated with these systems make the need for a response and confirmation by both pilots less critical.

- All checklists, except the after-takeoff and after-landing checklists, should be accomplished by one crewmember reading the checklist items and a second crewmember confirming and responding to each item. POIs shall ensure that critical items on the before-takeoff and before-landing checklists are confirmed and

- All checklists must be designed so that the flightcrew can maintain an adequate visual scan and monitor air traffic control (ATC) communications while simultaneously controlling the aircraft. The recommended method is for the operator to group the systems management checklist items after the configuration, thrust, and flight guidance items for each phase of flight. When systems management checklist items must be accomplished in a high workload environment, it is recommended that they be accomplished by a single crewmember. Usually the after-takeoff and after-landing checklists items can be accomplished silently as these items have not proven to be critical. POIs should carefully evaluate the operator's overall operation and experience before approving other checklists in which a single crewmember may accomplish a checklist.

- Operators should direct crewmembers to refrain from accomplishing action items assigned to other crewmembers. Crewmembers should be directed that when they observe that another crewmember is not taking or has not taken a required action they must inform the crewmember, the PIC, or the whole crew, as appropriate.

- Checklists should not be depended on to initiate changes in aircraft configuration. Operators should key aircraft configuration changes to specific operational events. For example, the operator may direct the landing gear to be extended at glide-slope intercept. For any adjustment of thrust, or configuration, a command from the PF and an acknowledgement from the crewmember taking the action are required.

- Flightcrew members frequently cannot complete a checklist when initiated either because of an interruption or because an item on the checklist has not yet been accomplished. POIs shall ensure that each operator has developed policies for the management of these situations. For short delays, the recommended policy is for the flightcrew to hold the checklist until the interruption is over and the item can be completed. When the checklist item is completed, the challenge should be repeated, the proper response given, and the checklist continued. POIs shall not accept policies that allow flightcrews to skip checklist items that have not been completed and then to depend on memory to accomplish the item later. When a mechanical or electronic device allows checklist items to be accomplished in a random sequence, the POI may allow policies appropriate to the system used.

5.7 DEVELOPMENT AND SEQUENCING OF CHECKLIST ITEMS

POIs must ensure that checklists are developed from a careful task analysis and are consistent with the procedures section of the operator's flight manual. Phase checklist items must be in an appropriate and logical sequence. When a checklist represents an abbreviated procedure, that checklist must follow the procedural sequence. POIs should use the following additional guidelines concerning individual topics of checklist design

A. Operators should standardize the sequence of checklist items as much as possible across aircraft types.

B. When the operator has a choice as to where an item should be placed on a checklist, it should be placed at a point where the crew workload is lowest.

C. Operators should keep checklists as short as possible in order to minimize interruptions. When an operator is using an electronic checklist with the ability to automatically detect the completion of an action, the POI shall encourage the use of that ability to the maximum extent possible.

   I. Operators should sequence checklist items to minimize interruptions of checklist accomplishment. For example, sequencing the "INS NAV MODE" as the first item on the engine-start checklist may allow the flightcrew to call for and complete the before-engine-start checklist at a convenient time even though INS alignment is not complete.

   II. Two short checklists may be preferable to a single long one. Operators may place a line or otherwise mark a checklist where the checklist can be held until a specific event occurs. This practice is acceptable because in essence, it creates two separate checklists.

D. Operators must include required pre-flight tests on checklists, but should design checklists to preclude the unnecessary testing of systems.

   I. Warning systems with built-in test and automatic monitor circuits do not need to be checked or included on checklists unless required by the AFM.

   II. Many test switches in the cockpit are designed for use by maintenance personnel. Operators should not require flightcrew members to perform these tests as a normal procedure.

   III. With concurrence of the aircraft evaluation group (AEG), POIs may approve the operator grouping required functional checks on a specific checklist which is performed before the first flight of the day (or at some other logical interval) and not repeated on subsequent flights.

E. Operators must clearly identify decision points and indicate the correct alternative action or alternative sequence of actions to be taken after each decision point. If the effect of adverse weather requires an alternate action, the operator should design the checklist to account for that alternate action. For example, if the auto throttles are normally engaged for takeoff except when engine anti-ice is being used, the checklist should contain a requirement that the auto throttles cannot be engaged with the engine anti-ice on.

5.8 IMMEDIATE ACTION ITEMS

Immediate action items are those items accomplished from memory by crewmembers in emergency situations before the checklist is called for and read.

1. A flightcrew's failure to correctly accomplish all immediate action items can result in a threat to continued safe flight. For example, should a flightcrew fail to close the tank valve.
2. During an engine fire procedure, leaking fuel in the engine pylon may be ignited. In such cases, the first items on the corresponding checklist must be verification that each immediate action item has been accomplished.
3. In some cases, an immediate action procedure may not be incorporated in a checklist. For example, there is no point in verifying that each item of an aborted takeoff procedure has been accomplished after the aircraft has been brought to a stop. In most cases, however, there should be a "follow-on" or "clean-up" checklist to be accomplished after the situation has been brought under control.
4. Another example of an immediate action memory item is the following statement: "All flightcrew members shall immediately put on O_2 masks and report to the captain on interphone in the event of loss of cabin pressure." In this example, the loss-of-cabin-pressure checklist would contain the immediate action memory item and subsequent follow on items to verify that each item has been accomplished.

5.9 CHECKLIST TERMINOLOGY

POIs should ensure that the operator's aircraft checklists contain terminology that is tightly controlled to ensure clarity and common understanding. The following recommendations should be considered by POIs when reviewing checklists.

1. The challenges and responses on the checklist should be consistent with the labelling on the switches and controls in the cockpit.
2. Terms such as "tested," "checked," and "set" are acceptable terms only when they are clearly defined and consistently used.
3. Operators should have a consistent policy concerning responses to items with variable settings. "As required" may be printed on the checklist, but should not be an authorized response. A response that gives the actual setting is normally appropriate. Items that require variable responses should be carefully evaluated. Such items may not actually be required on the checklist or may be more appropriately included in the system management portion of a checklist.
4. Responses to checklist items concerning liquid or gas quantities should be made in terms of the actual quantities on board compared to the specific quantity required, for example: "10,000 pounds required, 10,400 on board." When specific quantities are required, a response of "checked" is not acceptable. A response of "checked" is acceptable when a range of quantity is permitted and the range is marked on an indicator, such as a green arc on an oil quantity gauge.
5. Excess verbiage on checklists should be discouraged. For example, a checklist item of "Reduce airspeed to 130 KIAS for best glide" can be abbreviated as "BEST GLIDE - 130 KIAS."

6. Ambiguous verbiage on checklists is not acceptable. For example, “takeoff power” can mean either to advance the power or to retard the power.

5.10 SEQUENCING NORMAL CHECKLIST AND OTHER CHECKLISTS

Normal checklist items may be incorporated in non-normal or emergency checklists to simplify cockpit management. An acceptable alternative method is to require both the normal and non-normal or emergency checklists to be accomplished in a specified sequence. This method has the advantage of allowing the normal checklist to be requested and accomplished at the time that it would normally be accomplished. Checklists should be designed so that two checklists are not in progress simultaneously. The method may depend on the degree of sophistication of the airplane involved. In technologically advanced aircraft with short, simple checklists, it is usually preferable to keep the normal and the non-normal checklists separate. Some non-normal checklist actions may be deferred until initiation of the appropriate normal checklist. In airplanes with electronic checklists, checklists may be combined based on the priority of any one action, and/or the deferred non-normal checklist items may be automatically inserted in the appropriate normal checklist. In older airplanes, however, it may be necessary to add the normal checklist items to the non-normal or emergency checklist simply to keep the checklist manageable.

5.11 CHECKLIST FORMAT

POIs shall ensure that operators present checklists to flightcrews in a practical and usable format. POIs should use the following guidance when evaluating aircraft checklists for proper format.

I. Paper checklists should be protected either by plastic lamination or by being printed on heavy, folded pasteboard stock.

II. Non-normal, alternate, and emergency checklists must be in a format that allows crewmembers to quickly and accurately find the correct procedure while the crewmember is under stress. To expedite the referencing of these checklists, a tabbed manual or other quick reference format is recommended. When a paper checklist is required on the airplane, the methods used in an electronic checklist and the associated paper checklist for referencing a particular checklist shall be sufficiently similar to minimize flightcrew confusion or inappropriate flightcrew response. The methods for accessing electronic checklists may determine the format used to reference checklists in the paper version.

III. For single-pilot aircraft, the before-takeoff checklist and before-landing checklist can be appropriately presented as placards on the instrument panel.

The type size and contrast used on a checklist is a compromise. A large type size is preferred for legibility. A small type size is preferred to keep the number of checklist pages to a minimum, which then further ease the locating of a specific checklist. The legibility of printed material depends on the size of the letters, the spacing between letters, and the type of font used. The following is offered as a suggestion to POIs for what to consider in evaluating the legibility of checklists. This guidance must not be interpreted as being the only acceptable print size and contrast that can be used for checklists:

- Checklist headings or titles—12 point type, all caps, boldface, and a plain (sans serif) font

- Checklist text (challenge and response) and notes—10 point type, boldface, and a plain (sans serif) font
- Contrast for headings or titles—either black print on white or reversed for emphasis
- Contrast for text—black print on white
- Colored borders for ease of identification—green for normal checklists, yellow for non-normal checklists, and red for emergency checklists

NOTE: On airplanes with electronic checklists, these selections should be consistent with the display and symbology standards used by that system.

6 HUMAN FACTOR ASPECTS WHILE DESIGING A PROCEDURE

This chapter briefly explains Human Factor Engineering and considerations for civil aircraft flight design. Pilots, Mechanics, air traffic service personnel, designers, dispatchers, and many others are the basis for successful operations. There are many incidents caused by failing to adequately address human factor in the design and operations of these systems. This chapter elaborates on various human factor aspects which are essential to understand and should be considered while designing a procedures according to Abbott (2001)[21].

6.1 HUMAN FACTORS ENGINEERING

Human capabilities and limitations can be categorized in many ways, with one example being SHEL model. This describes the components *Software, Hardware, Environment*, and *Livewire*. The canter of the model is the human, or *Liveware*. This is the hub of Human Factors. It is the most valuable and most flexible component of the system. However, the human is subject to many limitations, which are now predictable in general terms. The "edges" of this component are not simple or straight, and it may be said that the other components must be carefully matched to them to avoid stress in the system and suboptimal performance. To achieve this matching, it is important to understand the characteristics of this component:

PHYSICAL SIZE AND SHAPE

In the design of most equipment, body measurements and movement are important to consider at an early stage. There are significant differences among individuals, and the population to be considered must be defined. Data to make design decisions in this area can be found in anthropometry and biomechanics.

FUEL REQUIREMENTS

[21] Dr. Kathy Abbott has over 30 years of experience specializing in aviation human factors. Dr. Abbott came to the FAA from the National Aeronautics and Space Administration (NASA). At NASA she led analytical, simulation, and flight studies with the specific objective of improving aviation safety and operational efficiency. She also co-chaired the FAA Human Factors Study Team that was chartered to address safety issues associated with crew interfaces with modern "glass" flight decks.

The human needs fuel (e.g., food, water, and oxygen) to function properly. Deficiencies can affect performance and well-being. This type of data is available from physiology and biology.

INPUT CHARACTERISTICS

The human has a variety of means for gathering input about the world around him or her. Light, sound, smell, taste, heat, movement, and touch are different forms of information perceived by the human operator; for effective communication between a system and the human operator, this information must be understood to be adequately considered in design. This knowledge is available from biology and physiology.

INFORMATION PROCESSING

Understanding how the human operator processes the information received is another key aspect of successful design. Poor human-machine interface or system design that does not adequately consider the capabilities and limitations of the human information processing system can strongly affect the effectiveness of the system. Short- and long-term memory limitations are factors, as are the cognitive processing and decision-making processes used. Many human errors can be traced to this area. Psychology, especially cognitive psychology, is a major source of data for this area.

OUTPUT CHARACTERISTICS

Once information is sensed and processed, messages are sent to the muscles and a feedback system helps to control their actions. Information about the kinds of forces that can be applied and the acceptable direction of controls are important in design decisions. As another example, speech characteristics are important in the design of voice communication systems. Biomechanics and physiology provide this type of information.

ENVIRONMENTAL TOLERANCES

People, like equipment, are designed to function effectively only within a narrow range of environmental conditions such as temperature, pressure, noise, humidity, time of day, light, and darkness. Variations in these conditions can all be reflected in performance. A boring or stressful working environment can also affect performance. Physiology, biology, and psychology all provide relevant information on these environmental effects.

USABILITY

The usability of a system is very pertinent to its acceptability by users; therefore, it is a key element to the success of a design. Usability has multiple components:

- ✓ Learnability: the system should be easy to learn.
- ✓ Efficiency: the system should be efficient to use.
- ✓ Memorability: the system should be easy to remember.
- ✓ Error: the system should be designed so that users make few errors during use of the system, and can easily recover from those they do make.
- ✓ Satisfaction: the system should be pleasant to use, so users are subjectively satisfied when using it.

WORKLOAD

In the context of the commercial flight deck, workload is a multidimensional concept consisting of:

(1) the duties, amount of work, or number of tasks that a flight crew member must accomplish; (2) the duties of the flight crew member with respect to a particular time interval during which those duties must be accomplished; and/or (3) the subjective experience of the flight crew member while performing those duties in a particular mission context.

Workload may be either physical or mental. Both overload (high workload, potentially resulting in actions being skipped or executed incorrectly or incompletely) and underload (low workload, leading to inattention and complacency) are worthy of attention when considering the effect of design on human-machine performance.

STRESS

This is one of the essential contributor to Human error. According to Burian (2006) there are few highlights that limit the human performance capabilities under high stress and workload. These affect, working performance on the long run, decreases prospective memory and mental computations, reduce correct judgment and decision making, narrowing visual and auditory processing attention, ability to shift mental sets and yields to poor differential diagnosis of situation.

SITUATION AWARENESS

This can be viewed as the perception on the part of a flight crew member of all the relevant pieces of information in both the flight deck and the external environment, the comprehension of their effects on the current mission status, and the projection of the values of these pieces of information (and their effect on the mission) into the near future. Situation awareness has been cited as an issue in many incidents and accidents, and can be considered as important as workload. As part of the design process, the pilot's information requirements must be identified, and the information display must be designed to ensure adequate situation awareness. Although the information is available in the flight deck, it may not be in a form that is directly usable by the pilot, and therefore of little value. Another area that is being increasingly recognized as important is the topic of organizational processes, policies and practices. It has become apparent that the influence of these organizational aspects is a significant, if latent, contributor to potential vulnerabilities in design and operations.

6.2 FLIGHT DESIGN PHILOSOPHY

Each airplane manufacturer has a different philosophy regarding the implementation and use of automation. Airbus and Boeing are probably the best-known for having different flight deck design philosophies. However, there is general agreement that the flight crew is and will remain ultimately responsible for the safety of the airplane they are operating.

Airbus has described its automation philosophy as:

- ✓ Automation must not reduce overall aircraft reliability; it should enhance aircraft and systems safety, efficiency, and economy.
- ✓ Automation must not lead the aircraft out of the safe flight envelope and it should maintain the aircraft within the normal flight envelope.
- ✓ Automation should allow the operator to use the safe flight envelope to its full extent, should this be necessary due to extraordinary circumstances.
- ✓ Within the normal flight envelope, the automation must not work against operator inputs, except when absolutely necessary for safety.

Boeing has described its philosophy as follows:

- ✓ The pilot is the final authority for the operation of the airplane.
- ✓ Both crew members are ultimately responsible for the safe conduct of the flight.
- ✓ Flight crew tasks, in order of priority, are safety, passenger comfort, and efficiency.
- ✓ Design for crew operations based on pilot's past training and operational experience.
- ✓ Design systems to be error tolerant.
- ✓ The hierarchy of design alternatives is simplicity, redundancy, and automation.
- ✓ Apply automation as a tool to aid, not replace, the pilot.
- ✓ Address fundamental human strengths, limitations, and individual differences for both normal
- ✓ and non-normal operations.

- ✓ Use new technologies and functional capabilities only when:
- ✓ They result in clear and distinct operational or efficiency advantages, and
- ✓ There is no adverse effect to the human-machine interface.

STANDARDIZATION

Generally, across manufacturers, there is a great deal of variation in existing flight deck systems design, training, and operation. Because pilots often operate different aircraft types, or similar aircraft with different equipage, at different points in time, another way to avoid or reduce errors is standardization of equipment, actions, and other areas.

It is not realistic (or even desirable) to think that complete standardization of existing aircraft will occur. However, for the sake of the flight crews who fly these aircraft, appropriate standardization of new systems/technology/operational concepts should be pursued, as discussed below.
Appropriate standardization of procedures/actions, system layout, displays, colour
philosophy, etc. is
generally desirable, because it has several potential advantages, including:

- ✓ Reducing potential for crew error/confusion due to negative transfer of learning from one aircraft to another;
- ✓ Reducing training costs, because you only need to train once; and
- ✓ Reducing equipment costs because of reduced part numbers, inventory, etc.

A clear example of standardization in design and operation is the Airbus A320/330/340 commonality of flight deck and handling qualities. This has advantages of reduced training and enabling pilots to easily fly more than one airplane type.

ERROR MANAGEMENT

Human error, especially flight crew error, is a recurring theme and continues to be cited as a primary factor in a majority of aviation accidents. It is becoming increasingly recognized that this issue must be taken on in a systematic way, or it may prove difficult to make advances in operations and safety improvements. However, it is also important to recognize that human error is also a normal by-product of human behaviour, and most errors in aviation do not have safety consequences. Therefore, it is important for the aviation community to recognize that error cannot be completely prevented and that the focus should be on error management. Human error can be distinguished into two basic categories: (a) those which presume the intention
is correct, but the action is incorrect, (including ***slips*** and ***lapses***), and (b) those in which the intention is wrong (including ***mistakes*** and ***violations***). ***Slips*** are where one or more incorrect actions are performed, such as in a substitution or insertion of an inappropriate action into a sequence that was

otherwise good. An example would be setting the wrong altitude into the mode selector panel, even when the pilot knew the correct altitude and intended to enter it.

Lapses are the omission of one or more steps of a sequence. For example, missing one or more items in a checklist that has been interrupted by a radio call.
Mistakes are errors where the human did what he or she intended, but the planned action was incorrect. Usually mistakes are the result of an incorrect diagnosis of a problem or a failure to understand the exact nature of the current situation. The plan of action thus derived may contain very inappropriate behaviours and may also totally fail to rectify a problem. For example, a mistake would be shutting down the wrong engine as a result of an incorrect diagnosis of a set of symptoms.
Violations are the failure to follow established procedures or performance of actions that are generally forbidden. Violations are generally deliberate (and often well-meaning), though an argument can be made that some violation cases can be inadvertent. An example of a violation is continuing on with a landing even when weather minima have not been met before final approach. It should be mentioned that a "violation" error may not necessarily be in violation of a regulation or other legal requirement.
There are a number of actions that should be taken with respect to dealing with error, some of them in the design process:

Stop the blame; that inhibits in-depth addressing of human error, while appropriately acknowledging the need for individual and organizational responsibility for safety consequences. The issue of blaming the pilot for errors has many consequences, and provides a disincentive to report errors.

Evaluate errors in accident and incident analyses; In many accident analyses, the reason an error is made is not addressed. This typically happens because the data are not available. However, to the extent possible with the data available, the types of errors and reasons for them should be addressed as part of the accident investigation.

Develop a better understanding of error management tasks and skills; that can support better performance of those tasks.
This includes:

- Preventing as many errors as possible through design, training, procedures, proficiency, and any other intervention mechanism;
- Recognizing that it is impossible to prevent all errors, although it is certainly important to prevent as many as possible; and
- Addressing the need for error management, with a goal of error tolerance in design, training, and procedures.

6.3 HOW TO DESIGN A CHECKLIST

Golden Requirements in order to design a checklist[22] according to human factor Engineering.

Note: The procedures should be understandable, actionable and auditable. They are understood to be mandatory, relate to realistic situation and completely prioritized.

Procedure Checklist	**Remarks**
Has the audience for the checklists determined?	
Has the process defined and scoped out?	
Have all units necessary to be in the checklist determined?	
Has it determined who will do which task?	
Has it determined who is responsible for completing each task?	
Has it determined output resulting from the task?	
Has it determined the time necessary to completing each task?	
Has it determined who verifies completion of the task?	
Has it determined what information needs to be collected?	
Has it determined how information needs to be used?	
Has it determined who information should be documented en presented to users?	
Has it determined any special resources required?	
Has it identified any training requirements?	
Has it determined the key tasks?	
Has it organized and prioritized information?	

[22] Eurocontrol [Internal EASA source, Retrieved February, 2012]

7 DISCUSSION & RECOMMENDATIONS

In the previous chapters; background, definitions and guidelines available to design normal/abnormal and emergency are provided. Also flight design philosophy, design requirements and human factor are extensively discussed.

It is important to point out that flight deck design should not occur in isolation. It is common to discuss the flight deck design separately from the flight crew qualification, considerations, and procedures. And yet, flight deck designs make many assumptions about the knowledge and skills of the pilots who are the intended operators of the vehicles. These assumptions should be explicitly identified as part of the design process, as should the assumptions about the procedures that will be used to operate the designed systems. Design should be conducted as part of an integrated, overall systems approach to ensuring safe, efficient, and effective operations (Abbott, 2001). Aircraft accidents have occurred in the past in which misuse of the checklist was a factor (Roos, 2004). These accidents may have been avoided if more emphasis had been placed on checklist during initial and recurring training. Checklists are an important aspect of aviation's system of safety backups. As more and more aircrafts becomes technologically sophisticated, checklists become even more important. Deviations from checklist can be caused by distractions, individualism, complacency, humour, fatigue and frustration. One way to minimize the effects of the above factors is to regularly and methodologically use a standard checklist routine.

Initiation and completing normal checklists in a timely manner is the most effective means of preventing the omission of actions or preventing inappropriate actions. Explicit calls should be defined in the SOPs for the interruption (hold) and resumption (continuation) of a normal checklist (i.e., in case of interruption or distraction). Also there are a significant number of issues representing a wide range of topics as discussed in aforementioned chapters that need to be considered when developing emergency and abnormal checklists for flight crews. There are so many factors inter-related and trade-offs between some will be required (Burian, 2006).

To provide a better understanding of the user view point a short questionnaire has been released via EASA towards ATP/CPL holder and manufactures (see appendix 5), unfortunately due to time restriction to prepare this paper a few replies were received. Thus, no valid scientific conclusion can be drawn from them but the received remarks are interesting to be reviewed.

The answers of JAR ATPL holders with an average of about 13117 of general flying hours to the question of whether do you consider the current normal/abnormal and emergency checklist provide adequate safety and efficiency is fairly positive, they also believe that some of these checklists are merely designed to please authorities and manufacturers than users.

They answered to the question whether by their opinion SOPs provided by operators and manufactures raise safety hazard concerns in various phase of the flight;

"Every phase of flight pilots are under pressure due to shortage of time and they need to react quickly to unpredicted situations".
"During approach (in TMA) at an outstation. Fatigue in combination with being unfamiliar with local procedures and often language barrier of local ATC may cause confusing situations. Also SOPs should provide the framework and not go too much into details. It is suggested to leave this for the pilots to judge in a particular situations".

Identification of possible safety hazard in the current abnormal/emergency checklists which should be taken more into consideration is answered as:

Some situations require use of multiple abnormal checklists. This can lead to confusion. Also, it is not always clear where to proceed in case of complicated failures (particularly when using paper checklists). Sufficient training and (technical) background knowledge should make pilots comfortable enough when handling complicated failures.

The most important factors which identified as distraction in the cockpit or caused to skip item(s) on the checklist for pilots, asked in the question 4 en 5 of the questionnaire are;1) Distraction coming from outside of the cockpit e.g. ATC, cabin crew, ground handling, radio calls, ramp people requests.2) Fatigue e.g. long flying hours 3) Confusion e.g. several failure alarm going off at a time, ambiguous checklist items.

The overall conclusion of the feedbacks received from operators to the questionnaire (see appendix 6) suggests that more emphasize on CRM training, implementing sterile cockpit e.g. under FL100. and procedural redundancy (double-checking) may mitigate the potential hazard situations related to checklists in the cockpit.

Since the pilot is in control and will continue to be so for at least foreseeable future, accommodation the human strength and limitations in conducting these procedures should be at heart of any checklist design. In short, checklists and cockpit procedures must be "human centred". It must be understood by all the parties or individuals while designing a cockpit checklist. But at the end, if the first officer chooses to not to use the checklist for any reason, no one should force him to use it (Degani, 1990).

The resilience of flight crews to deal with situations in which there is no specification, or underspecification, express itself through the need for them to extemporize, even invent procedures to accomplish multiple active goals simultaneously, and to manage the negative side effects of procedures. This sort of response is testimony to embellishment or increase of requisite variety that is necessary to meet situations that fall outside existing or even possible procedural guidance (van der ley, 2009).

In the end author concludes;

More investigation should be done on incorporation for the Flight Manual (FLM) into the Multi-Function Display (MFD), I-PAD solution in general[23]. There are also few concerns regarding replacement of paper checklist with electronic version, which are; redundancy, readability, reliability. i.e.:

- If for the future mix paper, electronic checklist documentations will be provided, which one is the master document?
- How the smart solution for the performance will be calculated (a hover chart of the FLM integrated on a MFD is unlikely usable).
- With the I-PAD solution the "Exterior checks "are feasible but with MFD solution are not.
- What would be the future of the checklists in the context of checklist error?

Boorman (2001) answers later question as follows: the fundamental role of checklists, to ensure that crew actions are accomplished at critical points in a flight, is likely to remain valid; and decreasing the chance of errors in the accomplishment of those actions will continue to benefit flight safety. Therefore, according to present findings, along with the very positive but non-scientific feedback from

[23] Eurocopter [Online source, retrieved, March 2012]

the user population, to draw the conclusion that ECL is and will continue to be an effective tool for prevention of accidents related to checklist errors.

In regard to use of normal checklist the following disciplines should be considered:

- Using the same terminology for the same checklist items on the different fleets.
- Adapted the same length of the checklists.
- Reduction of the items to the more safety relevant items.
- Removing the after landing checklist in order to avoid the first officer to be head down during taxi. This checklist can be performed after the runway is vacated or after arriving on the parking position together with the shutdown checklist.
- Improve and harmonise the checklist layout (i.e. two sided A4 plasticized paper)
- Usage of automated system had not reduces the level of basic airmanship skills required of an airline, it also does not reduces the training needs.
- Delegating few time consuming redundant pilot task to the aircraft on-board computer.
- Better training the pilot, more emphasis on CRM training.
- Reducing the workload at critical phase of the flight.

Human capability is vulnerable to errors by biological nature. Simply trying hard will not prevent errors (Dismukes, 2002). Interruptions, distractions, or preoccupations with one task to the detriment of another are found in nearly half of NTSB reports. Issue, may be management of attention rather than overload.

Highly practiced procedures vulnerable to omission when: Interrupted or performed outside normal sequence or context. Not to forget that these procedures become largely automatic; allows fast, smooth execution and requires minimal conscious supervision.

Avoid rushing procedures. Periodically review status and ask if anything is missing. It is recommended to emphasis on Error Management Training (Recognizing potential threats, Detecting errors, managing error outcome). Realize that error is inevitable, thus reduce the consequence of such errors.

Be aware that a disregard for SOPs is the common thread to aviation's. This cause for task management in the cockpit to prevent habit culture, A multiple demands atmosphere required in the cockpit which the tasks exceed conscious capacity of human automatic and also conscious processing.

Finally, today's aircraft are getting more and more sophisticated and along that more tasks are going to be added to the checklists. Therefore, using of ECL is inevitable. It is recommended that a separate research to be conducted on implementing/usage and potential expansion of ECL. It is obvious that ECL is going to replace the paper checklist in the future but the questions would be;1)how we can use the ECL in order to reduce the pilot workload, reduce confusion and improve the flight safety?2)how reliable is ECL? CAP708 (UK, 2006) is a valuable document can be used as a reference. At the end, the interaction between checklist, humans, machine, and the operational environment, makes the checklist issues a true human factor. The Human factor is still an uncharted territory and should be considered when a checklist is designed. Undermining this, will often ends disastrously.

BIBLIOGRAPHY

AAIB United Kingdom. (2009). *Occurance Bulleting EW/G2008/10/08, Airbus A330 at Montego Bay, Jamaica.* UK.

AAIB United Kingdom. (2009). *Occurance Bulleting EW/G2008/12/05, Boeing 767 at Menchester.* UK.

Abbott, K. H. (2001). *Human Factors Engineering and Flight Deck Design.* USA: CRC Press LLC.

Airbus Customer Service; Flight Operations Support and Line Assistance. (2004, April). Flight Operations Briefing Notes. Blanga Cedex, France.

Australian Transport Safety Bureau. (2009). *Tail Strike and Runway Overrun; Melbourne Airport, Victoria; 20 March 2009; Report AO-2009-012.* Australia.

Australian Transport Safety Bureau. (2011). *Stickshaker Activation, Kalgoorlie Airport, Western Australia 13 October 2010,Report A0-2010-81.* Australia.

Boorman, D. (2000). Reducing Flight Crew Errors and Minimiazing New Error Modes with Electronic Checklists. Seatle, USA.

Boorman, D. (2001). *Safety Benefits of Electronic Checklists: an Analysis of Commercial Transport Accidents.* Seatle, Washinton, USA.

Burian, B. K. (2006). *Design Guidance for Emegency and Abnormal Checklists in Aviation.* USA: San Jose State University at NASA Ames Research Center.

Comisón de Investigación de Accidents e Incidentes de Aviatión Civil. (2008). *Accident involving a McDonnell Douglas DC-9-82 (MD-82), EC-HFP at Madrid-Barajas Airport, 20 August 2008, Report A-032/2008.* Madrid, Spain.

Degani, A., & Wiener, E. L. (1990). *Human Factors of Flight-Deck Checklists: The Normal Checklist.* NASA Ames Research Center. Moffett Field, CA, USA: NASA Contractor Report 177549.

Degani, A., & Wiener, E. L. (1993). *Cockpit Checklists: Concepts, Design and Use.* San Jose, CA, USA: Human Factors 35(2).

Degani, A., & Wiener, E. L. (1994). *Philosophy, Policies, Procedures and Practices: The Four 'P's of Flight Deck Operation.* Hants, Engeland: Avebury Technical: Aviation Psychology in Practice (pp. 44-67).

Degani, A., & Wiener, E. L. (1997). *Procedures in Complex Systems: The Airline Cockpit.* San Jose, CA, USA: IEEE Transactions on Systems, Man, and Cybernetcis, SMC-27(3).

Degani, A., & Wiener, E. L. (1998). *Design and Operation Aspects of Flight-Deck Procedures.* Montreal, Canada: Proceeding of the International Air Transport Association (IATA) Annual Meeting.

Dismukes, K. (2002). *Lessons from Aviation: Memory, Skilled Human Preformance,m and All-too-human Error.* USA: NASA Ames Research Center.

Dismukes, K., Young, G., & Sumwalt, R. (1998, December). *Cockpit Interruptions and Distractions.* Opgeroepen op March 14, 2012, van NASA: http://asrs.arc.nasa.gov/publications/directline/d110_distract.htm

Federal Aviation Administration. (2007). *Volume 3 General Technical Administration; Manuals, Procedures, and Checklists for 14 CFR, Part 91K, 121, 125, and 135.* 8900.1. CHG 0, USA.

Lely, E. v. (2009). *What makes an Aircrew Resilient in Wake of Procedural Under-Specification?* Lund University School, Sweden.

NTSB United States. (2004). *Occurance Report CHI00LA116 at Decatur, Illinois.* USA.

NTSB United States. (2008). *Occurance Report FTW01LA166 at Decatur, Texas on 20 July 2001.* USA.

Oraldy, H. W., & Wheeler, W. A. (1989). *Training for Advanced Cockpit Technology Aircraft.* UAS: Aviation Safety Reporting System Office.

Rosenthal, L. J., Chamberlin, R. W., & Matchette, R. D. (1993). *Confusion on The Flight-Deck.* CA, USA: Aviation Safety Reporting System.

Ross, P. (2004). *Human Factors Issues of the Aircraft Checklist.* Pepperdine University of California, USA.

Royal Aeronautical Society. (2010). *Qantas 32.* Opgeroepen op March 16, 2012, van Aero Society Channel: http:\\www.aerosocietychannel.com/aerospace-insight/2010/12/exclusive-gantas-qf32-flight-from-the-cockpit/

Sweden Civil Aviation Authority. (2008). *Occurance Report LFH 2004-1750 at Skräckskär-Häradsskär,E Län on 18 September 2004.* Sweden.

Sweden Civil Aviation Authority. (2010). *Accident Report: Fuel Starvation, Autorotation at Broby Sateri, Katringeholm on 22 March 2007, Report LFH 2007-0630.* Stockholm, Sweden.

The Swedish Accident Investigation Board. (2010). *Accident to aircraft SE-GBL at Gothenburg City Airport, 6 july 2009, Report RL 2010:06e.* Stockholm, Sweden.

UK Civil Aviation Authority. (2005). *CAP 708: a Guidance on the Design, Presentation and Use of Electronic Checklists.* London, England: CAA Safety Regulation Group.

UK Civil Aviation Authority. (2006). *CAP 676: a Guidance on the Design, Presentation and Use of Emergency and Abnormal Checklists.* London, England: CAA Safety Regulation Group.

Willhauck, R. (2011, April). Future of The Checklist Become More Electronic. Europcopter.

APPENDIX 1 GUIDANCE MATERIALS

This section provides some guidelines about how to design checklist, i.e. normal/abnormal & emergency, and operating procedures to manufactures, operators, pilots, CAAs, trainers. This references CAP 676.

GUIDANCE FOR MANUFACTURERS

The manufacturer is required, in accordance with the aircraft certification requirements for each aircraft type, to provide procedures, which will allow the flight deck crew to deal with emergency and abnormal situations. These are defined within the approved AFM. Further procedures may also be provided in documents such as the FOM. The drills contained within the operator's checklists should not vary, in terms of functional content, from the approved AFM procedures but may be required to be translated into operational terminology and may need to be expanded to cover relevant failure situations.

CHECKLIST PHILOSOPHY

In order to ensure consistency within the checklist procedures and across the manufacturer's aircraft types and variants, a philosophy document should be produced. This should cover the style guides used in the production of the checklists and include the approach to layout, presentation, colour, philosophy, coding principles and overall document characteristics in terms of size and form. Additionally include a discussion of the intended meaning of statements such as "Land as soon as possible" or "Land as soon as practicable" or "Land at nearest suitable alternate" in the philosophy document.

NOTE: The Emergency and Abnormal Checklist is a tool to assist the crew in achieving the goals of safe flight. It need not include "airmanship" issues.

STOWAGE

The Emergency and Abnormal Checklist documents should be capable of being stowed in a readily accessible location. Consideration should also be given to the proximity of food and drink containers on the flight deck and the likelihood of spillages. The checklist documents should be protected from such spillages in order to remain usable afterwards.

DESIGN PROCESS

The manufacturer will determine the emergency and abnormal situations, which need to be included in the Emergency and Abnormal Checklist. This should be consistent with the AFM and FCOM. This guidance identifies the steps involved in designing, validating and implementing the checklist procedures.

- **IDENTIFY THE ENGINEERING SOLUTION TO THE PROBLEM**

This should be carried out in consultation with the specialist engineers for the relevant systems involved.
Ensure that all possible conditions associated with the fault have been captured.

- Identify all performance data required.
- Identify consequences associated with resultant system or aircraft performance.
- Ensure that the relevant steps in the drill have been identified.
- Establish any actions which require cautions regarding the implication of that action.

➢ TRANSLATE THE ENGINEERING DRILL INTO AN OPERATIONAL PROCEDURE

This should be carried out in consultation with flight crew familiar with the aircraft systems and human factors, maintenance and publications specialists familiar with the style guides.

- ✓ Define a clear and unambiguous title for the checklist.
- ✓ Establish any prerequisite information that needs to be included at the top of the checklist warnings, conditions, objectives, expected outcomes etc.
- ✓ Establish any memory or recall items associated with the checklist.
- ✓ Produce a layout of actions and notes in accordance with the style guide.
- ✓ Provide a clear indication when the drill has been completed where required.
- ✓ Provide a clear indication where navigation to other checklists is required.
- ✓ Establish actions which need to be deferred, and any performance consequences to the aircraft.

➢ VALIDATE THE DRILL

The validation of the new or updated checklist should be carried out by the designer of the checklist, in conjunction with other flight crew (preferably include some line pilots) and human factors, maintenance and publications specialists. It will involve trialling the checklist in a simulator under a range of operationally relevant conditions/ environments. The aim is to ensure that it is fit for purpose, takes account of other pilot tasks, is error-tolerant and can be carried out in the time required without imposing excessive workload.

- ✓ Establish the relevant fault triggers.
- ✓ Establish a range of operational scenarios.
- ✓ Monitor the time taken to complete the drill.
- ✓ Note any errors made or problems encountered.
- ✓ Debrief the crew and obtain comments and concerns.
- ✓ Update the checklist to address concerns.
- ✓ Repeat validation trials until the checklist design is deemed to be acceptable (minimised errors and acceptable workload).

➢ REVIEW THE DRILL

An independent review board, which may include safety specialists, technical specialists, technical pilots and human factors specialists, should review the checklist procedure, where appropriate, also representatives from the Regulatory Authority should be included.

- ✓ Demonstrate drill on simulator or show results from simulator trials.
- ✓ Demonstrate that airworthiness safety aspects have not been compromised through any actions or activities during the drill.
- ✓ Use Checklist Assessment Tool (Executive Summary to ensure good human factors principles have been adhered to.

FEEDBACK PROCESS

When operators experience difficulties in using the checklists, they should be encouraged to send information about the difficulty to the manufacturer who should facilitate this process by seeking feedback. Where for instance a UK operator believes that safety has been or could have been compromised, an Air Safety Report (ASR), or equivalent, should be raised and a Mandatory Occurrence Report (MOR) may be raised in accordance with CAP 382(UK). However the Operator feedback may also highlight problems with the manufacturer's style guide or design process, in which case these should be updated accordingly. The CAA tracks checklist-related MORs in order to monitor checklist-related safety issues. Manufacturers may request copies of checklist-related MORs for their aircraft types from the CAA as additional feedback.

GUIDACNE FOR OPERATORS

The operator is responsible for ensuring that the Emergency and Abnormal Checklists provided by the manufacturer are appropriate to their operation and do not compromise the safety of the aircraft. The operator is responsible for taking the necessary actions in rectifying all situations where problems with Emergency and Abnormal Checklists are identified. This guidance identifies the process by which this should be achieved.

It is the responsibility of operators to ensure that appropriate and current Emergency and Abnormal Checklists are placed on each aircraft.

It is the operators' responsibility to provide all flight crew with a set of OMs in order that they can adequately prepare for flight. This includes Emergency and Abnormal Checklists. A copy of the relevant QRH should therefore be made available to each flight crewmember or adequate copies should be provided in the company briefing room or library for private study.

The operator should establish a system of controlled documentation in relation to Emergency and Abnormal Checklists. An amendment number and date must be available on each page of the document. The amendment status, list of effective pages and other administrative items should be available in each document. Amendments should be incorporated as soon as reasonably practical. In the case of significant or important changes, a Flight Crew Notice or equivalent may be issued to ensure crew awareness.

CHECKLIST AMENDMENT PROCESS

1 REVIEW THE CHECKLISTS

This should be carried out by the Flight Operations Manager, Technical Pilot, Fleet Training Captain or their equivalent in conjunction with the Chief Pilot.

- ✓ Check that the procedures correspond to those laid down in the AFM.
- ✓ Check that the checklist meets the design attributes identified later on in this annex.
- ✓ Use Checklist Audit Tool (see Appendix 4) to ensure good human factors principles have been adhered to.
- ✓ Ideally, test the procedures in a flight simulator using line crew members where possible.

NOTE: If the procedure in the AFM requires amendment, this must be carried out by the manufacturer or other organisation approved to make such amendments prior to changing the checklist.

2 UPDATE OR REDESIGN THE DRILL

In the situation where the operator wishes to use the manufacturer's checklist, the operator will raise a problem report to the manufacturer requesting a change. In the situation where the operator wishes to update or redesign the layout of the checklist, the operator should produce a philosophy and procedures document similar to that described in Guidance for Manufacturers to ensure a consistent approach.

- ✓ Provide a clear and unambiguous title for the checklist.
- ✓ Establish any prerequisite information that needs to be included at the top of the checklist warnings, conditions, objectives and expected outcomes etc.
- ✓ Establish the memory or recall items associated with the checklist.
- ✓ Produce a layout of actions and notes in accordance with the style guide.
- ✓ Provide a clear indication when the drill has been completed in all places where this occurs throughout the checklist.
- ✓ Provide a clear indication where navigation to other checklists is required.
- ✓ Establish actions which need to be deferred and any performance consequences to the aircraft.

3 VALIDATE THE DRILL

Validation should be carried out in conjunction with experienced company pilots and preferably someone with appropriate human factors knowledge (the larger the change the more important it is to involve someone specifically trained in human factors). It may involve trialling the checklist in a simulator under a range of conditions. The purpose will be to ensure that it is fit for purpose, takes account of other pilot tasks, is error tolerant and can be carried out in the time required without imposing excessive workload.

- ✓ Establish the relevant fault triggers.
- ✓ Establish a range of scenarios covering varying contexts (e.g. landing gear problems may well only be discovered at the end of a flight when in busy airspace with time pressures due to fuel state, changing weather etc. The usability of the checklist should be considered in this context).
- ✓ Monitor the time taken to complete the drill.
- ✓ Note any errors made or problems encountered.
- ✓ Debrief the pilot and obtain comments and concerns.
- ✓ Update checklist to address concerns.
- ✓ Repeat validation trials until the checklist design is deemed to be acceptable (minimised errors and acceptable workload).

4 REVIEW THE CHECKLIST

Any changes to the checklist need to be accepted by the CAA. The operators' checklist amendment procedure should clearly identify the criteria for seeking manufacturers' input to the change if required and who is competent to make the judgments required.

- ✓ Demonstrate drill on simulator or show results from simulator trials.
- ✓ Demonstrate that airworthiness safety aspects have not been comprised through any actions or activities during the drill**.**
- ✓ Use Checklist Audit Tool (See Appendix 4) to ensure good human factors principles have been adhered to.

CHECKLIST MAINTENANCE

Manufacturers typically send amendments out every six months and it is the responsibility of the operator to ensure that the amendments are reviewed and distributed to the fleets.

- ✓ Checklist construction should enable pages or cards to be changed easily when amendments are necessary.
- ✓ Each checklist should contain a record of the amendment state of the checklist, ideally no more than one page.
- ✓ The amendment record page(s)/card(s) may be included in the checklist and should be differentiated from the pages/cards containing the drills.
- ✓ Each amended page/card should be dated (in small print).
- ✓ Worn or damaged checklists, or those with loose pages, should be replaced.

PROBLEM REPORTING AND INVESTIGATION

When a problem is encountered with a checklist the pilot will raise an MOR or company ASR. It is the responsibility of the operator to send the MOR or ASR to the following organisations:

- ✓ Manufacturer
- ✓ CAA

One method for investigating an event is as follows:

Step 1: Identify relevant procedures

List the checklists that should have been used following the event.

Step 2: Establish problems encountered

- ✓ Identify the difficulties encountered by the PF or PNF/PM.
- ✓ Identify the error condition, (e.g. completing the wrong checklist).
- ✓ Identify the sequence of procedural deviations.
- ✓ List all the contributory factors e.g. distractions, high workload etc.

Step 3: Recommend and Implement Changes (where appropriate)

- ✓ Identify improvements that could be made to the checklist, SOP or training to
- ✓ Prevent event from recurring.
- ✓ Work with manufacturers and CAA as required to implement changes.

PILOT TRAINING

It is the operators' responsibility to ensure that a satisfactory training plan approved by the CAA is in place. The frequency and content of the emergency and abnormal situations and procedures training must cover the requirements of JAR-OPS 1, 3 and JAR-FCL as applicable, and provide training for the pilot so that emergency and abnormal situations are recognised when they are encountered. Later in this appendix elaborates the required training philosophies. In addition, if it is known that a checklist has a fault or anomaly leading to common mistakes or confusion, then these faults and anomalies should not be 'trained around'. The operator should amend the procedure.

GUIDANCE FOR PILOTS

It is the responsibility of the pilots to ensure that they are familiar with the procedures laid out in the Emergency and Abnormal Checklists. It is both the commanders' and/or operators' responsibility to ensure that the checklists are on board before each flight. In addition, it is the pilots' responsibility to ensure that company SOPs are rigorously applied in the use of and execution of Emergency and Abnormal Checklists. Ultimately the captain will take all responsibilities for decisions on the flight deck which may include a veto of an SOP, if appropriate, in dealing with an emergency situation.

STANDARD OPERATING PROCEDURES

- ✓ The Pilot Flying (PF) should not be distracted from controlling the aircraft to perform a checklist item that another crew member can or should accomplish.
- ✓ The crew-member responsible for reading the checklist should ensure that it is completed systematically and expeditiously.
- ✓ In the situation of two or more crew aircraft, checklists would normally be accomplished by one crewmember reading the checklist item and performing the action and a second crewmember monitoring and verifying that the action is correct.
- ✓ In the situation of a critical procedural step (e.g. shutting down an engine) a positive confirmation must be made by the monitoring crewmember before any action is taken.
- ✓ Following an interruption in a checklist it is recommended that the actions already completed are re-verified.
- ✓ SOPs should take account of the crew's workload and their ability to complete Emergency and Abnormal Checklists in conjunction with other tasks (for example, if an emergency occurs during an approach SOPs should consider whether it is better to abandon the approach before dealing with the situation).
- ✓ A policy for the management of a situation where an action is deferred must be identified.

PROBLEM REPORTING

It is the responsibility of the pilot to raise ASRs when problems with Emergency and Abnormal Checklists are encountered. The pilots should be proactive in notifying the Company Flight Safety Officer of checklist design issues, which could be a factor contributory to an incident or accident in the future.

GUIDANCE FOR CAA

The CAA's responsibility lies mainly with acceptance of the Emergency and Abnormal Checklists as part of the suite of documents supporting aircraft operations.

REVIEW OF CHECKLISTS

The Flight Operations Inspector (FOI) as part of his OM review will look at the Emergency and Abnormal Checklists to confirm technical accuracy and that they are consistent with CAP 676 best practice guidance. The FOI should:

- ✓ Use Checklist Assessment Tool as guidance to review checklist against good human factors principles.
- ✓ Identify areas of poor checklist design which could contribute to errors being made.

It is important to recognise that many operations require a checklist to be tailored to their operation in some way. It is therefore the operators' responsibility to make the appropriate changes using this information as guidance and in consultation with the manufacturer as defined in their procedures.

INVESTIGATION OF INCIDENTS

When an incident is reported to the CAA where the checklist was an issue it is important to establish all the factors that contributed to the incident using a consistent method. Very often a checklist incident can be indicative of problems with the operators' SOPs or flight training programme and the investigation should not be limited to the physical checklist. Prime responsibility for investigating incidents lies with the operator, with the CAA reviewing and accepting the operators' investigation and subsequent actions.

ACCEPTANCE OF PILOT TRAINING PROGRAMMES

The CAA is responsible for review and acceptance of operators' pilot training programmes including training of checklist use and discipline.

GUIDANCE FOR TRAINERS

Trainers must be conversant with the philosophy, content and use of the Emergency and Abnormal Checklist in order to deliver effective training.

Training providers are responsible for ensuring that the training in the use of the Emergency and Abnormal Checklist is conducted using training aids appropriate to the task.

A training course should address the use of the Emergency and Abnormal Checklists in a progressive manner. The following system of training may be used:

- ✓ An introduction to the checklist philosophy and layout, conducted in a classroom.
- ✓ The use of cockpit ‘mock-ups’ to practice familiarity with cockpit layout.
- ✓ Practice of emergency and abnormal drills in a Flight Training Device.
- ✓ Practice of emergency and abnormal drills in a Full Flight Simulator.
- ✓ Practice of emergency and abnormal drills in a static aircraft.
- ✓ Practice of emergency and abnormal drills in-flight.

This training should be conducted at a pace conducive to learning. Such training should highlight the need for prioritisation, crew co-ordination, and other nontechnical skills.

The training plan should identify the training aids required to rehearse and learn the drills associated with a range of failures to achieve the required level of competency. This will include a description of the failure situations and the appropriate training device.

Training staff are in a unique position to see checklists being put into action. They are therefore able to identify shortcomings in checklist design and content. Where shortfalls are noted, trainers must feed the information back to the training organisation to enable appropriate corrective action to be taken.

CHECKLIST DESIGN RECOMMENDATIONS

This Chapter details the attributes that should be applied in the design of a checklist. They are not intended to be prescriptive and design solutions can meet the high level attributes in different ways. Examples are provided in Appendix 4 to reinforce the intended messages.
There have been many incidents where use of checklists has been a contributory factor and four such incidents are detailed in Chapter 1 to further reinforce the need for good human factors principles in the design of checklists. The key design driver is to ensure that the procedures can be carried out with minimum error to maintain the required level of airworthiness. This involves a clear process based upon HF principles. The table below outlines design approaches that could mitigate the risk of these types of errors occurring. Cross-referencing to the relevant paragraph later in this appendix is provided.

Table 2

Error Condition	**Possible Mitigation Design Solution**
Become Disorientated within checklist	Number items in list; Improve layout.
Complete the wrong checklist.	Provide index; provide checklist objective; provide a description of the failure conditions and any altering cues; provide a picture of the warning legend.
Difficult to find a checklist item.	Provide index; provide tabs.
Difficult to confirm checklist is correct.	Provide objective; provide emphasis where steps are similar in content.
Fail to complete a step after an interruption.	Provide numbers; interruptions policy contained within SOPs.
Difficult to understand checklist.	Provide system status information; provide notes.
Difficult to understand conditional statement.	Improve layout; clarify end of drills.
Difficult to read a checklist.	Increase font size; improve contrast.
Not sure what does what.	Indicate PF or PNF/PM.
Fail to complete a checklist.	Training; familiarisation.
Difficult to interpret information in checklist.	Improve layout; provide notes; provide system status information.
Crew not alerted to performance issues	Provide cautionary notes; provide system status information.

PHYSICAL CHARACTERISTICS OF EMERGENCY AND ABNORMAL CHECKLISTS

The checklist should not be a direct copy or photocopy of the AFM or FCOM or equivalent emergency and abnormal procedures. The presentation of the procedures should be appropriate for use in emergency or abnormal conditions. The Emergency and Abnormal Checklists should be differentiated clearly from normal checklists, ideally by a separate and self-contained `document', or contained in a QRH. Alternatively, emergency and abnormal drills may be contained in a separate section in the flight deck checklist as long as this section is clearly differentiated from the remainder of the document. The document should be robust enough to withstand normal handling by flight crew.

Size of Document

- ✓ The size of the document should be appropriate to the stowage space and workspace available.
- ✓ Consideration should be given in the use of the document in situ to avoid interference with controls or obscure the displays.
- ✓

Binding/Spine

- ✓ The binding should ideally allow pages to be opened through 360º, to enable pages to be folded back onto themselves.
- ✓ The binding should be such that all the text on a page/card can be read.
- ✓ The binding should allow for replacement pages to be inserted easily by hand whilst being secure enough to prevent pages becoming loose.
- ✓ Rugged spiral or ring side binding is recommended.

Cover

- ✓ The cover of the Emergency and Abnormal Checklist should be sufficiently robust to protect the pages or cards within.
- ✓ The cover should be of a suitable colour, to allow the document to be easily located and distinguished (from all angles) from other documents.
- ✓ The cover should be easily distinguishable (e.g. slightly larger) from the other pages/cards such that it is easy to find if the checklist has been folded open at a particular page.
- ✓ The title of the checklist and the aircraft to which the checklist is applicable should appear on the front of the cover and, where appropriate, the spine.
- ✓ If fleets of aircraft are at different states of modification the title should reflect the modification state.
- ✓ It is a design feature of many modern aircraft that places the drinks cup holder directly above the Emergency and Abnormal Checklist stowages. It is recommended that operators take steps to ensure that QRH checklists are protected from spillage thereby ensuring that they are readable when required. Laminated pages or clear plastic bags are frequently used.

Tabs and Dividers

- ✓ The use of tabs is recommended to assist in the location of specific drills or groups of drills associated with sub-systems.
- ✓ Tabs may utilise printed titles, numbers and/or colour to assist with this task, as long as the titles, numbering and/or colour usage is consistent throughout the document (and, ideally, consistent in checklist documents throughout the fleet).
- ✓ The index and the tabs should be clearly and logically linked. (See Appendix 3, Example 1).

- ✓ Tabs should be wide enough for a thumb to be placed upon them, without misreferencing. (See Appendix 3, Example 1).

Font Type

- ✓ Font types (such as Helvetica, Gill Medium or Arial), which have clear differentiation between characters are recommended.
- ✓ Sans serif fonts should be used (no tails).
- ✓ Font type should be consistent throughout the checklist.
- ✓ Use of lower case is recommended with upper case initial capitals; use of upper case for large blocks of text should be avoided (see Appendix 3, Example 6).
- ✓ Use of upper case for headings is desirable.
- ✓ Italics should not be used for drill actions. Use of italics for comments, notes, or supporting information is acceptable, although use of italics should be avoided for large blocks of text.

Print Size

The drill should be legible at 600 mm. The font size does vary between font types and sizes given in this paragraph are approximate based upon Arial font type.

- ✓ The recommended type size for headings is 14pt (with a minimum of 12pt).
- ✓ The recommended type size for normal text is 12pt (with a minimum of 10pt).
- ✓ A larger font size is recommended for smoke-related procedures (and those procedures which may follow on).
- ✓ Bold type may be used to improve legibility. Note: it may be more important for a drill to be contained on one page, in which case a type size smaller than 12pt may be appropriate (but no smaller than 10pt).

Margins

There should be a margin to permit:

a) Binding without hiding text; and
b) Holding the list using the thumb as cursor.

Emphasis and Differentiation

- ✓ Emphasis and differentiation may be required to highlight a particular challenge or response.
- ✓ Alternatively it could be used where the checklist contains two similar lines of text, which can contribute to missing a step. See example below where a pilot missed the main gear release handle action.

L/G ALTERNATE RELEASE DOOR	OPEN FULLY & LEAVE OPEN
MAIN GEAR RELEASE HANDLE	PULL FULLY DOWN
L/G ALTERNATE EXTENSION DOOR	OPEN FULLY & LEAVE OPEN
Insert pump handle and operate until main landing gear locks down.	

The presentation of the checklist can be improved by using numbers, lower case text and bolding the text:

1.	L/G alternate **release** door	open fully & leave open
2.	Main gear release handle	pull fully down
3.	L/G alternate **extension** door	open fully & leave open

- ✓ The following techniques provide effective methods of emphasising or differentiating information on a checklist. They should be used sparingly to maximise the effect:
- ✓ Bold type
- ✓ Larger type
- ✓ Underlining
- ✓ Boxing text on a white or coloured background

Contrast and Colour

- ✓ Black text on a yellow background is recommended, with black text on a white background as an acceptable alternative.
- ✓ Coloured text is not recommended because of difficulties in reading colours in some lighting conditions.
- ✓ Use of colour to describe the alerting cues is recommended where the colour is the same as the warning caption on the aircraft, see examples in Appendix 3.
- ✓ Pastel shading can be used effectively to discriminate specific items on the checklist e.g. memory items, deferred items, cautions, consequences but they should be used sparingly (see Appendix 3, Example 4).
- ✓ Pink or red pages are not recommended.
- ✓ If colour is used for tabs/borders to distinguish between an Emergency and Abnormal Checklist, red should be reserved for emergencies, and orange/amber for abnormal procedures.
- ✓ If the emergency and abnormal drills are contained in the main aircraft checklist document, the pages should be distinguished from the normal drills by red, yellow or yellow-and-black edging, in addition to a suitable divider or tab page.

Whichever of the above methods is chosen the ability to differentiate Normal, Emergency and Abnormal Checklists under night lighting conditions should be checked.

CONTENTS LIST AND INDEX

- ✓ The Emergency and Abnormal Checklist should have a tabbed contents list at the front (see Appendix 3, Example 1).
- ✓ The contents list should list the aircraft subsystems.
- ✓ The contents list should not exceed a single page, if possible.
- ✓ The contents list should follow the same order as the drills whether in alphabetical order or critical system failure order.
- ✓ The drills within each subsystem should be listed on the front of the relevant tab page. They may also be listed in the main contents list at the front of the checklist, if appropriate.
- ✓ Critical drills may be highlighted in bold to aid recognition e.g. Fire and Smoke.
- ✓ Clear delineation of systems should be shown (e.g. by a line or colour) linking each system to the relevant tab (see Appendix 3, Example 1).
- ✓ The contents list page must be easy to access when the checklist document is folded back onto itself.

If the Emergency and Abnormal Checklists form part of the main flight deck checklist, the contents list for the emergency and abnormal procedures should be:

- ✓ at the front of the document; and
- ✓ On the tab or divider which separates the two parts of the normal checks from the emergency/abnormal drills.
- ✓ An alphabetical index, as well as a contents list, is desirable. This should guide the user to the correct drill (e.g. \`engine fire' should be listed under both \`engine' and \`fire' in the index). This could be located near the back of the checklist or after the main contents list page.

Page Numbering

- ✓ All pages should be numbered consistently, including tab pages. If a page is blank it should have 'INTENTIONALLY BLANK' printed on it.
- ✓ Pages should be numbered within each section, starting at page 0 (for the tab page).
- ✓ Where tabs are numbered the page numbering should correspond to the tab number. E.g. Tab 06 Engines and APU failures page numbers should be 06-01, 06-02 etc.
- ✓ The number should be clearly presented at the top or bottom of the page.
- ✓ Large font should be used for page numbers.
- ✓ The dedicated page numbering is to ensure that the correct page can be located from the index and that the correct pages are replaced when the checklist is updated.

Action Numbering

- ✓ The actions in the drill may be numbered consecutively as an aid to place keeping
- ✓ and a means of distinguishing the action items.

RECOMMENDED CONTENTS LIST FOR EMERGENCY AND ABNORMAL CHECKLISTS

Structure

The checklist must be adequately structured to take account of fuel, time and environment. Landing gear abnormal situation more often than not occurs during low fuel states.

- ✓ Ensure that the number of operations required in a drill is kept to a minimum in time or fuel critical situations.
- ✓ Avoid diagnostic actions that attempt to eliminate the source of the problem when smoke conditions pervade.

Checklist Layout Instructions

Philosophy notes should be provided to identify the coding philosophies used in the checklist. This should include any shape, position or colour coding used. The notes should also include all presentation items such as decision points, continuation overleaf indication etc. They should also include definitions of terminology where appropriate e.g. explain the differences between 'land as soon as possible' and land as soon as practicable'. The notes may either form part of the checklist or be provided as part of the aircraft documentation suite. The checklist must be a controlled document with the appropriate date and amendment status and/or list of effective pages clearly visible. Ideally, a statement that this publication forms part of the operator's OM should be included. Any changes to the checklist drills from the last amendment should be highlighted in
the margins e.g. some operators use a short vertical line (change bar).

Title

The title should be displayed at the start of each drill. It must be meaningful and reflect the error condition. It must be prominently displayed and be clearly distinguishable from the action items and notes on the drill, see (Appendix 3, Example 2).

Failure Condition

A short explanation, if required, of the symptoms associated with that drill provides confirmation that the correct drill has been selected. The list of symptoms should be clearly differentiated from the subsequent list of actions and notes. The alerting cues may be included as shown in the example below (see Appendix 3, Examples 2 and 4). A picture of the alert caption provides a powerful means of correct checklist confirmation (see Appendix 3, Examples 2 and 4).

NOTE: If the alerting cues could also be symptomatic of another failure condition an explanatory note may be required.

Objective

A short narrative, if required, explaining the expected outcome of the drill provides further confirmation that the correct drill has been selected and provides expectations for the Pilot (see Appendix 3, Example 4). This should be displayed below the title and be clearly distinguished from the action items.

Memory Items

Memory or Recall items are actions that are carried out immediately following the onset of a failure situation. They relate to situations where the safety of the aircraft is compromised. Pilots are trained to memorise the immediate actions and carry them out without reference to the checklist. However under stressful conditions memory recall can be poor and error-prone therefore they should be strictly limited to only those actions necessary to stabilise the situation.

- ✓ Memory items should normally be at the start of a drill.
- ✓ Memory items should clearly be indicated, e.g. by colour shading, or by `boxing'.

An explanation in the OM or Philosophy Notes showing how these memory items are indicated should be included.

- ✓ The number of steps in a memory item should be kept to a minimum (preferably fewer than four and certainly no more than six for multi-crew operations; single pilot operations may require a greater number of steps).
- ✓ Simple mnemonics can be used as an aid.

Cautionary Notes

Cautionary Notes have associated performance implications. They must occur before the related action. Cautionary Notes should be differentiated from other notes either by colour shading, textual highlighting and/or use of the word caution.

Action Items

- ✓ The action items should take the form of 'do' lists, in the 'read-do ' format, with the action required at the left and the required execution response or status on the right (right justified).
- ✓ Responses to actions should be full, specific and unequivocal.
- ✓ The action and response should be clearly associated, ideally by dots or dashes (a suggested density is one dot/dash per 6mm) (see Appendix 3, Example 2 and 4).
- ✓ Action items should be clearly distinguished from explanatory notes.
- ✓ Critical actions which require a positive verification from the monitoring crewmember should be discriminated in some manner (e.g. font size, bold font etc.).

Explanatory Notes

- ✓ Explanatory Notes are required where the action has some unusual characteristic, e.g. a lever may have two detents, a long delay on activation, or require a high force to operate.
- ✓ Explanatory Notes should be clear, concise and succinct.
- ✓ Explanatory Notes should be clearly linked, by position on the checklist, to the action items to which they relate.
- ✓ They should be clearly differentiated from the action items. The following techniques are suggested as a means of differentiation:
- ✓ Italics
- ✓ Colour shading
- ✓ Font size.

Decision Items

- ✓ Complicated decision items should be avoided, particularly those with embedded items.
- ✓ The following techniques can be used effectively to deal with decision choices:
- ✓ Different style of bullets.
- ✓ Choice directive (e.g. ‘choose one’).
- ✓ Highlight choices using underline.
- ✓ Margin lines if used, should be on the opposite side to change bars.
- ✓ Indent to group items together.

LOSS OF BOTH ENGINE DRIVEN GENERATORS

Condition All TRANSFER BUS OFF, BUS OFF and GEN OFF BUS lights illuminated indicating the loss of both engine driven generators.

Objective: To restore Generator Power

⇒ **Memory item 1**
⇒ **Memory item 2**
⇒ **Memory item 3**

> **Caution** With both buses off only one start attempt is recommended

➢ if **both** BUS OFF Lights remain illuminated then:

- <u>Action item 1</u>
- <u>Action item 2</u>
- <u>Action item 3</u>

➢ if **either** or both BUS OFF Lights extinguish then:

- <u>Action item 1</u>
- <u>Action item 2</u>
- <u>Action item 3</u>

> <u>**Note**: If the APU is the only operating generator connect it to the No 2 bus as it will power TR no 3</u>

<u>**Land as soon as possible**</u>

REVIEW OF SYSTEM STATUS FOLLOWING COMPLETION OF CHECKLIST

It is helpful to provide a review of system status and considerations of operational effects after equipment failure and completion of checklist items. This may include a set of performance limitations and constraints or provide a list of alternative operative systems. Such guidance should be clearly distinguished and would normally be tabulated in a manner similar to the example shown in Appendix 3, Example 5.

Deferred Items

Deferred items are those items which need to be carried out at a later phase of flight. They will be at the end of the checklist and should be clearly labelled as "deferred items" (see Appendix 3, Example 4). Consider the following:

- ✓ Grouping according to phase of flight.
- ✓ Grouping according to operational environment e.g. low visibility operations.
- ✓ Deferred items should have sufficient information to avoid any risk of ambiguity and promote understanding.

Crew Responsible

If appropriate, in the event of a complex procedure (and particularly with a three person crew), an indication should be given in the checklist or SOPs as to whose responsibility it is to respond to any challenge.

LAYOUT AND FORMAT

Drills per Page

- ✓ The number of drills per page depends upon the length of the drill and multiple drills per page are acceptable provided the start and finish of each drill are clearly identified.
- ✓ If a drill is too long to fit onto one page, it should be separated into logical sections where each section is contained within a page.
- ✓ If a drill runs onto a second (or further page) it must be clearly marked as incomplete and requiring to be continued (see Appendix 3 Example 4).

Start and Finish

Drills must have a clearly defined start and finish:

- ✓ The start of the drill will be indicated by a clearly defined and meaningful title.
- ✓ The end of the drill will be indicated by either an 'end of drill' statement or graphical symbol indicating completion (see Appendix 3, Example 2 and 4).
- ✓ Completion of a drill could occur in several places within a drill and these must all be clearly defined (see Appendix 3, Example 2).
- ✓ A completion call should be clearly defined by company SOPs.

Continuation Pages

Drills must clearly show when a drill continues onto another page:

- ✓ A clear indication should be provided at the bottom of the page.
- ✓ A clear indication should be provided at the top of a continued page together with drill title (see Appendix 3, Example 5).

Order

The following order is suggested:

- ✓ If not otherwise specified in the AFM or FCOM for reasons of priority emergency selection, actions or checks within a drill should be listed in a flow pattern (logical/ functional flow, or `geographical' flow, i.e. listed according to the physical location of the instrument in the cockpit (e.g. left-to-right or right-to-left).
- ✓ Long procedures should be separated, where possible, into short groups of
- ✓ logically or geographically related steps.

CROSS-REFERENCING

Cross-referencing should be minimised where possible. If steps need to be repeated within a drill then they should be duplicated. Internal cross-referencing should be used if drills become too lengthy to handle.

Internal to Drill

- ✓ When using cross-referencing within a drill it is strongly recommended that the action steps be numbered to ensure that the instruction is clear and unambiguous.
- ✓ When cross-referencing, be clear about the bounds of the instruction e.g. 'carry out steps 3 to 6'.

External to Drill

Where reference to explanatory material is required, the relevant page number and title of the expanded checklist should be given.
When a drill is complete but requires another to follow on then the appropriate checklist title, tab and page number, where possible, must be clearly stated.

Figures and Tables

If figures, tables or graphs are to be included, they should be clearly linked to the drill(s) with which they are associated.
Tables or graphs reproduced from AFMs should be legible and usable (see Appendix 3, Example 3).

Abbreviations, Phraseology and Consistency

- ✓ Drills should use no more words than required to ensure that drills are understandable and unambiguous. However excessive brevity can result in drills taking longer to read and understand.
- ✓ Phraseology should be straightforward and in standard aviation terms.

- ✓ Abbreviations other than the ampersand (&) should be avoided. However, if these are to be used, they must be standardised and clearly explained either in the Emergency and Abnormal Checklist document or in the expanded checklist.
- ✓ Where the checklist calls refer to a particular switch, light, lever or instrument, the entry must be the same as that used to identify it on the aircraft panel.
- ✓ Checklist design should be consistent within fleets.
- ✓ A consistent format should be maintained throughout each checklist (although not at the expense of making drills more difficult to understand).

A purpose-designed checklist should be produced for each type or variant of aircraft. However, one checklist may be used for two variants of the same type of aircraft if there are only minor differences and the checklist shows clearly the differences between variants, provided:

- ✓ the type prefix appears in the response column; or
- ✓ clearly labelled, type-specific subsections are included within the checklist.

Special Cases

- ✓ The emergency evacuation drill should be easy to locate e.g. on the outside back cover of the Emergency Checklist. In addition a separate quick access card can be used.
- ✓ The rejected take-off and overrun drills should be easily and quickly accessible, e.g. located inside the back cover.

CONTENTS

Reference JAR-OPS 1 or 3 for items that must be included.

- ✓ Engine failure on take-off.
- ✓ Abandoned take-off at or before V1.
- ✓ After V1. Instruction must be given that drills are not to be performed before reaching a minimum safe altitude.
- ✓ Engine fire/failure after V1 drills. Include a reminder to carry out after take-off checks.
- ✓ Engine shut down.
- ✓ Engine fire.
- ✓ Propeller malfunctions.
- ✓ Failures of normal feathering system.
- ✓ Fuel filter de-icing.
- ✓ Re-lighting of turbine engines and re-light envelope graph.
- ✓ Instant re-light.
- ✓ Normal re-light.
- ✓ Re-starting reciprocating engines and re-start envelope graph.
- ✓ Bus bar and other serious electrical failures.
- ✓ Pressurisation failures.
- ✓ Emergency descent (to include oxygen mask and microphone).
- ✓ Malfunction of power control systems.
- ✓ Cabin and hold fires.
- ✓ Smoke removal (to include, where applicable, maximum IAS for flight with direct vision window open).
- ✓ Undercarriage fires.
- ✓ Landing with gear asymmetry or gear up.
- ✓ Overweight landing.
- ✓ Ditching.

- ✓ Evacuation drills.
- ✓ Pilot cockpit pre-evacuation drills.
- ✓ Imminent overrun of manoeuvring area drill.
- ✓ Crew incapacitation.
- ✓ Bomb threat.
- ✓ Hijack.
- ✓ Volcanic ash encounter (if appropriate).
- ✓ GPWS warning.
- ✓ Wind shear.
- ✓ TCAS warning.

APPENDIX 2 ELECTORNIC CHECKLIST REQUIREMENTS

The following table provide the suggested requirements to design an Electronic Checklist[24].

Electronic Checklists System Requirements	Remarks
The resulting crew actions called for in the checklist should be identical for paper and electronic versions.	
Layout: All checklists shall be similar to the paper version. Headings, sub-headings and titles shall be consistent to the paper version.	
The Title of the checklist must be displayed and distinguished at all times when in use.	
If one or more checklist can be opened at a time, a master checklist shall be available defining the actual status of each checklist.	
If more than one checklist can be opened at once, other checklist should be accessible without closing the display.	
If more than one checklist can be opened at once, user should be select which one is active.	
If a checklist is “child” of another checklist, the use should be select whether parent or child is active.	
The ECL (Electronic Checklist) should allow a state where no checklists are open.	
The Electronic checklist shall allow a state where no checklist is open and shall therefore give a positive indication. A blank screen is not sufficient.	
The completion status of each checklist shall be indicated clearly.	
Access, ambiguity and readability: quick-access for any checklist, on crew request, must be provided at all times. Note: all supported checklists should be accessible for reference/review at any time while system is active.	
Ambiguity and readability shall be equivalent to paper checklists.	
Electronic checklists should be as quick and accurate to access as paper checklist, even better.	
The ECL system should open checklists only upon crew request	
The user’s current position within the checklist as well as the possibility to look ahead in the checklist must be continuously possible. Note: without changing the active item	

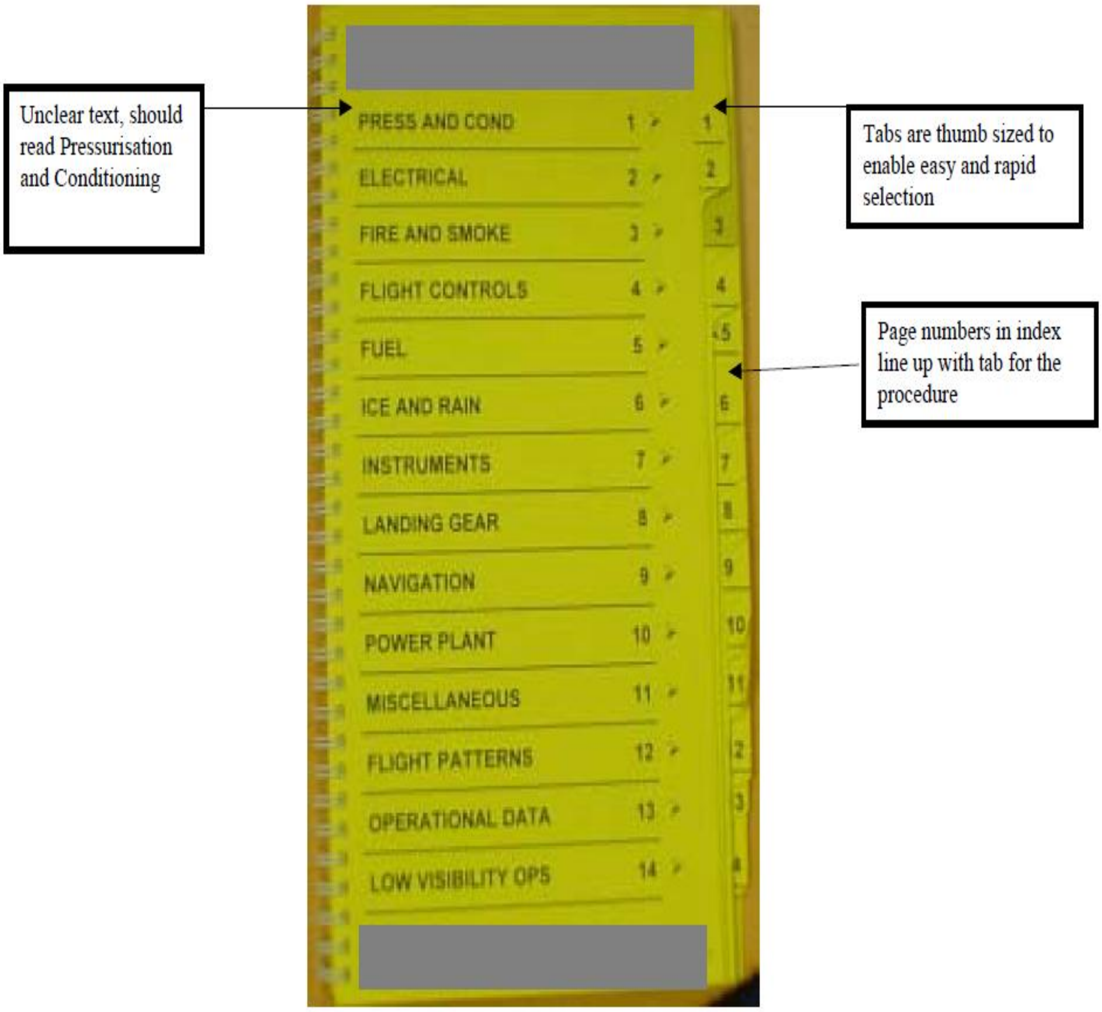
[24] Source: EASA internal document

Information regarding the length of checklist, the user's current position within the checklist, and how much of the checklist had been completed should be continuously available	
The active-item pointer should be moved to the next item with a simple action. Returning to the previous item should not change the status of any item.	
The system indicates active items: -The next item should become active when an item has been completed, unless it is on the next page. A separate action should be required to move to the next page. -Moving to the next item without completing the current item should require an input distinct from that of specifying the item as complete.	
An *undo* function should be available.	
The user should be able to quickly select one item after another; system processing should not induce delay.	
If the active item is off-screen and the use makes an "item completed" entry, and error massage should appear or the active item should be called into view. Note: It should also possible to change the status of off-screen items.	
If the user attempts to close incomplete checklists, the system should provide an indication that the checklist is incomplete. The user should be able to close incomplete checklists after acknowledging this indication, when returning to an incomplete checklist, the active item prior to the move should be active again. Positive indications should be presented when the entire checklist is completed. Note: It should be a reminder available on the screen to notify the user of incomplete checklist. Also a place holder should be used to indicate which item was active prior to leaving the checklist.	
The ECL should track and indicate the active checklist item.	
When returning to the incomplete checklist, the item active prior to the move should be active again.	
The option shall be provided to change certain items by the user to a deferred status. The deferred status of the item then shall be visible for clear identification.	
If normal checklists are supported, then all normal checklists should be supported.	
If non-normal checklists are supported, then all non-normal checklists shall be supported.	
Normal checklists should be accessible in accordance with the normal sequence of use.	
Can checklists be accessible individually for review or reference?	
Users' actions to mark an item after completion should be simple.	
Completed items should not be removed from the screen immediately. The crew should be able to review the item and undo their action, if necessary.	

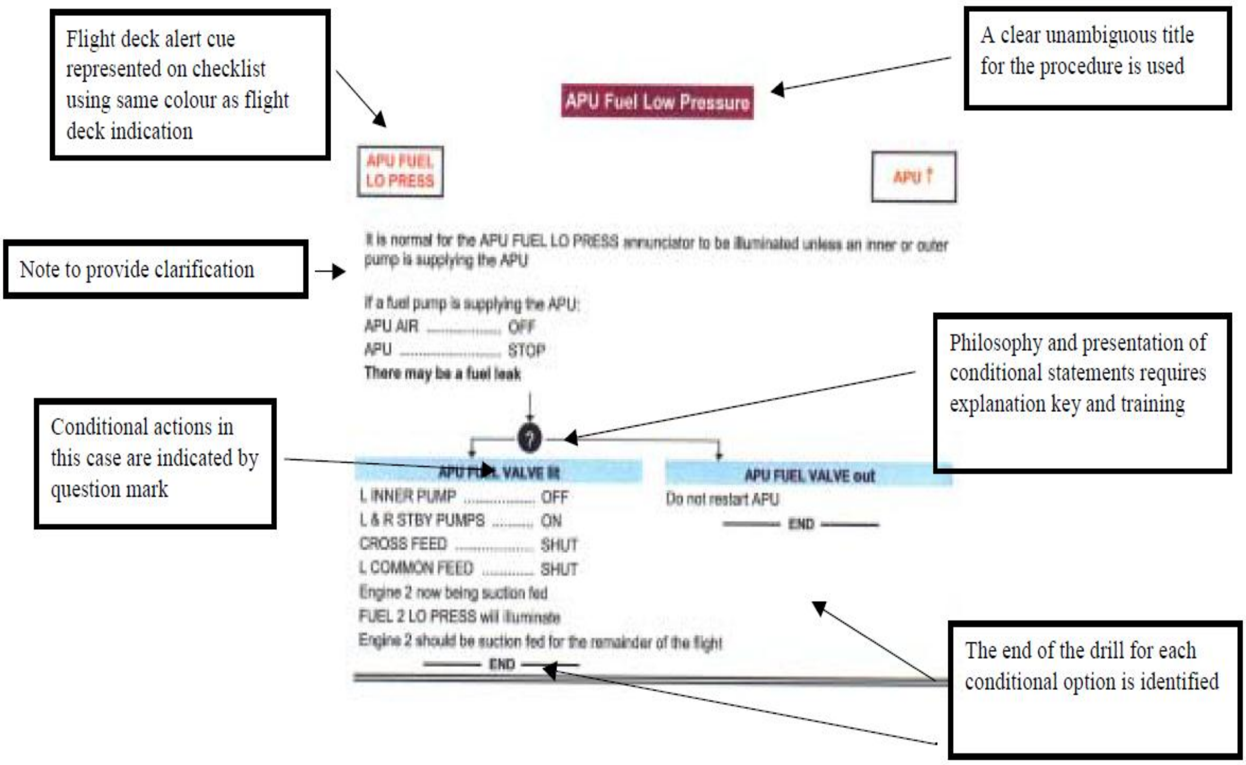
All checklists associated with on-going non-normal conditions that are sensed should be listed on one master list indicating the status of each one.	
During non-normal conditions, are relevant checklists easy to access?	
During non-normal conditions, does the device indicate which checklists and /or checklist items are required and which are optional?	
It is easy to reset the ECL to start over again. Note: the crew should be reset the checklist with a simple input.	
Does the checklist provide appropriate reminders for tasks that require a delayed action?	
Does the checklist clearly highlight decision branches? Note: the selected branch should be clearly indicated.	
Can one return to the checklist from links or related information in one step? Note: the navigation between links in the ECL and related information needs to be simple and clear.	
Related information should be appear in a single window or area of the screen	
Does the next item automatically become active when the previous one is complete?	
Is there a clear indication that all items as well as the whole checklist are complete when finished?	
Can the crew remove complete actions in order to recommence the checklist from the beginning?	
High-and Recall-function: The possibility shall be available, for checklists that are not in use, to be hi8dden by the user, and it shall be possible for recalling them as well by the user via a quick access option.	

APPENDIX 3 CHECKLIST PRESENTATION EXAMPLES (PAPER VERSION)

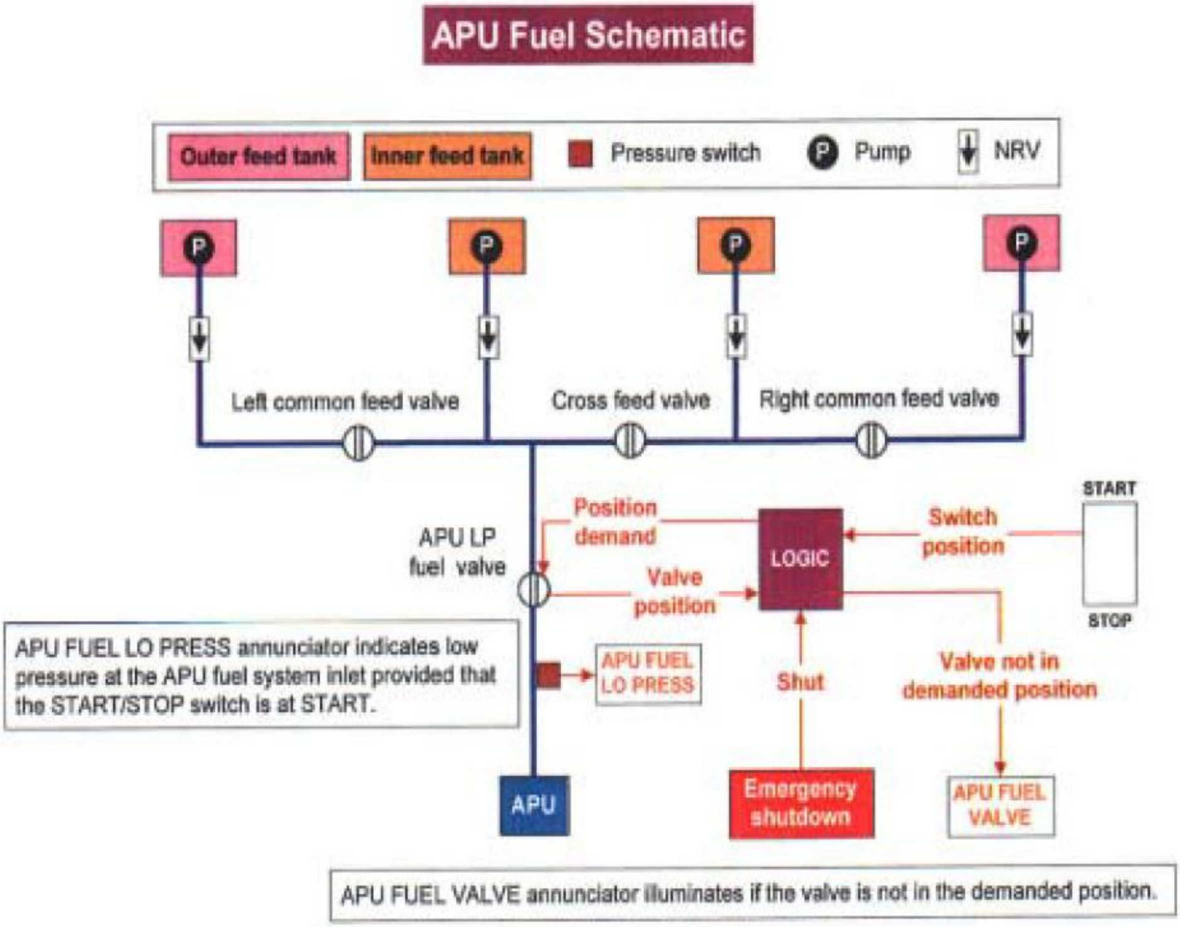
Example 1: Indexing of Emergency and Abnormal Checklist



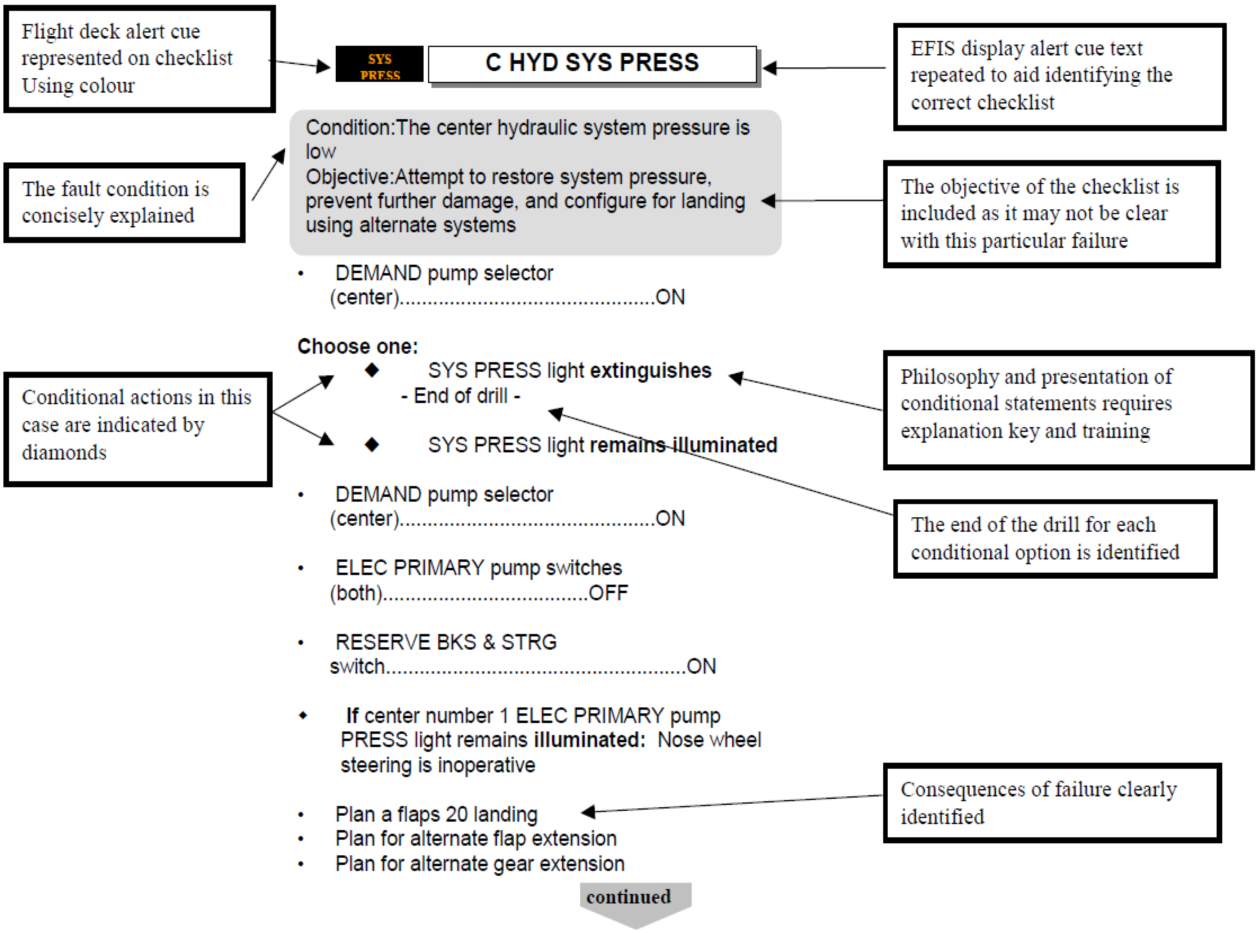
Example 2: Checklist Presentation



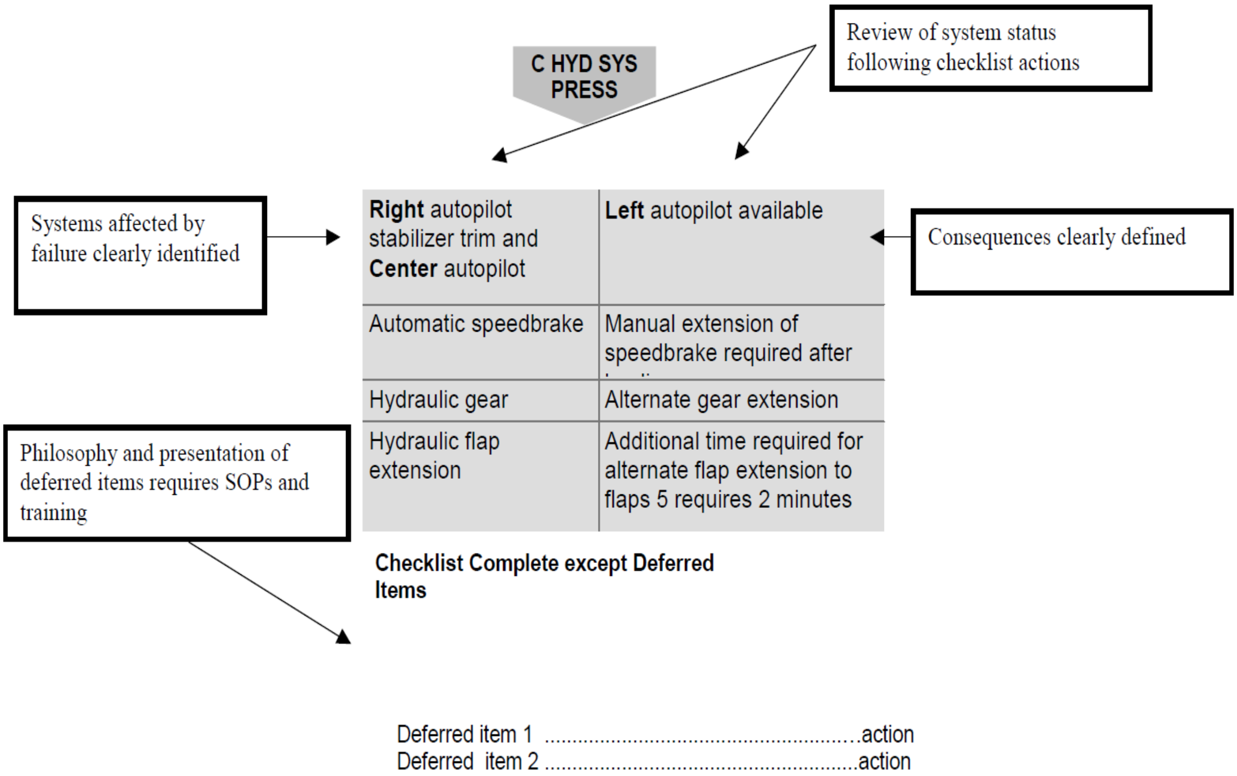
Example 3: Checklist Schematic



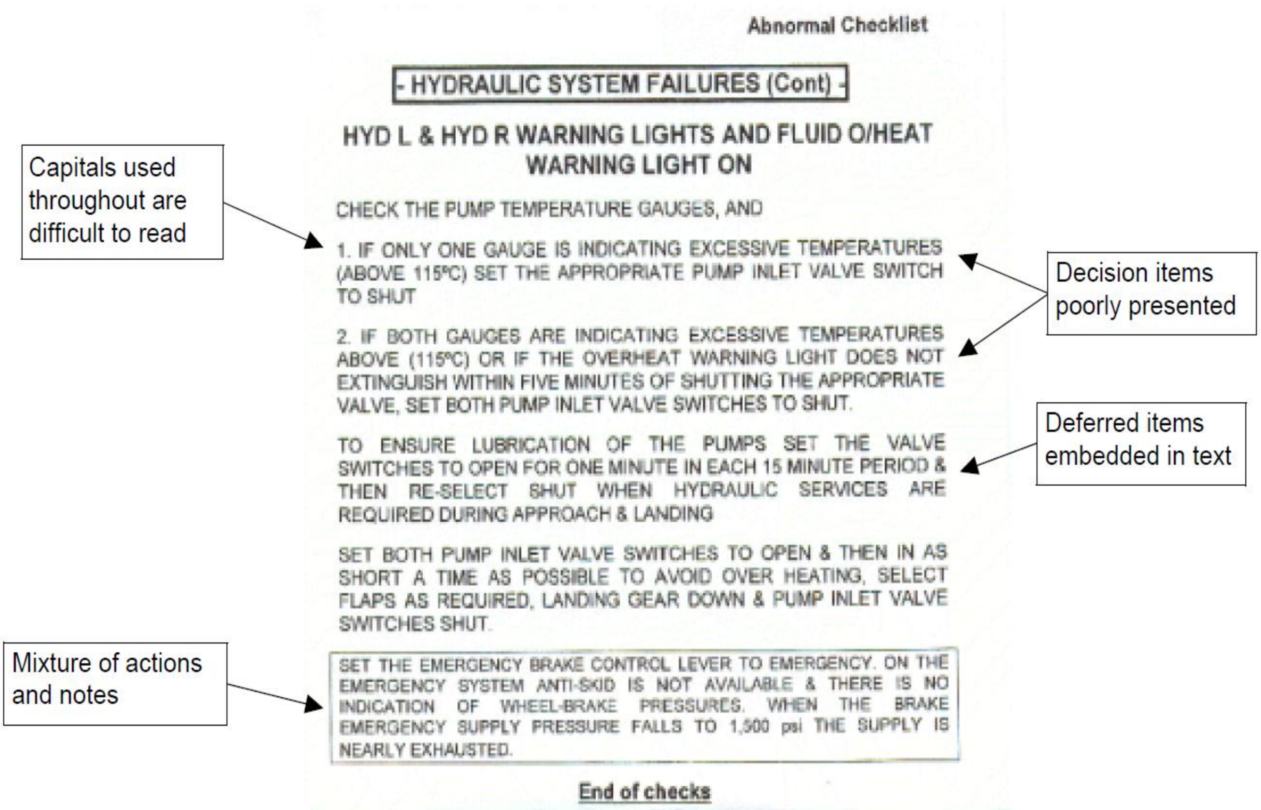
Example 4: Checklist Presentation



Example 5: Continuation Page



Example 6: Checklist Presentation Lacking HF or Usability Attributes



Abnormal Checklist

- HYDRAULIC SYSTEM FAILURES (Cont) -

HYD L & HYD R WARNING LIGHTS AND FLUID O/HEAT WARNING LIGHT ON

CHECK THE PUMP TEMPERATURE GAUGES, AND

1. IF ONLY ONE GAUGE IS INDICATING EXCESSIVE TEMPERATURES (ABOVE 115°C) SET THE APPROPRIATE PUMP INLET VALVE SWITCH TO SHUT

2. IF BOTH GAUGES ARE INDICATING EXCESSIVE TEMPERATURES ABOVE (115°C) OR IF THE OVERHEAT WARNING LIGHT DOES NOT EXTINGUISH WITHIN FIVE MINUTES OF SHUTTING THE APPROPRIATE VALVE, SET BOTH PUMP INLET VALVE SWITCHES TO SHUT.

TO ENSURE LUBRICATION OF THE PUMPS SET THE VALVE SWITCHES TO OPEN FOR ONE MINUTE IN EACH 15 MINUTE PERIOD & THEN RE-SELECT SHUT WHEN HYDRAULIC SERVICES ARE REQUIRED DURING APPROACH & LANDING

SET BOTH PUMP INLET VALVE SWITCHES TO OPEN & THEN IN AS SHORT A TIME AS POSSIBLE TO AVOID OVER HEATING, SELECT FLAPS AS REQUIRED, LANDING GEAR DOWN & PUMP INLET VALVE SWITCHES SHUT.

SET THE EMERGENCY BRAKE CONTROL LEVER TO EMERGENCY. ON THE EMERGENCY SYSTEM ANTI-SKID IS NOT AVAILABLE & THERE IS NO INDICATION OF WHEEL-BRAKE PRESSURES. WHEN THE BRAKE EMERGENCY SUPPLY PRESSURE FALLS TO 1,500 psi THE SUPPLY IS NEARLY EXHAUSTED.

End of checks

APPENDIX 4 HUMAN FACTOR CHECKLIST AUTDIT TOOL (HR-CHAT)

The goal of CHAT is to determine whether prepared checklist complies with best human factors as defined in the appropriate Appendix 1.

Title	Attribute	Y	N	N/Y	Comments
Physical Characteristics					
Document size	Is the size of the document appropriate to the stowage space available?				The checklist must be able to be stowed in an accessible location and easily retrieved in an emergency.
	Can the document be used without interfering with the controls or obscuring the displays?				This check needs to be carried out on the flight deck. The document should be reduced in size if there is any interference or obscuration
Binding	Can the document be opened through 360º?				Access to required page(s) needs to be accomplished without requiring the crew to hold the pages open. Thus ideally the checklist will be able to fold back on itself. Recommend change if this cannot be achieved.
	Can amendment pages be easily inserted?				Two Sided A5 or A4 plasticised is recommended
Cover	Is the cover robust to protect pages within?				
	Is the colour significantly different to minimise incorrect checklist selection?				The Emergency and Abnormal operation should be easy to distinguish. Recommend change colour of cover.
	Is the cover easily distinguishable from the pages within?				If the checklist is folded back on a particular page when stowed it may not be easy to locate. Recommend change the colour or size.
	Does the title of the checklist and aircraft type appear on the front cover?				In a multi fleet operation this could result in the wrong checklist being used. Recommend change cover.
	Is the checklist stowed out of proximity of drink containers?				Drink stains could render the checklist unusable. Recommend protecting checklist in some manner (e.g. using laminated pages).

Title	Attribute	Y	N	N/Y	Comments
Tabs and dividers	Are the tabs clearly identified?				Tabs are used to assist in the location of drill. If they are not clearly identified this will cause delay in finding the correct drill. Recommend change tab numbering to be consistent throughout document.
	Are the tabs logically linked to the index?				If they are not logically linked this will cause delay in locating the correct drill. Recommend change tabs to provide logical linking (see Example 1, Appendix 3).
	Are the tabs wide enough to place a thumb on?				If the tabs are too small access to the correct drill will be more difficult. Recommend changing the size of the tabs (see Example 1, Appendix 3).
	Are the tabs and dividers consistent in colour?				Where colour coding has been used to discriminate drills the colour coding should be consistent. Recommend changing the colours of the tabs and dividers to maintain consistency.
Font type	Does the font type used provide clear differentiation between characters?				Difficulty in reading the text may cause errors to be made. Recommend sans serif fonts (without tails) such as Helvetica, Gill Medium or Arial fonts are used.
	Is lower case with upper case initial letters used for blocks of text?				Research has shown that lower case text is easier to read than uppercase (see Example 6, Appendix 3). Recommend change text to lower case. Upper case can be used for titles and attention getting warnings and alerts.
Print size	Is the checklist legible at arms' length?				Text must be legible under all lighting conditions at arm's length (approximately 600mm). Smaller text will cause eye fatigue and may not be legible particularly in low visibility conditions. Recommend increase font size until it is legible at 600mm.

Title	Attribute	Y	N	N/Y	Comments
	Are the smoke procedures in large print? (Also consider any procedures that may be carried out under poor lighting conditions.)				Font size should be large to be legible in a smoke filled cabin. Recommend increase size of font.
Margins	Is there at least 19mm space between the binder and the text?				The binding should not hide the text. Recommend changing margin to typically 19mm.
	Can you use your thumb as a cursor to keep track of drill progress?				It should be possible to hold the list using the thumb as a cursor without obscuring the text. Recommend changing margin to typically 19mm.
Emphasis and differentiation	Are similar action items on the checklist clearly differentiated?				Similar lines of text could result in an action item being missed. Recommend highlighting the difference in the sentence using bold type.
Contrast and colour	Has black text on a white or yellow background been used?				Coloured backgrounds provide a poor contrast ratio, which is difficult to read. Recommend using white or yellow background. If other colours are used check legibility under low ambient lighting.
	Is all the text in black?				Coloured text is difficult to read particularly under low ambient lighting conditions and should be avoided. Recommend changing coloured text back to black. Alert cues may be coloured.
	When the Emergency and Abnormal procedures are in the Operating Manual are the pages distinguished from the main drills?				It is important to be able to quickly and accurately locate the correct drill. Recommend using colour tabs - red for emergency and amber for abnormal procedures.
	Where colour shading has been used to discriminate actions or notes, is there sufficient contrast between the text and background?				Colour shading provides a good method of discrimination but must be used with care. Recommend the use of pastel colours (low saturation) for shading.
Contents list and index	Does the checklist have a tabbed content list at the beginning of the checklist?				The checklist is unusable without a contents list. Recommend adding a contents list (see Appendix 3, Example 1).

Title	Attribute	Y	N	N/Y	Comments
	Does the contents list clearly identify the sub-systems?				The pilots should be trained to know in which sub-system the fault has occurred. Recommend clearly listing each subsystem (see Appendix 3, Example 1).
	Are critical drills highlighted in the index?				The critical drills need to be attended to very rapidly. Recommend highlighting in some manner to make these drills easier to find. Alternatively put the critical drills at the top of the index.
	Does the checklist have an index of all fault captions covered in the checklist?				An alphabetical index will provide a quick route to the correct drill particularly when the Pilot is unfamiliar with the fault and does not know which sub-system to try first. Recommend including an alphabetical index.
	Is there a contents list at the beginning of each sub-system section of the checklist?				Lack of a list can make the checklist unusable. Recommend putting an index at the beginning of each sub-system section.
Numbering	Within each sub-system section do the page numbers correspond to the tab numbers?				Lack of numbering, incorrect or confusing numbering can make the checklist unusable. Recommend numbering each page in correspondence with the tab number or other logical manner.
	Is the number clearly identified on the page?				Lack of a page number can make the checklist unusable. Recommend putting the number at the bottom or top of the page. Large font size is recommended.
	Are actions consecutively numbered in the drill?				Research has shown that numbering actions assists in place keeping. Recommend consideration be given to numbering actions.

Title	Attribute	Y	N	N/Y	Comments
Checklist Content					
Structure	Have the number of action items been minimised to take account of time available to complete the drill? For example, landing gear problems are likely to be discovered when fuel is low.				It is essential that the minimum number of actions be carried out to establish a safe aircraft state. Consider carefully whether diagnostic actions that attempt to eliminate the source of the problem are essential when there are likely to be time constraints.
Checklist instructions	Is a set of notes outlining the checklist coding philosophy contained in the checklist?				The notes should detail the coding and presentation philosophy used throughout the checklist. Recommend including instructions in the checklist or providing easy access to the instructions in the documentation suite.
	Do they adequately describe the presentation and philosophy principles used in the checklist?				The notes should provide explicit details on how to interpret the information contained within the checklist. They should also define terminology such as land as soon as possible and land as soon as practicable.
Title	Is a title prominently displayed at the start of each drill?				Lack of a title will make the checklist unusable. The drill must have a title (see Appendix 3, Examples 2 and 4).
	Does the title fully reflect the failure condition?				A misleading title could result in the incorrect drill being carried out. An unambiguous and practical title should be used (see Appendix 3, Examples 2 and 4).
	Is the title completely distinguishable from the rest of the drill?				The title must stand out from the action items and notes on the drill. Recommend using a method like boxing and/or bold font (see Appendix 3, Examples 2 and 4).

Title	Attribute	Y	N	N/Y	Comments
Failure condition	Does the checklist contain a description of the failure condition(s)?				A repeat of the warning captions and failure states provides a useful confirmation that the correct checklist has been selected. Recommend including a description of the failure conditions (see Appendix 3, Examples 2 and 4).
	Does the checklist contain an illustration of the alerting trigger captions?				A repeat of the warning captions in the checklist (using the same colour as it appears on the flight deck) provides a useful confirmation that the correct checklist has been selected. Recommend including an illustration of the relevant warning captions (see Appendix 3, Examples 2 and 4).
Objective	Does the checklist contain an objective?				An objective statement serves as a useful confirmation that the correct checklist has been selected and the expected outcome of the drill. Recommend including an objective statement where appropriate in the checklist (see Appendix 3, Example 4).
Memory items	Are the memory items listed at the beginning of the drill?				Memory items should be carried out first and verified on the checklist. When they exist they must be the first set of action items.
	Are the memory items clearly distinguished from the other action items?				It is recommended that the memory items be distinguished in some fashion - boxing, shading, line marking, numbering (M1, M2),etc.
	Are there six or less memory items on a single drill				It is recommended that the memory items should be kept to a minimum - preferably four or less. Recall can be impaired under stressful situations.

Title	Attribute	Y	N	N/Y	Comments
Cautionary notes	Are cautionary notes clearly discriminated on the checklist?				Cautionary notes highlight resultant performance constraints and should be differentiated from ordinary explanatory notes. It is recommended that appropriate colour shading highlights caution notes. Ideally they should be accompanied by the word 'caution'.
	Are the cautionary notes printed above the action item that they relate to?				It is essential that the crew are aware of the implications of any action item before they carry it out. Recommend moving the cautionary note to precede the action that it relates to.
Action items	Are the action items distinguishable from the notes in the checklist?				It is important to identify the 'do' list items in the list. Recommend that they are distinguished from other items in the checklist (e.g. text font size, font type or bold font are potential candidates).
	Are the 'read' and 'do' items clearly linked?				The items should be linked to avoid the possibility of associating the wrong challenge and response. Recommend using dots or dashes to link challenge and response items (see Appendix 4, Examples 2 and 4).
	Are the critical items (e.g. actions resulting in the deactivation of the flight controls) discriminated?				Critical items which could create a hazardous situation require positive verification by the monitoring crewmember and therefore it is important that these actions are clearly discriminated from other action items. Recommend changing presentation of critical items to provide discrimination.
Explanatory notes	Are the explanatory notes clearly distinguished from action items?				The notes should not clutter the action items. It is recommended that they are visually distinguishable.

Title	Attribute	Y	N	N/Y	Comments
	Are the notes linked to the action item that they relate to?				It is essential that the notes either precede or follow the action item. It is recommended that notes are consistently placed close to the action items that they refer to.
Decision items	Are conditional steps clearly laid out?				An error prone situation exists with complicated conditional statements particularly when action items are embedded within them. It is recommended that decision items are discriminated either by using special bullets or line marking or choice directives (see Appendix 3, Examples 2 and 4).
Review of system status	Is a review of system status and operational capability provided on the checklist?				A system status review provides the crew with diagnostic information regarding system capability. They are useful in dealing with a failure situation, which cannot be rectified. It is recommended that consideration be given to including a table or list detailing system failures and alternate operational capability in the checklist (see Appendix 3, Example 5).
Deferred items	Are deferred items clearly identified?				Actions, which will be carried out at a later phase of flight, should be at the end of the checklist and should be clearly labelled. It is recommended that a label such as 'deferred item' precedes the final deferred action items (see Appendix 3, Example 5).
	Are they grouped accordingly?				Deferred items are easier to use if they are clearly grouped according to phase of flight or an environmental condition. It is recommended that grouping techniques are used.

Title	Attribute	Y	N	N/Y	Comments
	Is there sufficient information to carry out the deferred step?				When returning to a checklist to carry out items that have been deferred it is necessary to recall the system deficiencies and carry out the actions correctly. To aid recall it is recommended that 'do' actions be spelt out explicitly.
Crew responsible	Where appropriate does the checklist indicate who is responsible for carrying out the drill?				The instructions should indicate who is responsible for carrying out the drill but if this changes for any of the drills it should be specifically stated as to who is responsible for specific actions.
Layout and Format					
Drills per page	If the drill runs onto a second page is it split at a logical place in the drill?				Drills should be split into logical sections and the logical sections should not be split at a page break as it impacts continuity of the drill.
Start and finish	Does the drill have a clearly defined start?				The drill will be unusable if it is not clear where the drill starts. It must have a clearly defined start
	Does the drill have a defined end?				The end of drill must be indicated with an 'end of xxx drill' indication or graphical equivalent (see Appendix 3, Examples 2 and 4).
	Are the end of drill indications provided in every place on the drill where it is complete, including decision steps?				The end of drill must be included at all places in the drill when it is complete (see Appendix 3, Example 2).
Continuation pages	Is it clear when the drill continues onto another page?				The drill may not be completed if it is not clear that it continues onto another page. It is recommended that a clear indication be provided at the bottom of the page and top of the continuing page (see Appendix 3, Examples 4 and 5).
Order	Does the order of the action items ensure that the failure is fixed at the earliest opportunity?				The design of the drill must ensure that priority items, i.e. those that will deal with the fault in the most time efficient way, are in the appropriate order.

Title	Attribute	Y	N	N/Y	Comments
	Are the action items listed in a logical, functional or physical cockpit layout pattern?				Procedures that are logically listed will be completed in a timely fashion.
Cross referencing	Where cross-referencing is used within a drill is it clear as to which step should be carried out?				An error-prone situation exists with internal cross-referencing if it is not clear which step it refers to. It is recommended that the use of cross-referencing is minimised and that steps are numbered when cross-referencing is used.
	Where cross-referencing to other material is it clear which page and document it refers to?				It is not ideal to have to refer to other documents because it could result in the crew losing their place. However if it is necessary it is recommended that a place keeper symbol be used to aid return to the right place in the drill. It is also recommended that the document and page number if possible are clearly referenced.
Figures and tables	Are the figures and tables clearly linked to the drills they are associated with?				Errors will occur if the wrong figures or tables are referred to. It is recommended that the figures and tables should be clearly labelled to allow correct referencing.
	Are the figures legible and usable?				Performance data contained in graphs will not be usable if the presentation is too small particularly in low visibility situations. Ensure that performance data is legible under operational conditions.
Abbreviations and consistency	Do all captions and labels used in the drill correspond exactly to the labels used on the flight deck?				It is essential that exact correspondence is achieved and any differences must be corrected.
	Does the checklist identify clearly aircraft type, model, variant and modification state?				This could result in the wrong checklist or wrong drill being used. It is recommended that all checklists visually highlight any differences in variants relating to the drills. It is recommended that the checklist relates to the individual aircraft tail.

Title	Attribute	Y	N	N/Y	Comments
Special cases	Is the emergency evacuation drill easy to locate?				It should be on the cover of the Emergency Checklist and/or on a separate quick access card.
	Are the rejected take-off and overrun drills easy to locate?				They should be located on a cover of the Emergency Checklist.

APPENDIX 5 SUVERY CONDICTED FOR ATPL/CPL HOLDERS

March 2012

Section 1. General questions.

Q1. Male / Female?

Q2. Age?

Q3. Please tick what type of licence you hold:

JAR ATPL JAR CPL FAA ATPL FAA CPL

Q4. Tick if you have any other qualifications in aviation apart from your pilots licence:

Instructor Examiner Other – please specify

Q5. How many hours of general flight experience do you have in total? ---------------- Hrs

Q6. How many hours have you flown in the last 12 months? ---------------------------- Hrs

Q7. Describe the type of operations you have been involved in during the last 12 months? Commuter/short-haul/long haul/other-please specify

Q8. What is the average duration of the leg in your type of operation?----------------- Hrs

Q9. Please mention the type(s) of aircraft you fly:

Helicopter(i.e. bell 407, Sikorsky S-76c etc.) Aircraft(i.e. Boeing 777,AirbusA340 etc.)

Q10. What aircraft type you are currently flying? Please specify the mass category:

Below 5700 kg MTOM
Between 5700 kg and 15000 kg MTOM
Above 15000 kg MTOM

Section2. Specific questions concerning normal/abnormal and emergency checklist.

1) Do you consider the current normal/abnormal and emergency checklists provide adequate safety and efficiency?

Strongly Disagree			Strongly agree	
1	2	3	4	5

In case of disagreement please motivate your answer by an example.

2) In your opinion do the current Standard Operation Procedures (SOPs) in the cockpit provided by operators and manufacturers raise possible safety hazard concerns?

Never	Not often	Fairly often	All the time

Please specify and indicate in which area or phase of the flight this would most likely happen. I.e. pre-start/taxi /take off/climb/descend/ approach/ landing procedure. Any suggestions for improvement?

3) Do you identify any possible safety hazards in the current abnormal/emergency checklists which should be more considered?

Never	Not often	Fairly often	All the time

Please indicate clearly and how these should in your opinion be mitigated?

4) Many reported incidents happened when the SOPs were overlooked by the pilot's mistakes due to various circumstances such as workload or even routines of the procedures. How do you think this safety issue can be mitigated? Please elaborate preferably with some examples.

5) According to your experience, what operational distractions can you identify which contribute to checklist interruptions or mistakes? Please provide examples.
6) Have you already experienced any possible safety hazard case related to a human error while performing normal/abnormal/emergency checklist which can be mitigated but it has not considered yet? Please indicate.
7) Do you have any other suggestions for the checklist improvement?

APPENDIX 6 SURVEY CONDUCTED FOR OPERATORS

March 2012

1) Has your company recently developed any instructions or guidelines relative to the design of the checklist (normal/abnormal and emergency) and/or working methods in the cockpit which has an added value to improve the safety? Would you mind to send me a copy of these items.

2) Has your company recently implemented any new revisions or improvements in order to mitigate pilot errors and increase the safety explicitly on the Standard Operations Procedures (SOPs)? Would you please provide me with these documentations.

3) Does your company have implemented any innovative ways on design and use of normal/abnormal and emergency checklist in the recent years which according to you have the potential to increase the safety and efficiency in the cockpit?

4) Would you mind to consider sending me these items.

5) What type of measures has your company taken to reduce the potential safety hazard caused by human errors (i.e. overlooking the items in the checklist during emergency, stressed situation and/or increasing workload)? Would you mind to send me a copy.

6) Are there any policy, guideline and training in your organisation about cockpit task management and Sterile Cockpit rule? Would you mind to provide me with a copy.

7) According to your experience, do you have any other suggestions concerning the improvement of current methods used to design of checklists or working methods in the cockpit which can assist me to make a better assessment?

EUROPEAN AVIATION SAFETY AGENCY
AGENCE EUROPÉENNE DE LA SÉCURITÉ AÉRIENNE
EUROPÄISCHE AGENTUR FÜR FLUGSICHERHEIT

Postal address
Postfach 101253
50452 Cologne
Germany

Visiting address
Ottoplatz 1
50679 Cologne
Germany

Tel +49_221_89990-000
Fax +49_221_89990-999
Mail info@easa.europa.eu
Web easa.europa.eu